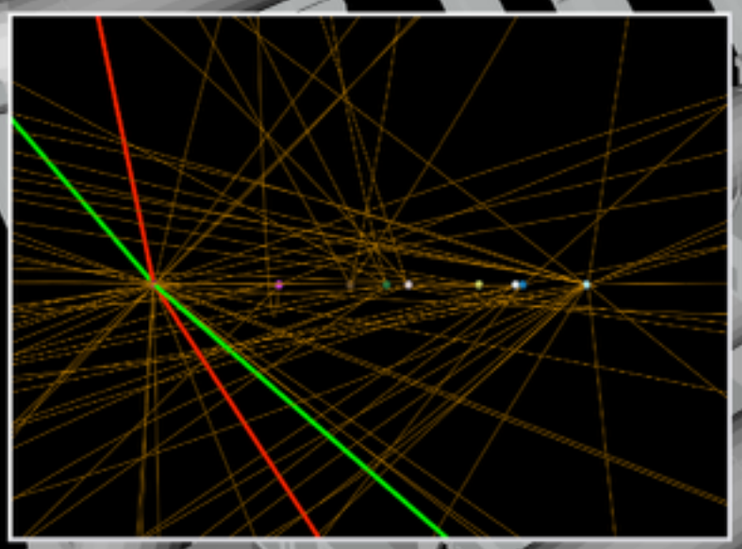
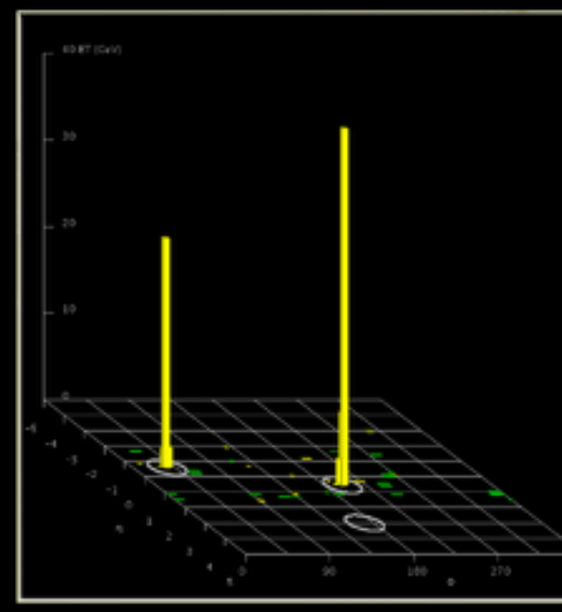
INSTITUTE OF PARTICLE PHYSICS

ATLAS Canada

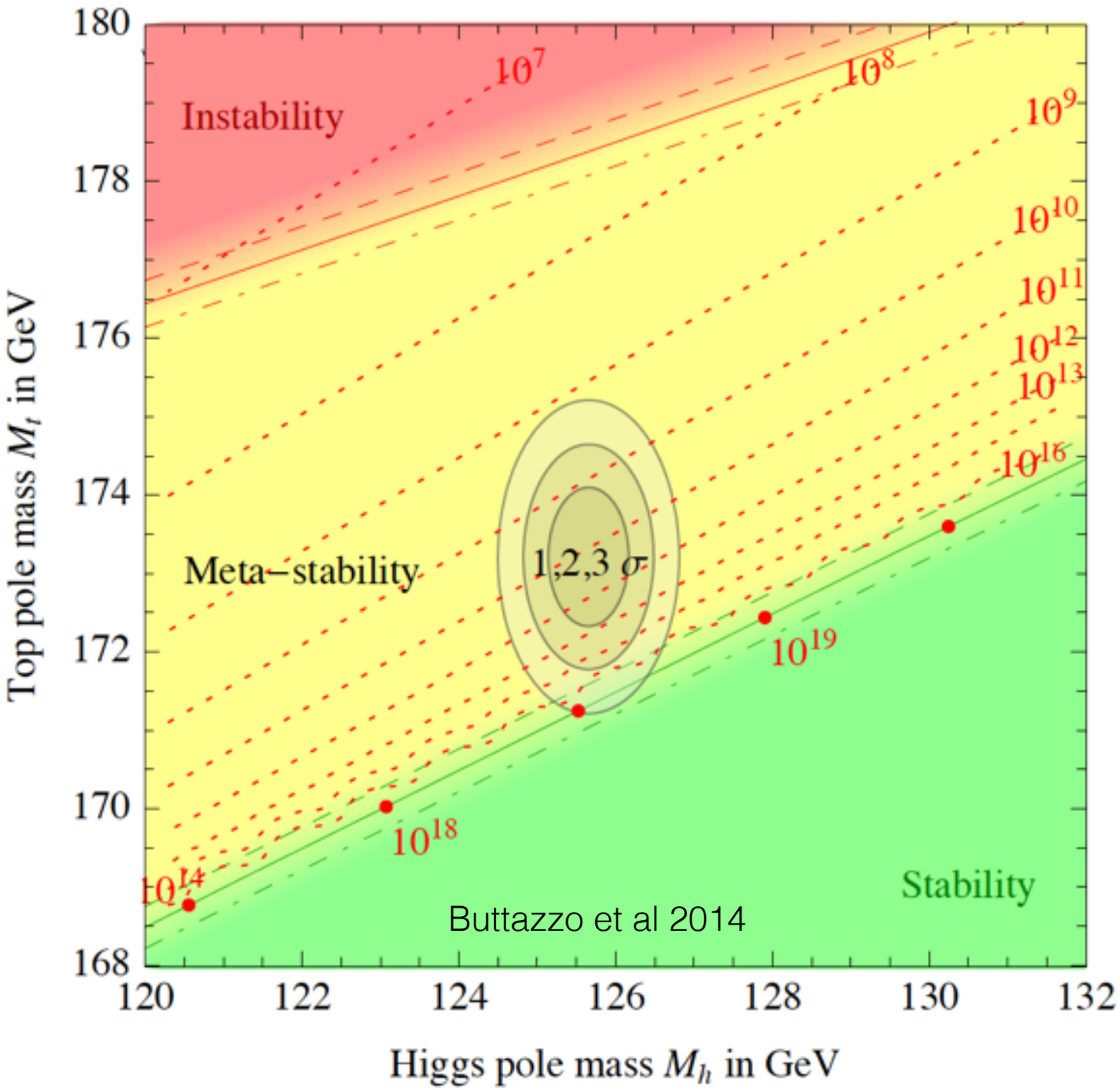
Richard Teuscher
IPP / Toronto





Higgs candidate (H→ZZ→eeμμ)

1) Higgs mass



Buttazzo et al 2014

vacuum is meta stable?

International New York Times

Finding Higgs leads to more puzzles

Physicists see fluctuation in 10,000 years or so as likeliest wipeout moment

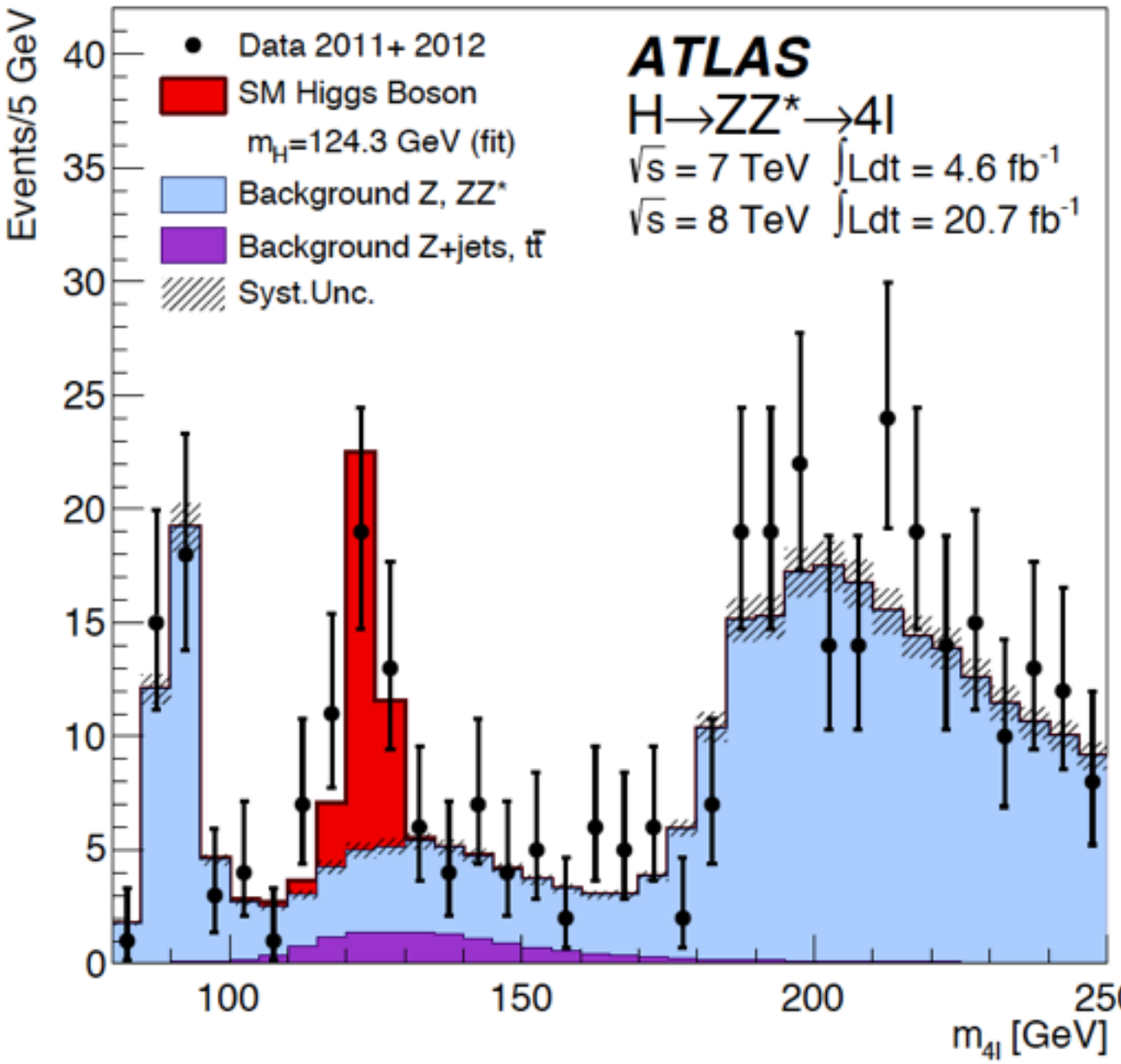
"Taken at face value, the result implies that eventually (in 10,000 years or so) an unlucky quantum fluctuation will produce a bubble of a different vacuum, which will then expand at the speed of light, destroying everything."

Ref. M.Spiropulu & J.Lykken

editor: $10^{100} \rightarrow$ 10 000

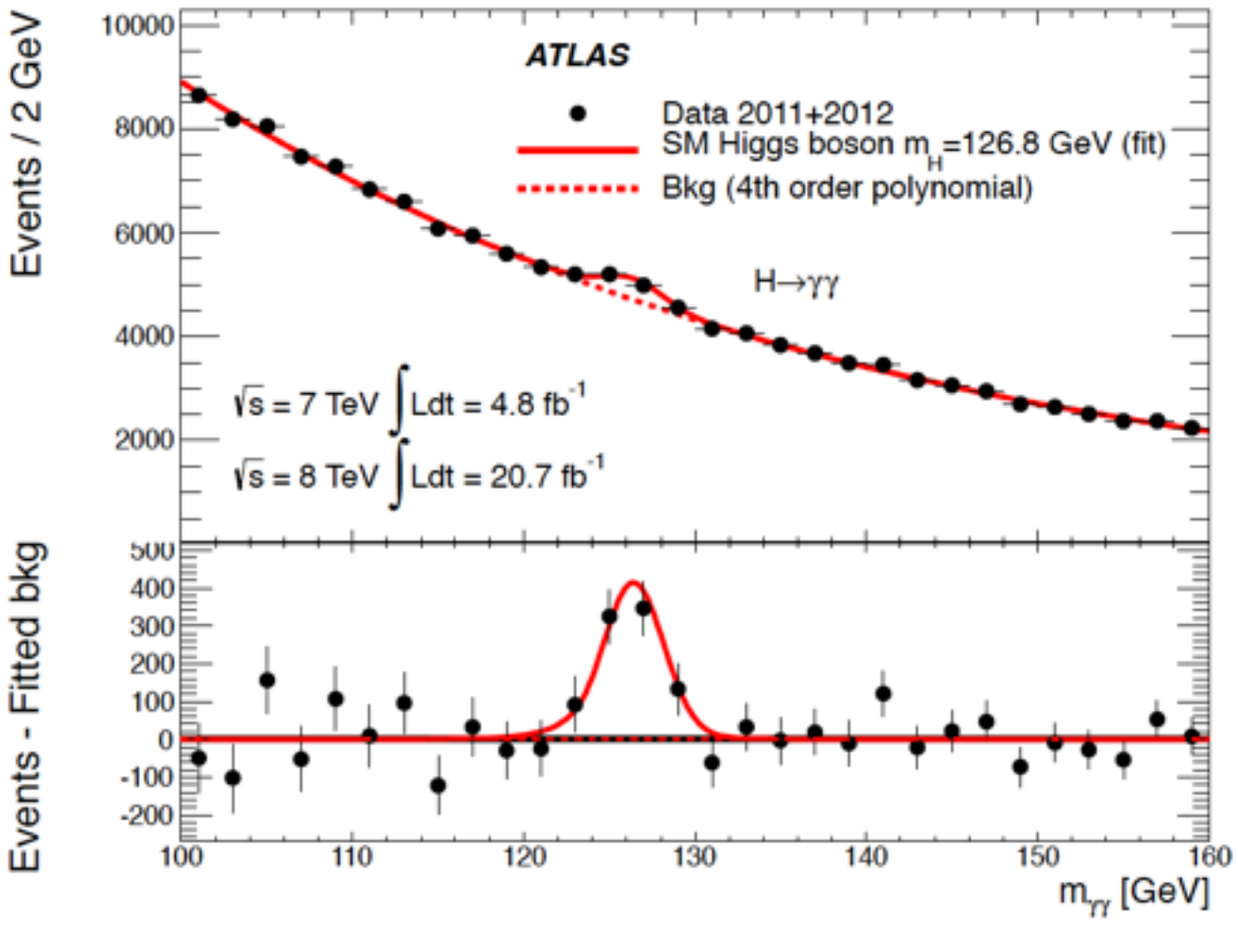
Higgs

H→ZZ: 6.6σ (obs) 4.4σ (exp)



	Signal	ZZ^*	$Z+\text{jets}, t\bar{t}$	Observed
4μ	6.3±0.8	2.8±0.1	0.55±0.15	13
$2e2\mu/2\mu2e$	7.0±0.6	3.5±0.1	2.11±0.37	13
$4e$	2.6±0.4	1.2±0.1	1.11±0.28	6

H→$\gamma\gamma$: 7.4σ (obs) 4.3σ (exp)



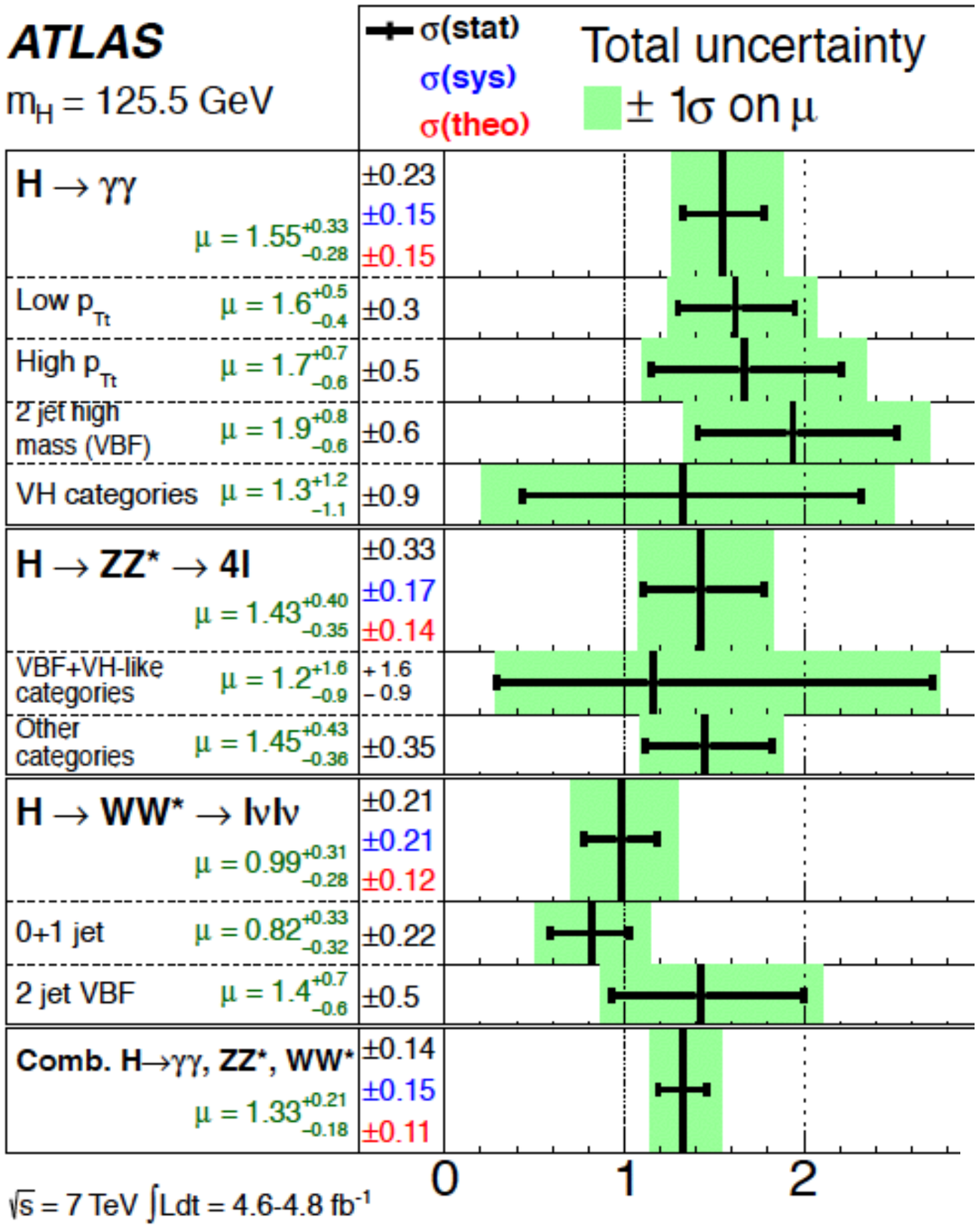
Combined mass:

$$m_H = 125.5 \pm 0.2\,(\text{stat})\,^{+0.5}_{-0.6}\,(\text{sys})\ \text{GeV}$$

$$\Delta m_H = 2.3^{+0.6}_{-0.7}\,(\text{stat}) \pm 0.6\,(\text{sys})\ \text{GeV}$$

See talk by D. Schouten

Higgs Signal Strength



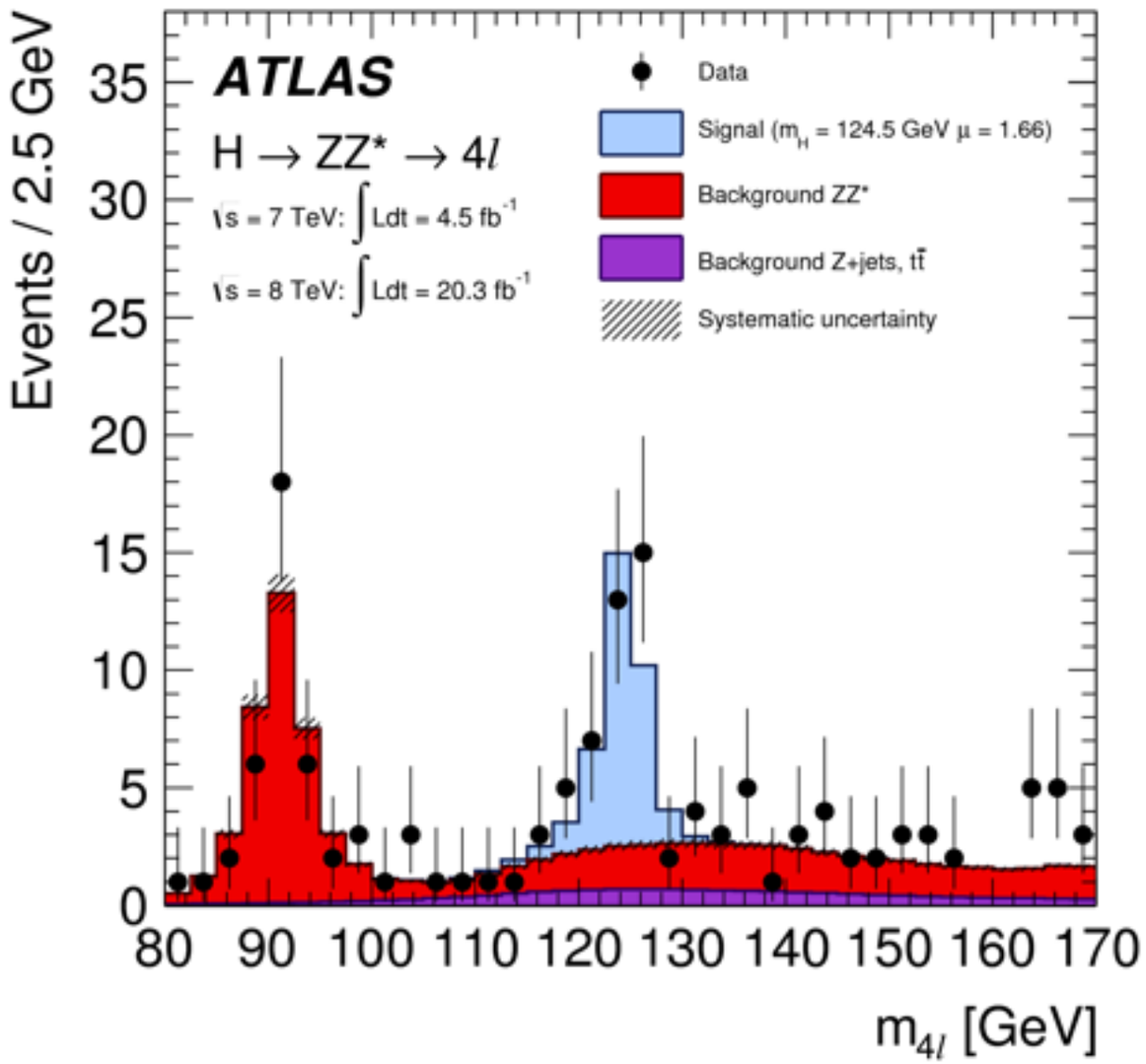
$$\mu = \sigma_{obs} / \mu_{SM}$$

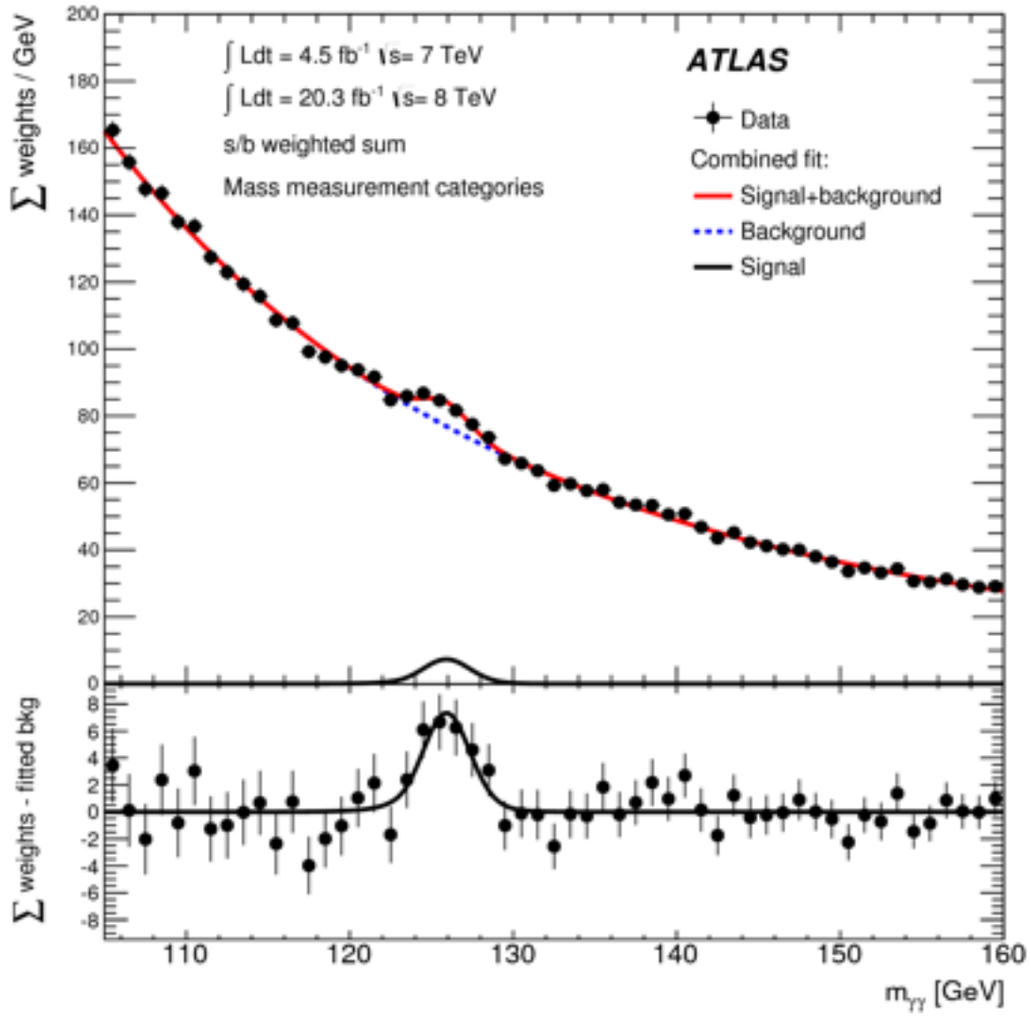
$$\mu = 1.33 \pm 0.14\,(\text{stat}) \pm 0.15(\text{sys})$$

Many Canadians leading contributors to Higgs analyses, including convener, sub-convenors, analyses, statistics, detector performance, editors, … IPP summer student exceptional paper author (approved by spokesperson)

INSTITUTE OF PARTICLE PHYSICS

NEW (approved 15-June-14)





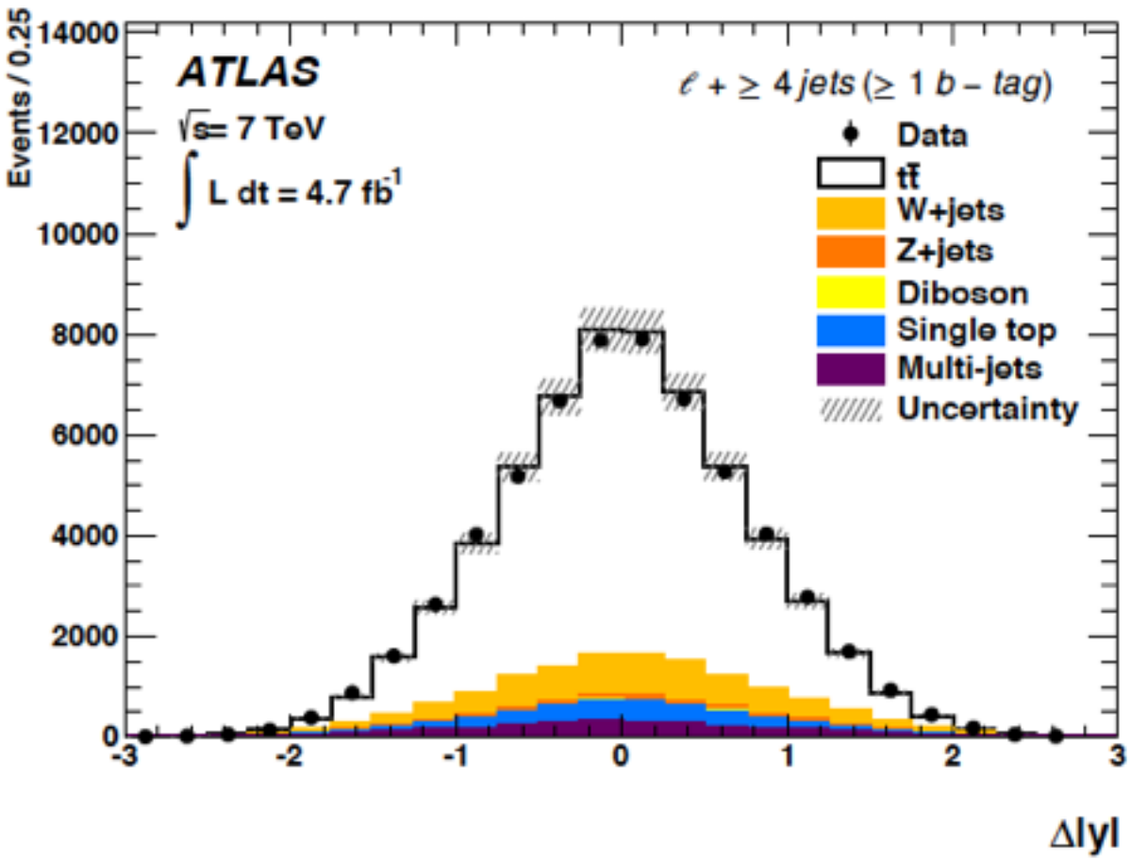
CERN-PH-EP-2014-122 submitted to PRD

Channel	Mass measurement [GeV]
$H \to \gamma\gamma$	$125.98 \pm 0.42\,(\text{stat}) \pm 0.28\,(\text{syst}) = 125.98 \pm 0.50$
$H \to ZZ^* \to 4\ell$	$124.51 \pm 0.52\,(\text{stat}) \pm 0.06\,(\text{syst}) = 124.51 \pm 0.52$
Combined	$125.36 \pm 0.37\,(\text{stat}) \pm 0.18\,(\text{syst}) = 125.36 \pm 0.41$

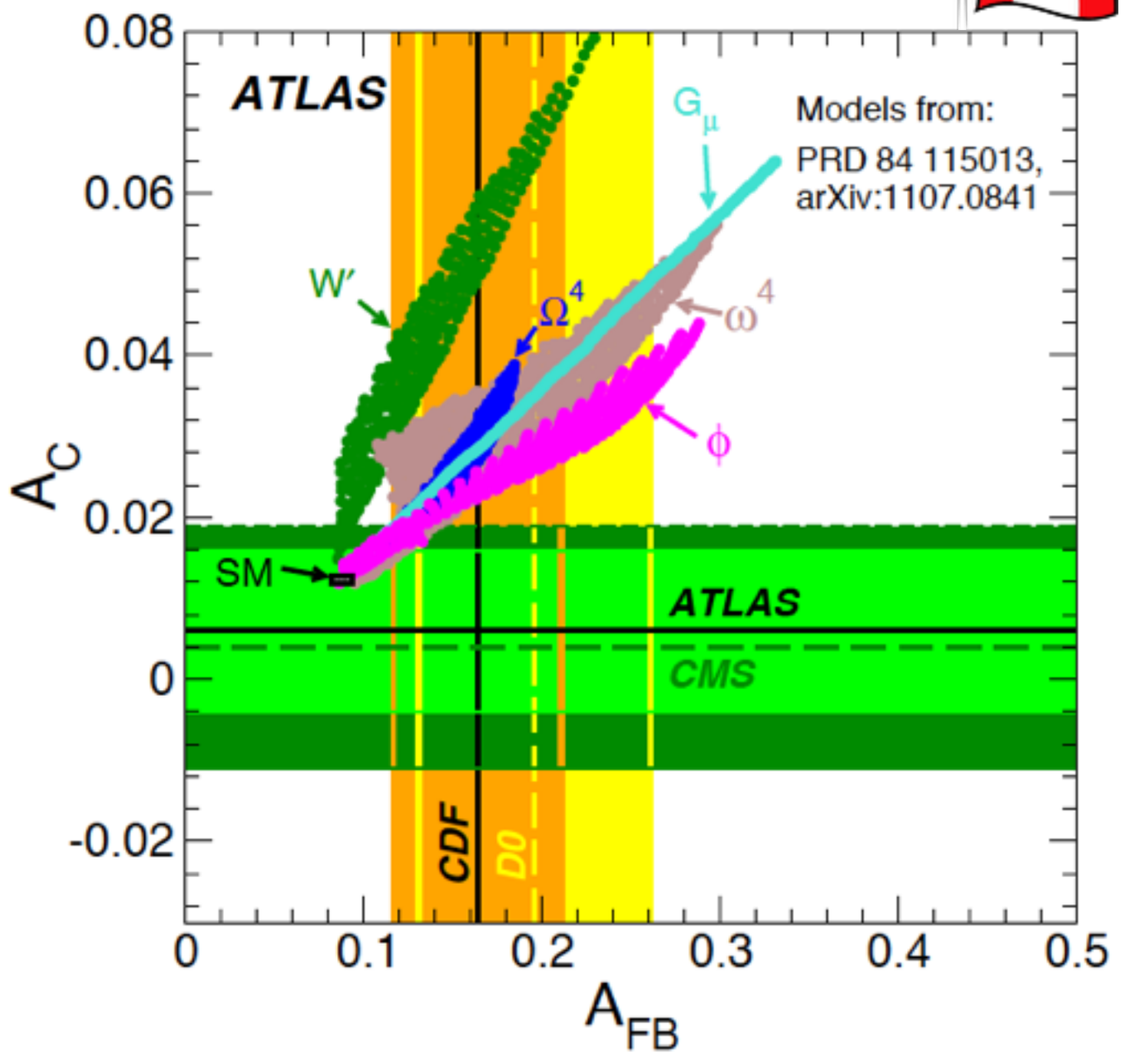
$$\Delta m_H = 1.47 \pm 0.67\,(\text{stat}) \pm 0.28\,(\text{syst})\ \text{GeV}$$
$$= 1.47 \pm 0.72\ \text{GeV}$$

Standard Model: top charge asymmetry

- Similar to forward-backward asymmetry A_{FB} at Tevatron
- Measure asymmetry A_C with difference of t and $\bar{t}$ absolute rapidity



Canadians lead top physics



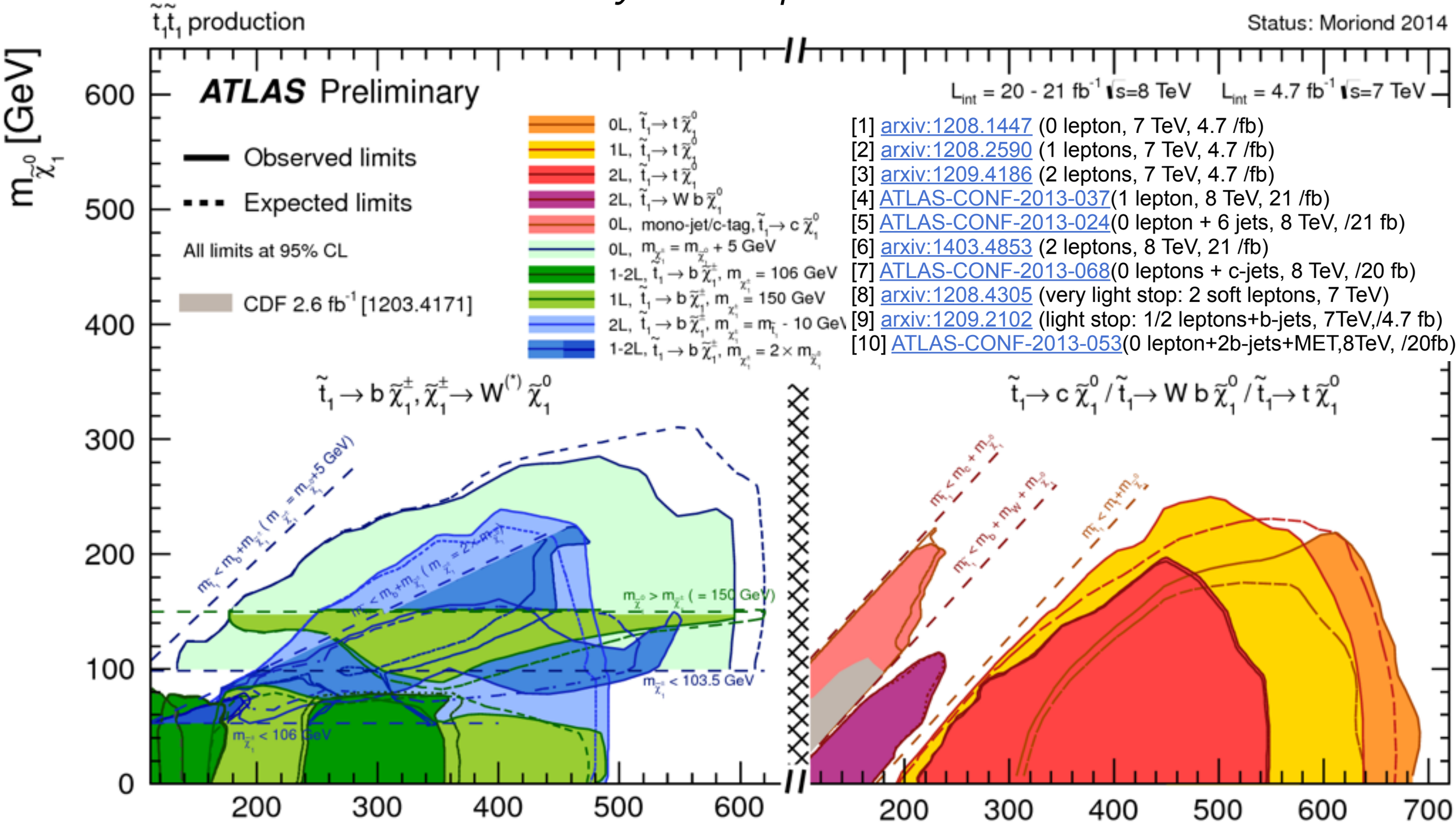
JHEP 02 (2014) 107 See talk by M. Rudolph

$$A_{\mathrm{C}} = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

$$A_{\mathrm{C}} = 0.006 \pm 0.010$$

Beyond the SM: stop quark $\tilde{t}$

Summary of stop searches



[1] arxiv:1208.1447 (0 lepton, 7 TeV, 4.7 /fb)
[2] arxiv:1208.2590 (1 leptons, 7 TeV, 4.7 /fb)
[3] arxiv:1209.4186 (2 leptons, 7 TeV, 4.7 /fb)
[4] ATLAS-CONF-2013-037(1 lepton, 8 TeV, 21 /fb)
[5] ATLAS-CONF-2013-024(0 lepton + 6 jets, 8 TeV, /21 fb)
[6] arxiv:1403.4853 (2 leptons, 8 TeV, 21 /fb)
[7] ATLAS-CONF-2013-068(0 leptons + c-jets, 8 TeV, /20 fb)
[8] arxiv:1208.4305 (very light stop: 2 soft leptons, 7 TeV)
[9] arxiv:1209.2102 (light stop: 1/2 leptons+b-jets, 7TeV,/4.7 fb)
[10] ATLAS-CONF-2013-053(0 lepton+2b-jets+MET,8TeV, /20fb)

see talk by J.F. Arguin

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Moriond 2014

ATLAS Preliminary

$\int \mathcal{L}\, dt$ = (4.6 - 22.9) fb^{-1} $\sqrt{s}$ = 7, 8 TeV

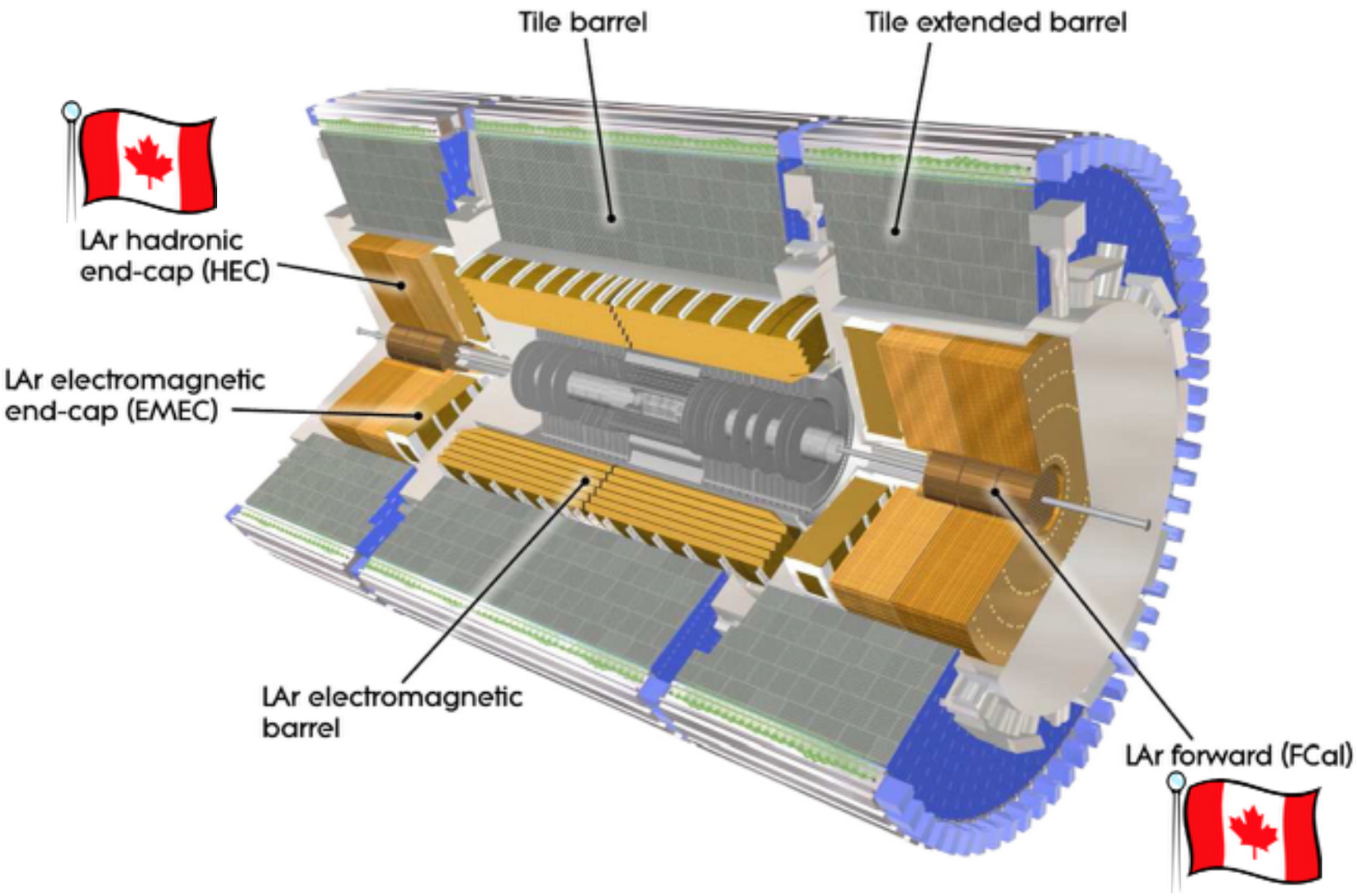
	Model	e, μ, τ, γ	Jets	$E_{\mathrm{T}}^{\mathrm{miss}}$	$\int \mathcal{L}\, dt$[fb^{-1}]	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}_1^0)<200$ GeV, $m(\tilde{\chi}^*)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	$\tan\beta<15$	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$ 1.4 TeV	$\tan\beta>18$	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.28 TeV	$m(\tilde{\chi}_1^0)>50$ GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}_1^0)>50$ GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}_1^0)>220$ GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	$m(\tilde{H})>200$ GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.2 TeV	$m(\tilde{\chi}_1^0)<600$ GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}_1^0)<350$ GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}_1^0)<400$ GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)<300$ GeV	ATLAS-CONF-2013-061
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	$m(\tilde{\chi}_1^0)<90$ GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$ 275-430 GeV	$m(\tilde{\chi}_1^\pm)=2\ m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV	$m(\tilde{\chi}_1^0)=55$ GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 130-210 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{t}_1)-m(W)-50$ GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}_1^+)$	1403.4853
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$ 215-530 GeV	$m(\tilde{\chi}_1^0)=1$ GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}_1^0)<200$ GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)=5$ GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e,μ	1 b	Yes	20.7	$\tilde{t}_1$ 200-610 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$ 320-660 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-200 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)<85$ GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}_1^0)>150$ GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$ 290-600 GeV	$m(\tilde{\chi}_1^0)<200$ GeV	1403.5222
EW direct	$\tilde{\ell}_{\mathrm{L,R}}\tilde{\ell}_{\mathrm{L,R}}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$ 90-325 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$ 140-465 GeV	$m(\tilde{\chi}_1^0)=0$ GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 180-330 GeV	$m(\tilde{\chi}_1^0)=0$ GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^+\tilde{\chi}_2^0\to\tilde{\ell}_{\mathrm{L}}\nu\tilde{\ell}_{\mathrm{L}}\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_{\mathrm{L}}\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm,\tilde{\chi}_2^0$ 700 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)=0$, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm,\tilde{\chi}_2^0$ 420 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)=0$, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm,\tilde{\chi}_2^0$ 285 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)=0$, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$ 270 GeV	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)=160$ MeV, $\tau(\tilde{\chi}_1^\pm)=0.2$ ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$ 832 GeV	$m(\tilde{\chi}_1^0)=100$ GeV, 10 μs$<\tau(\tilde{g})<$1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$ 475 GeV	$10<\tan\beta<50$	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$ 230 GeV	$0.4<\tau(\tilde{\chi}_1^0)<2$ ns	1304.6310
	$\tilde{q}\tilde{q}, \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	$1.5<c\tau<156$ mm, BR(μ)=1, $m(\tilde{\chi}_1^0)=108$ GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	$\lambda'_{311}=0.10$, $\lambda_{132}=0.05$	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	$\lambda'_{311}=0.10$, $\lambda_{1(2)33}=0.05$	1212.1272
	Bilinear RPV CMSSM	1 e,μ	7 jets	Yes	4.7	$\tilde{q},\tilde{g}$ 1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}<1$ mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 760 GeV	$m(\tilde{\chi}_1^0)>300$ GeV, $\lambda_{121}>0$	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 350 GeV	$m(\tilde{\chi}_1^0)>80$ GeV, $\lambda_{133}>0$	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$ 880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e,μ (SS)	2 b	Yes	14.3	sgluon 350-800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale 704 GeV	$m(\chi)<80$ GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

$\sqrt{s}$ = 7 TeV full data | $\sqrt{s}$ = 8 TeV partial data | $\sqrt{s}$ = 8 TeV full data

10^{-1} 1 **Mass scale [TeV]**

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

2) Canadian Detector Operations: Calorimeter



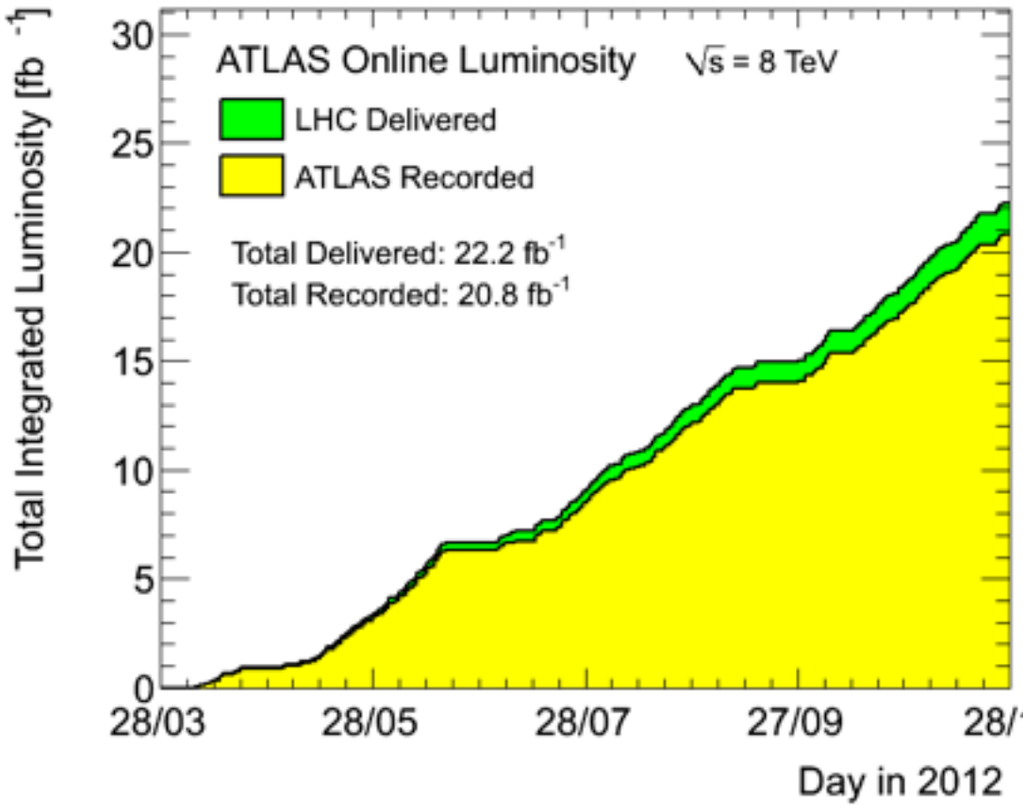
Subdetector	Channels	Operational
LAr EM Calorimeter	***170 k***	***99.9%***
LAr Hadronic Endcap (HEC)	***5600***	***99.6%***
LAr Forward Calorimeter (FCal)	***3500***	***99.8%***
Hadronic Tile Calorimeter	***9800***	***98.3%***

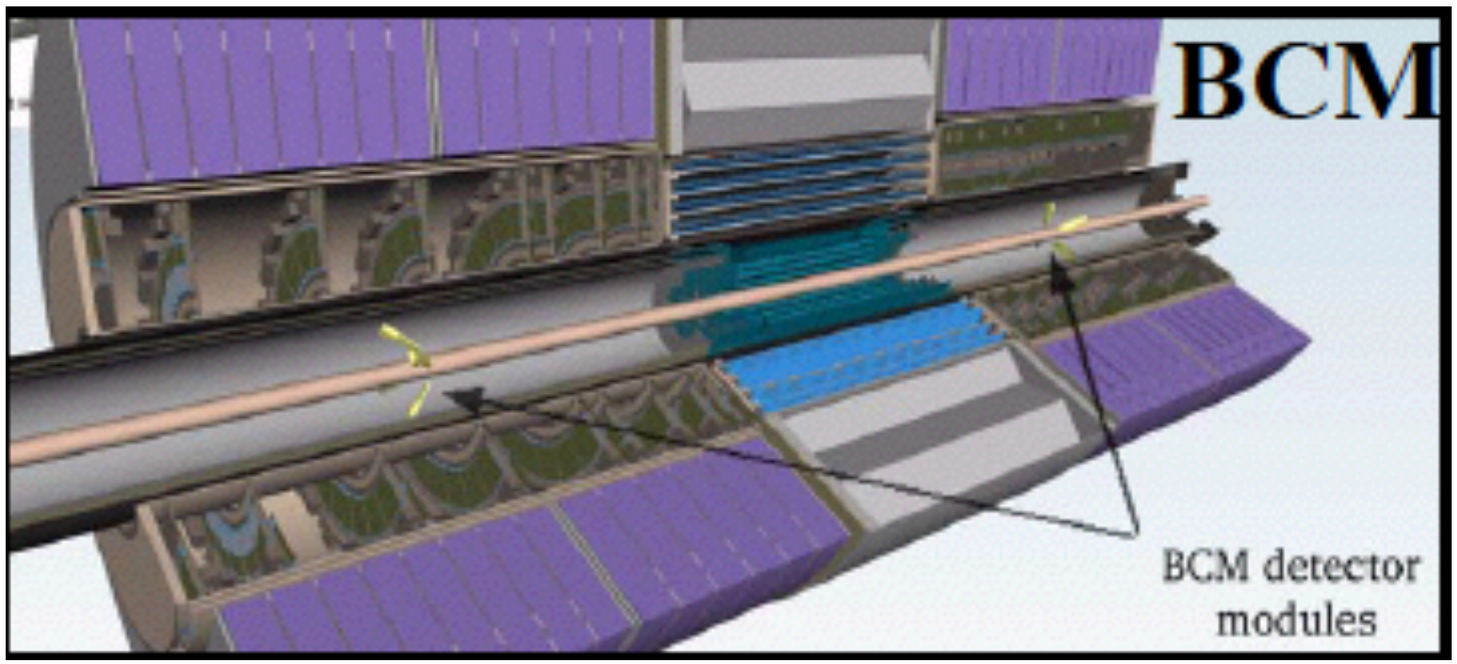
- Liquid Argon (LAr) maintained an overall **99.1%** data-taking efficiency during 2012 pp run

→ ATLAS Canada personnel provided the bulk of the LAr hardware expert tasks & on-call shifts in 2012

- Run coordinator: 40%
- "Supershifter": 25%
- Hardware experts on call: 20%
- Data Quality team: 10%

3) Luminosity



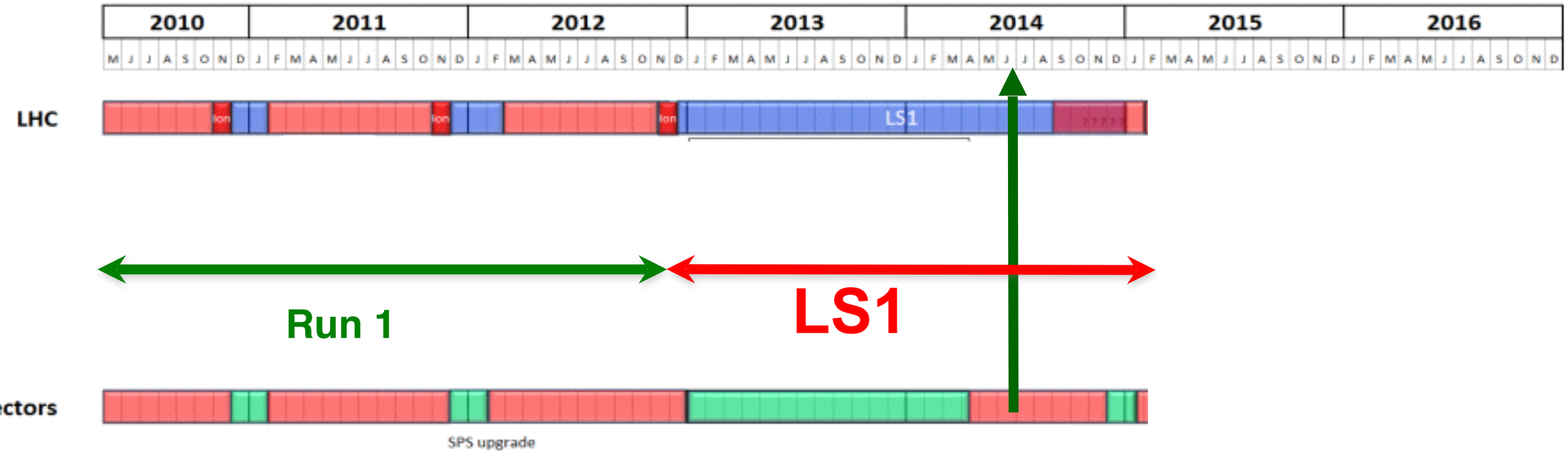


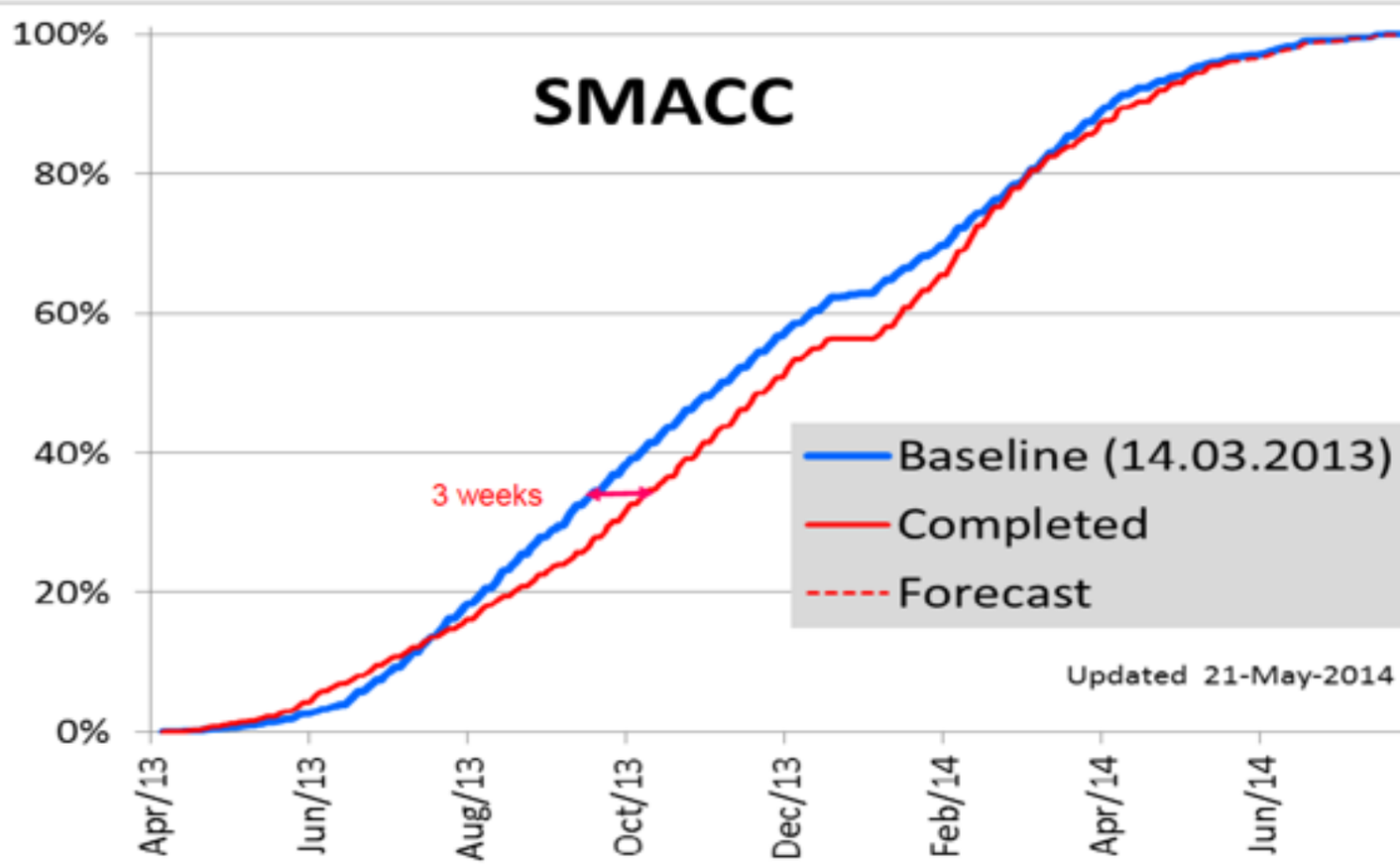
Luminosity uncertainty: 2011: 1.8%, 2012: **2.8%**

- Beam Conditions Monitor now default ATLAS detector for luminosity
- BCM provides 12 luminosity algorithms based on hit combinations from different modules

Canada BCM/BLM: 1 Faculty, 2 postdocs, 2 graduate students, 1 summer student,
→ **Canadian Run Coordinator in 2012**

4) LHC Long Shutdown 1 (LS1)





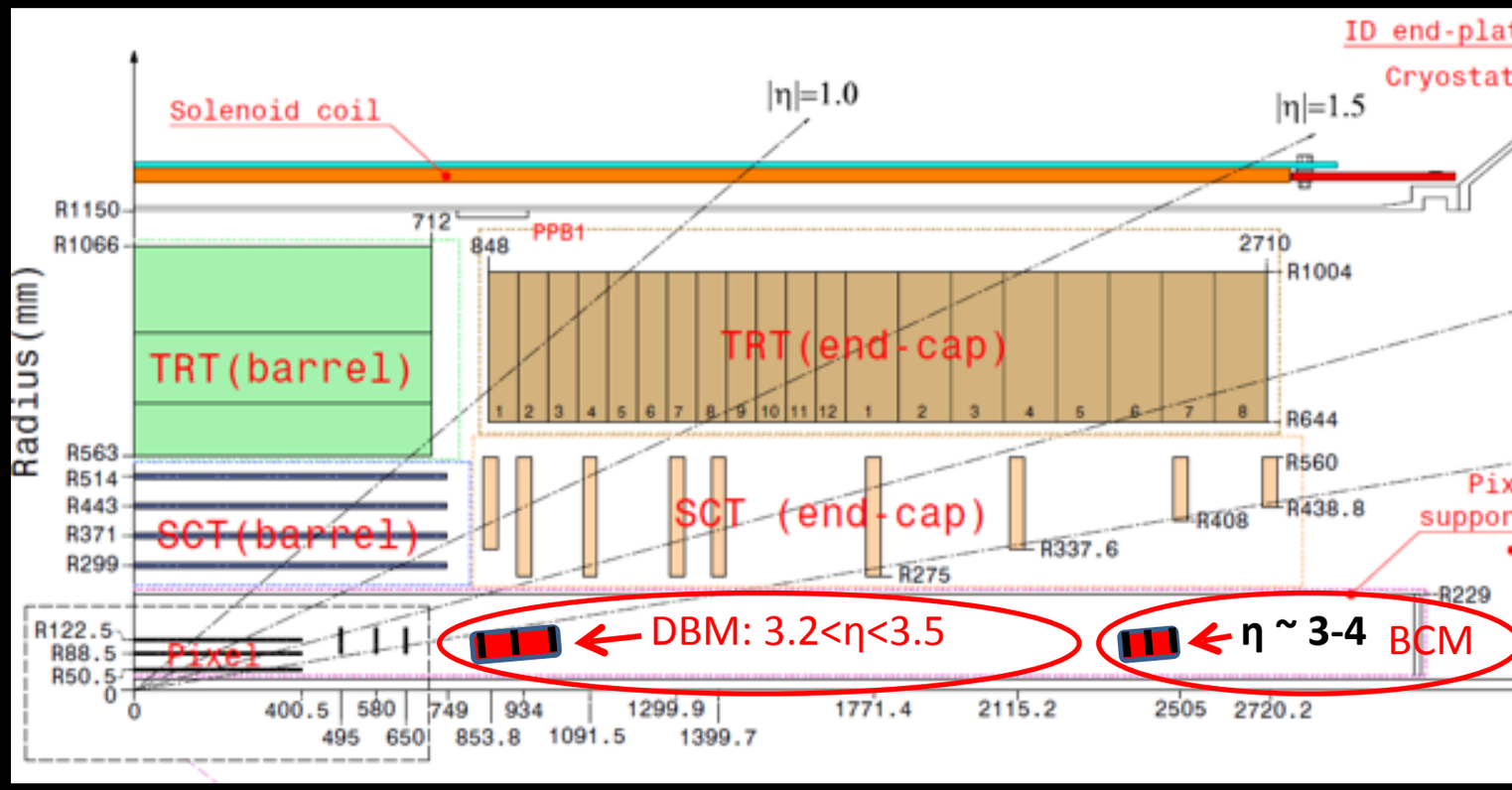
LS1 & Canada: Install Diamond Beam Monitor (DBM)

Bunch-by-bunch luminosity monitor

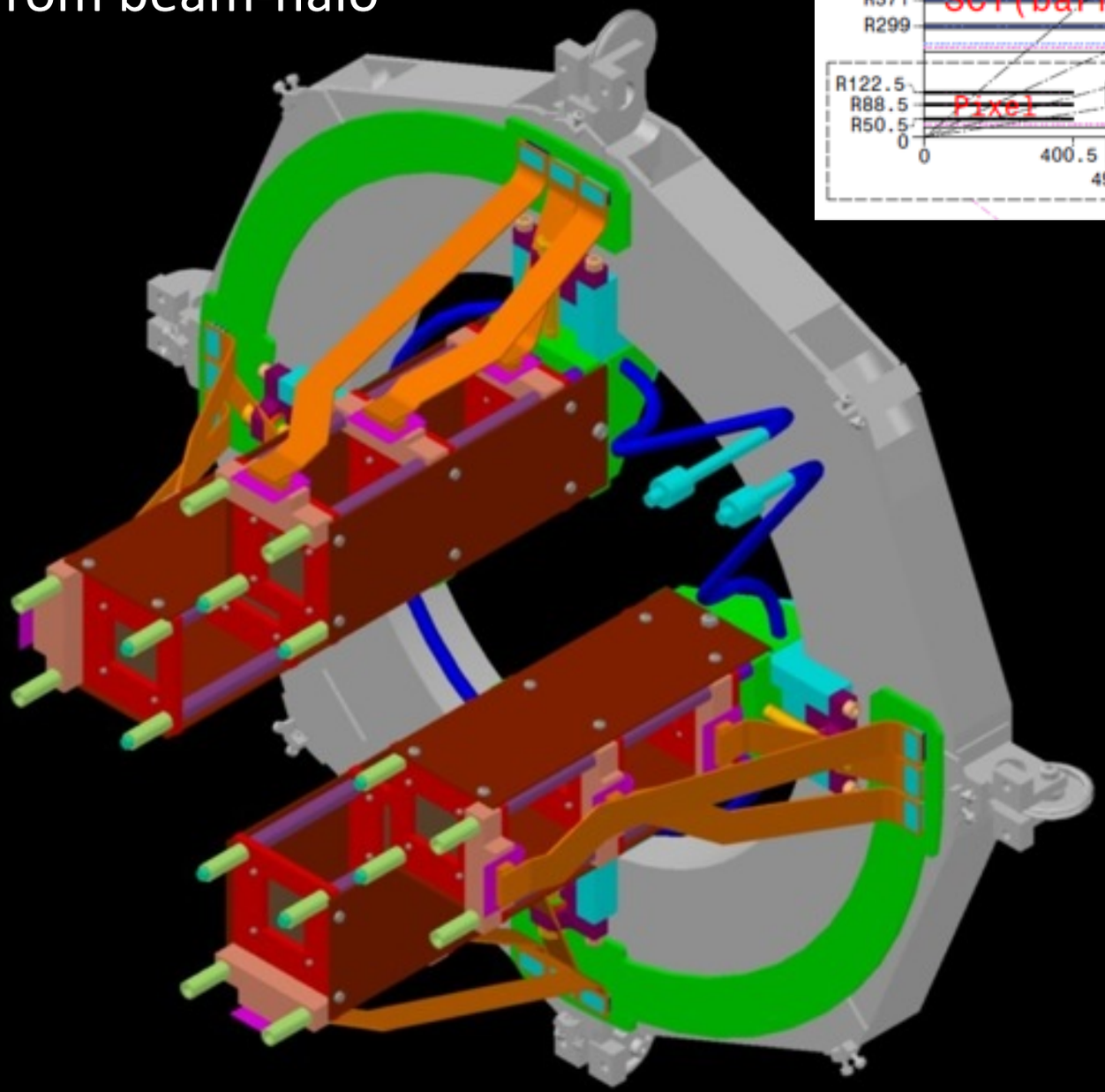
- complements Beam Conditions Monitor (BCM)

Bunch-by-bunch beam spot monitor

- distinguish collision products from beam-halo

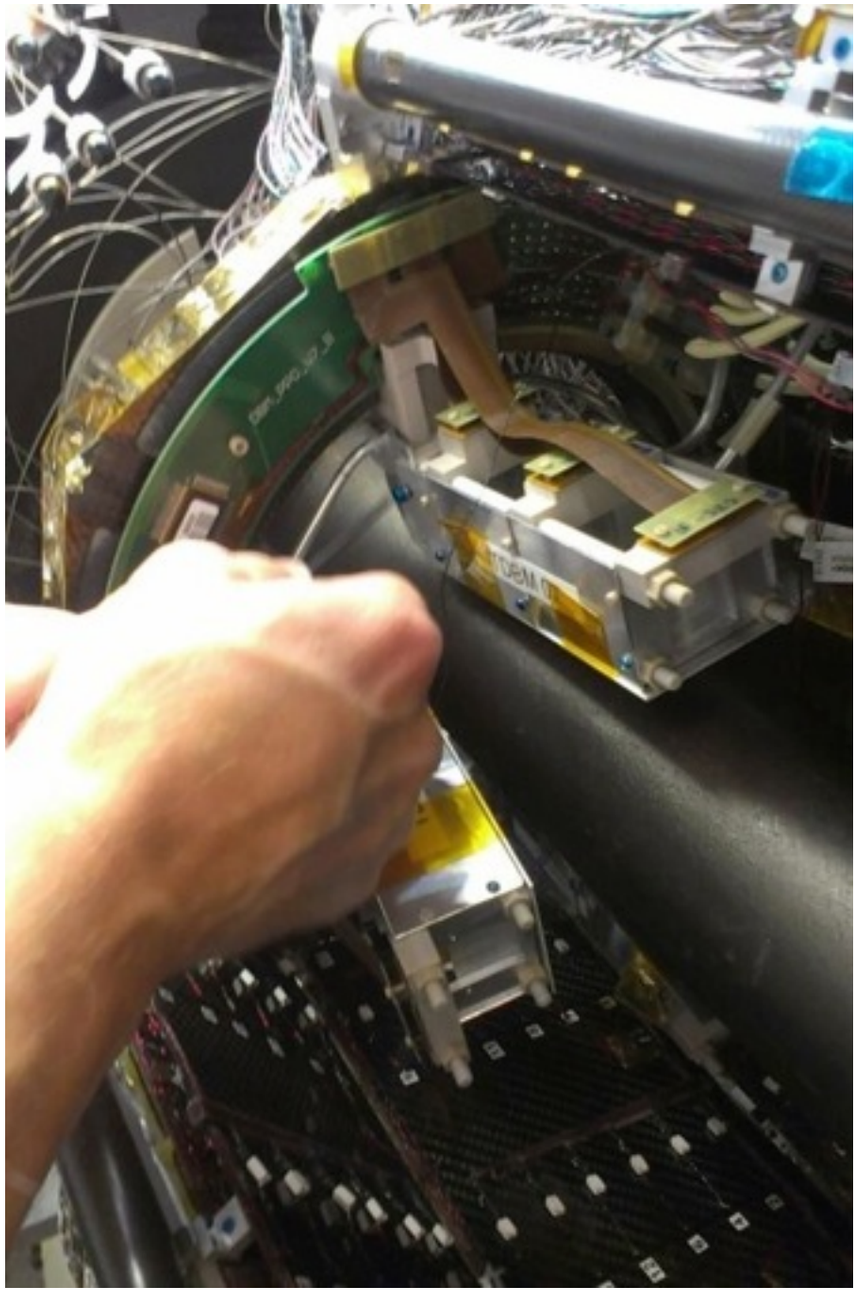


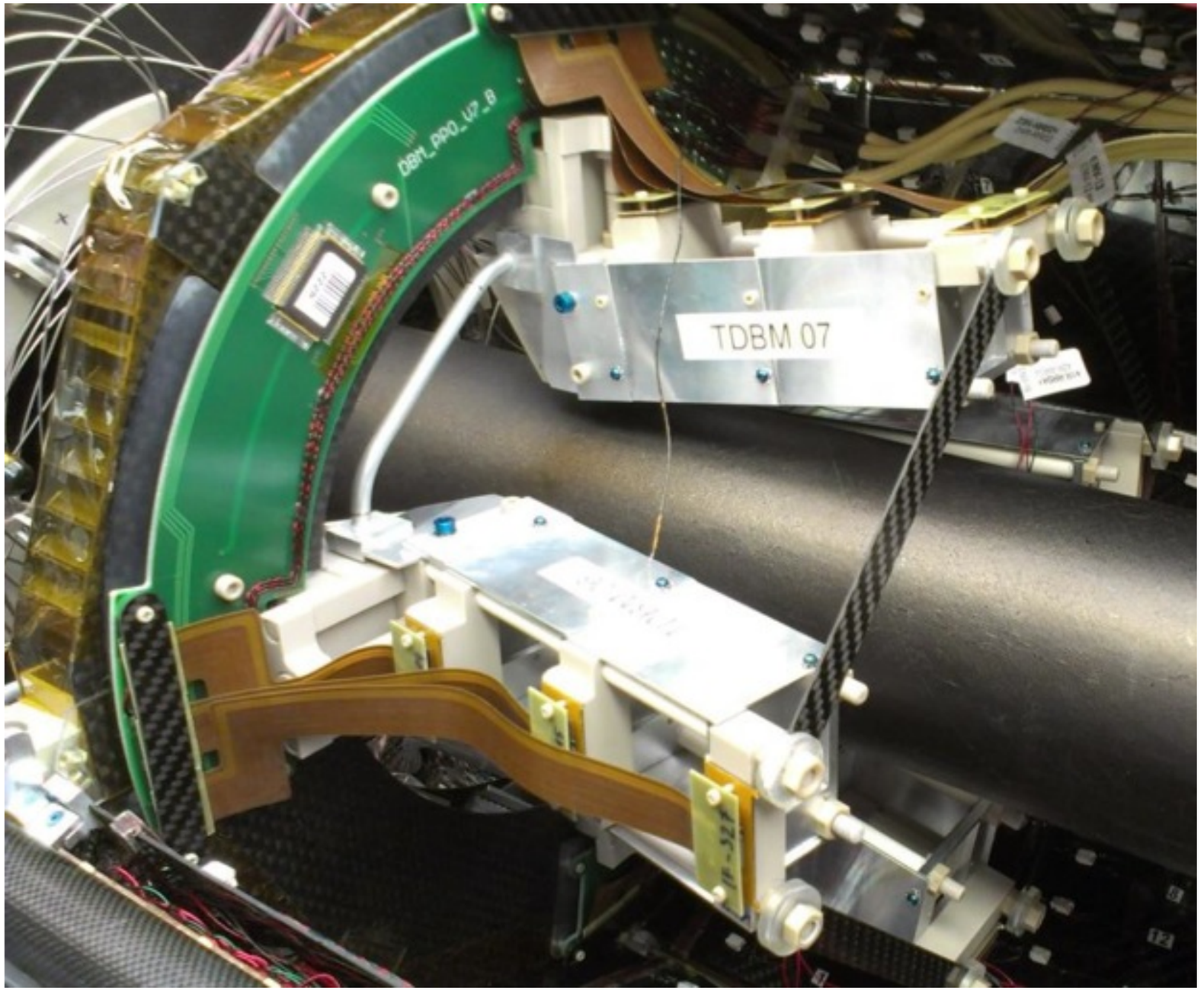
DBM: 3.2<|η|<3.5



Canadian Group designed and manufactured the support structure

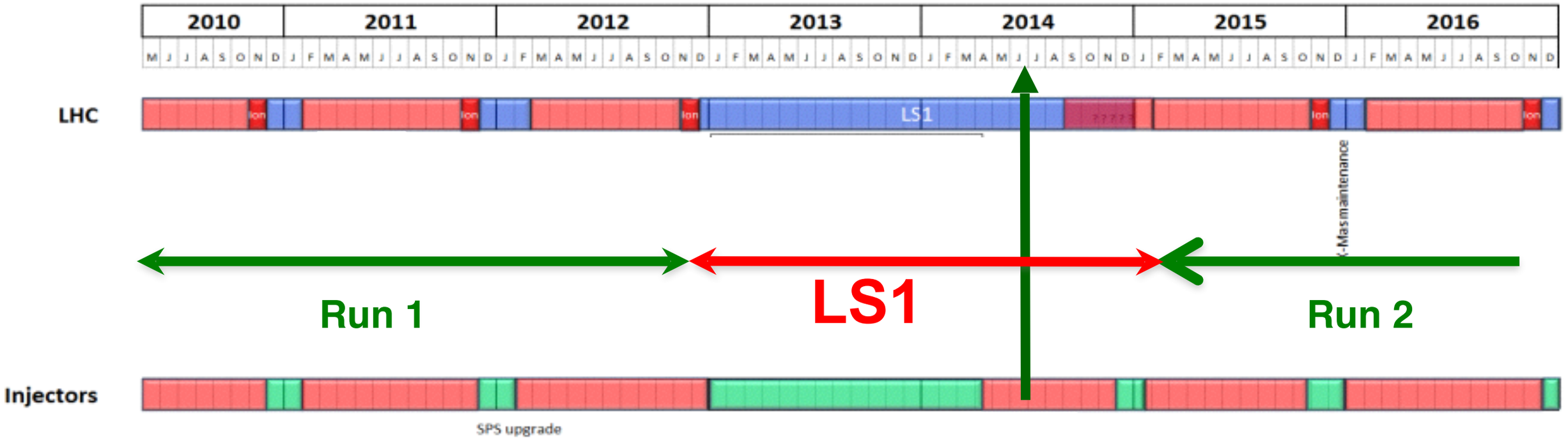
DBM Telescope Installation

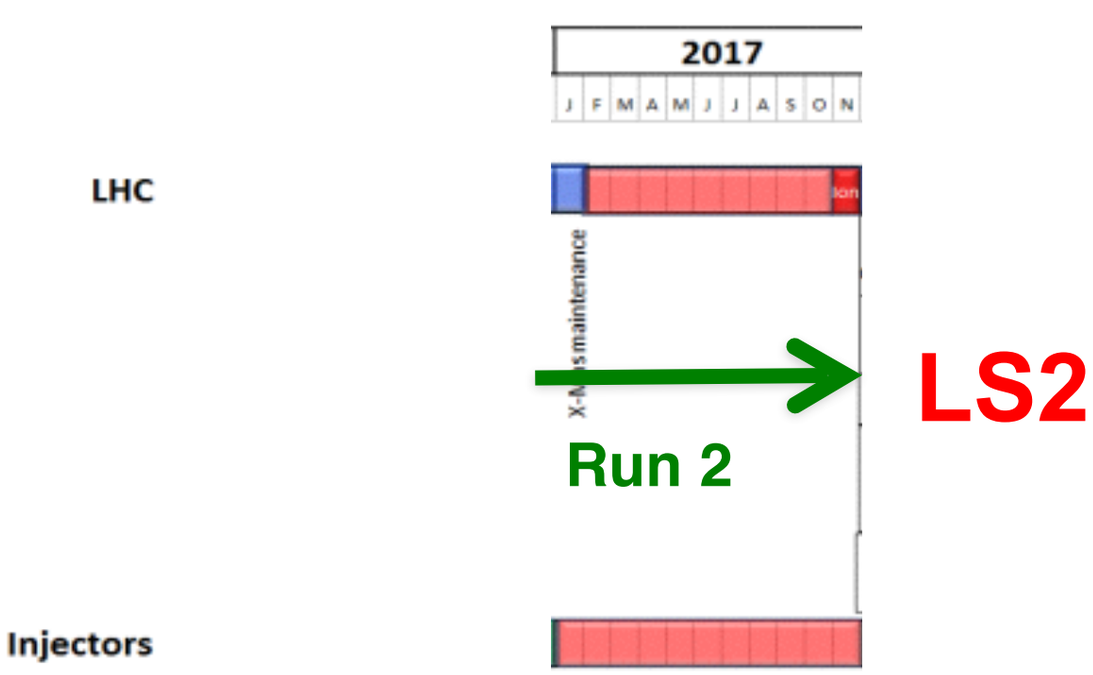




See talk by M.Diamond

Run2: 3 years Operation Run after Long Shutdown 1 (LS1)

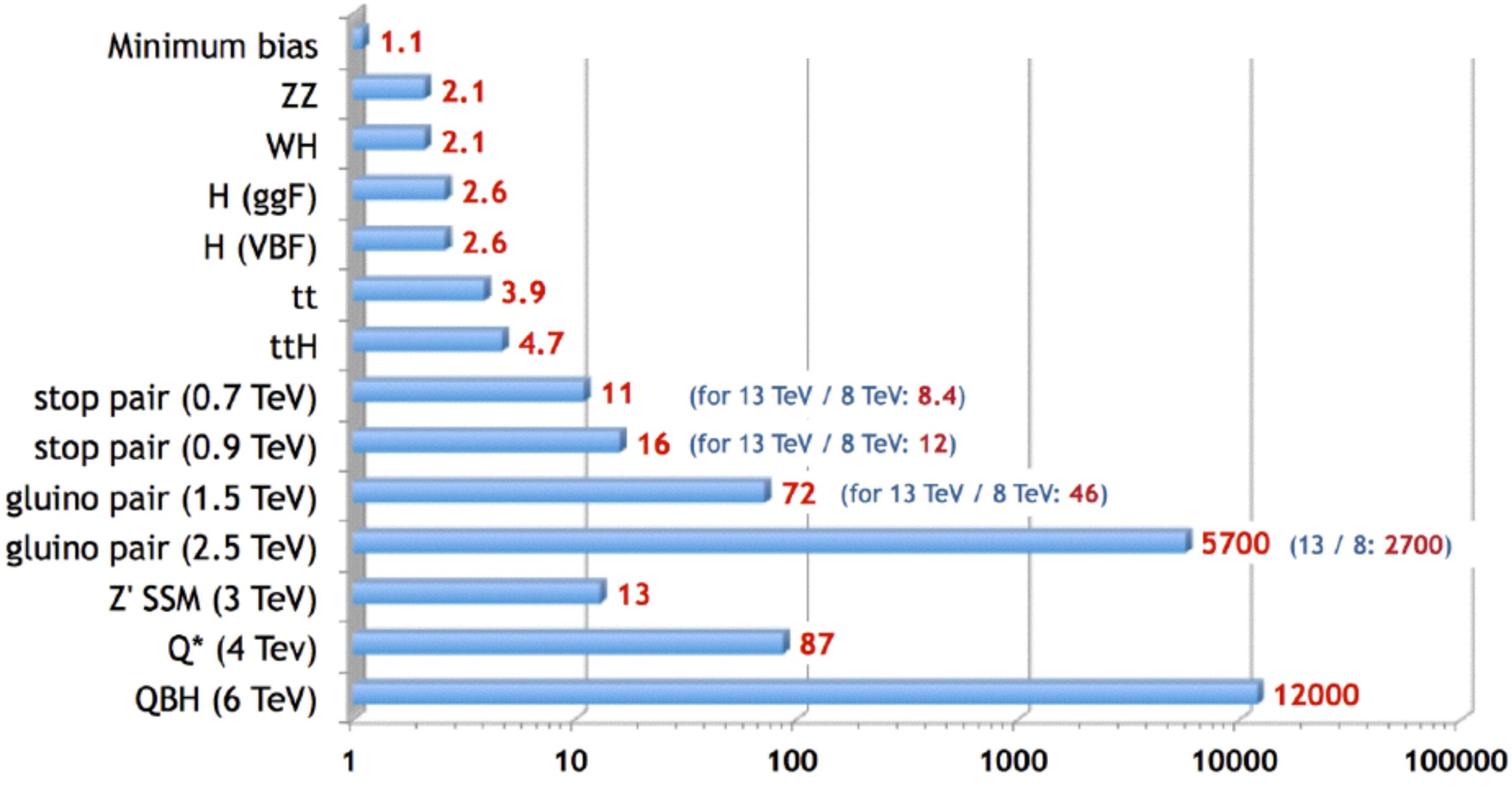




Run 2:
Start with 13 TeV and later decision towards 14 TeV according to magnet training

Prospects for Run-2

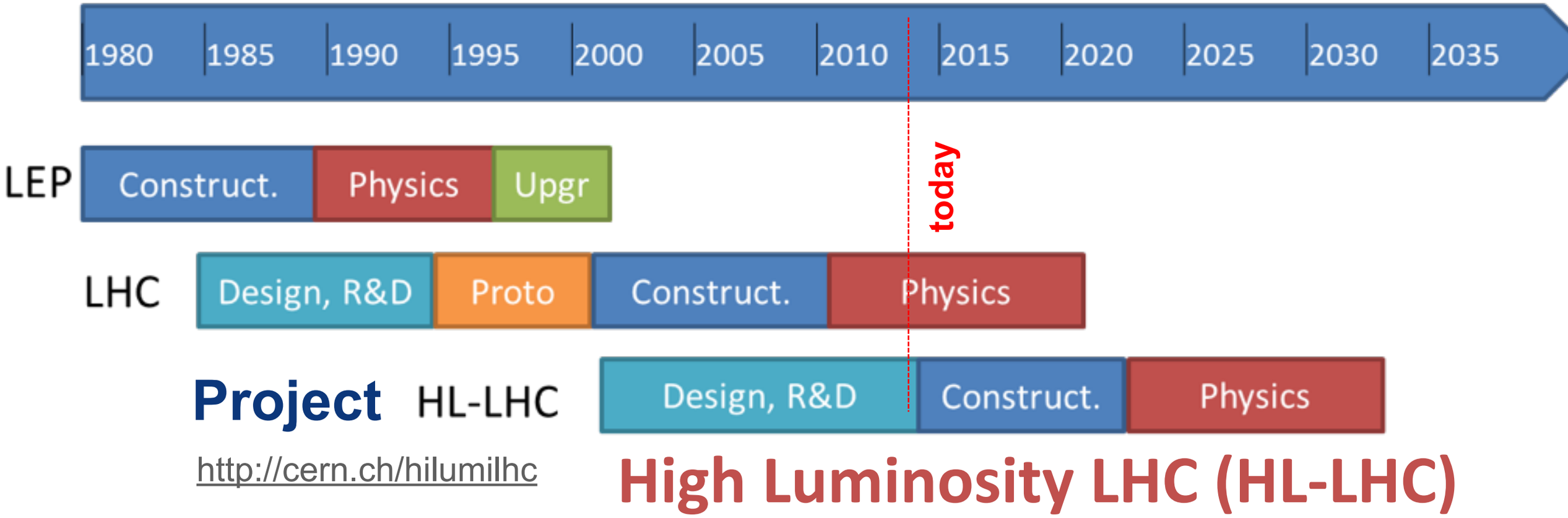
Increase in cross sections from 8 TeV to 13 (14) TeV



5) Physics with ATLAS for the Next 20 Years

Update of the European Strategy for Particle Physics
adopted 30 May 2013 in a special session of CERN Council at Brussels:

"Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030."



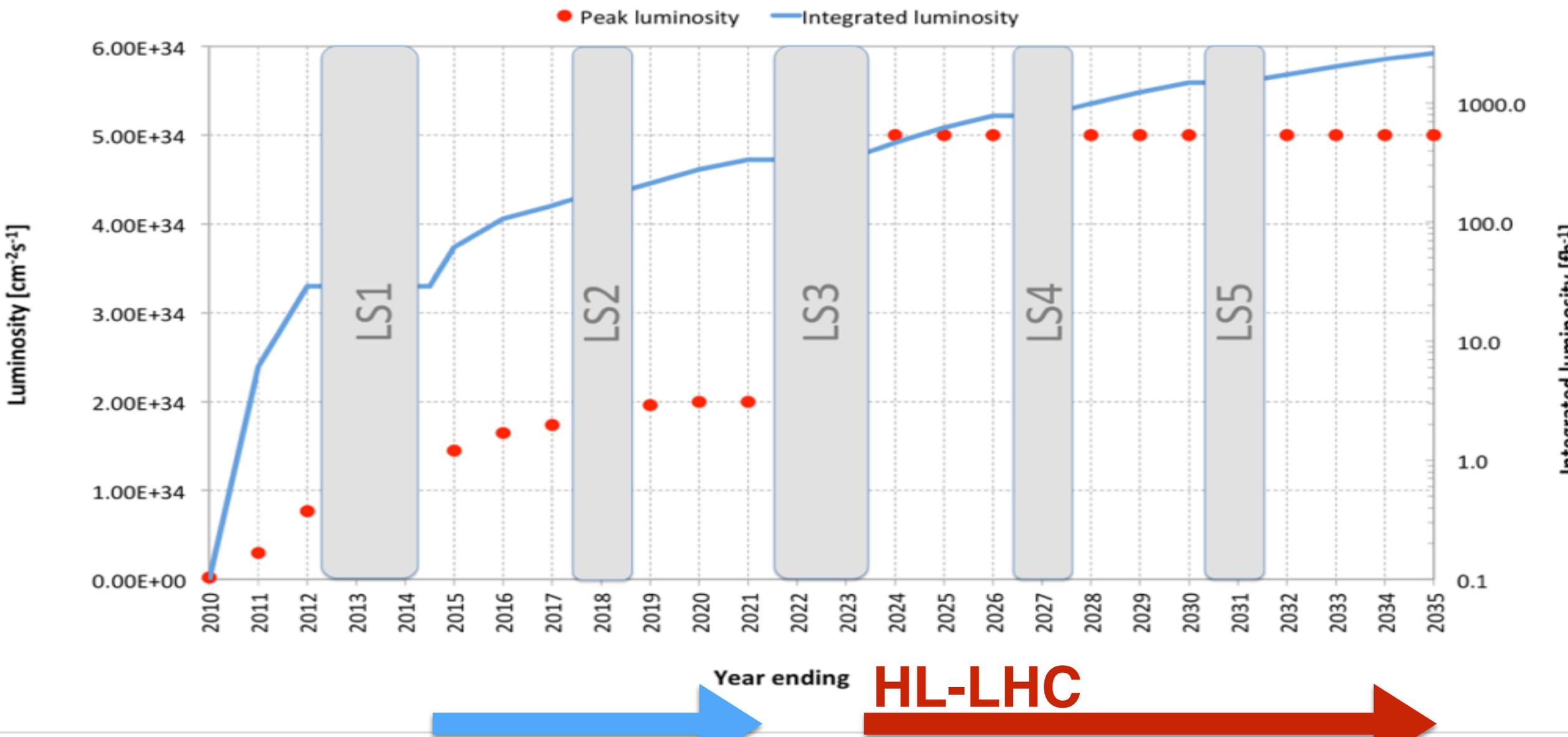
http://cern.ch/hilumilhc

High Luminosity LHC (HL-LHC)

US High Energy Physics Advisory Panel - P5 Report, June 2014:

"The HL-LHC has a compelling and comprehensive program that includes essential measurements of the Higgs properties."

LHC Luminosity for the Next 20 Years



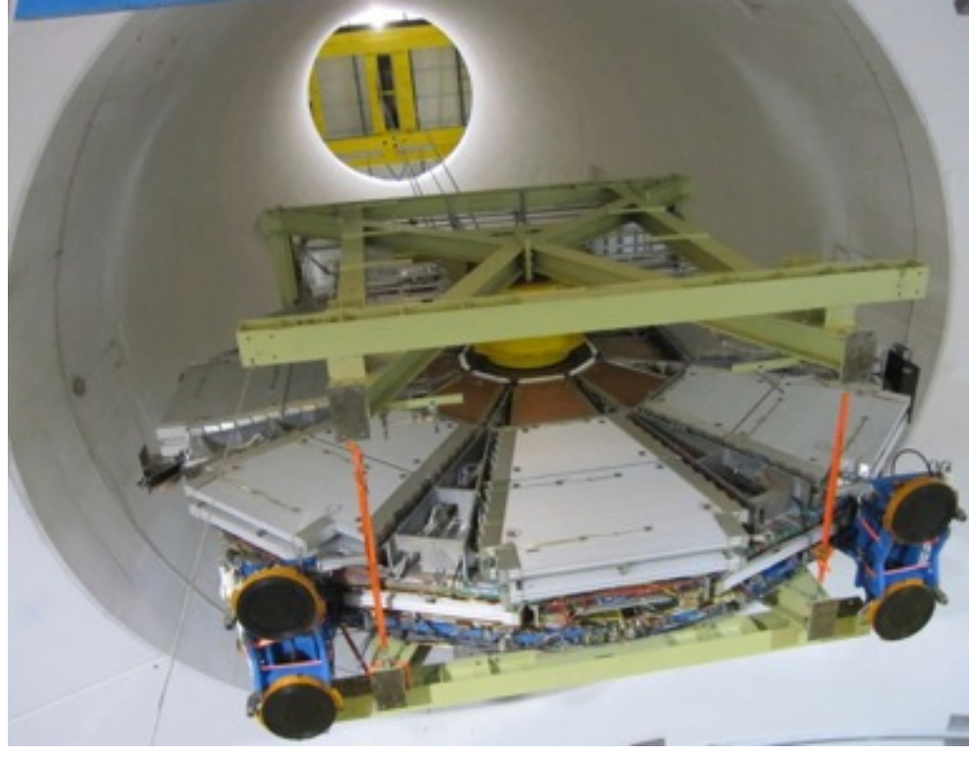
Now: ATLAS Phase 1 upgrades, LHC 2-3 x design luminosity, install in 2018 shutdown, collect to **300 fb^{-1}**

Future: ATLAS Phase-2 Upgrades for HL-LHC, 5-6 x design luminosity, install in 2022 shutdown, collect to **3000 fb^{-1}**

Canada & Phase 1 Upgrade: New Small Wheel (NSW)

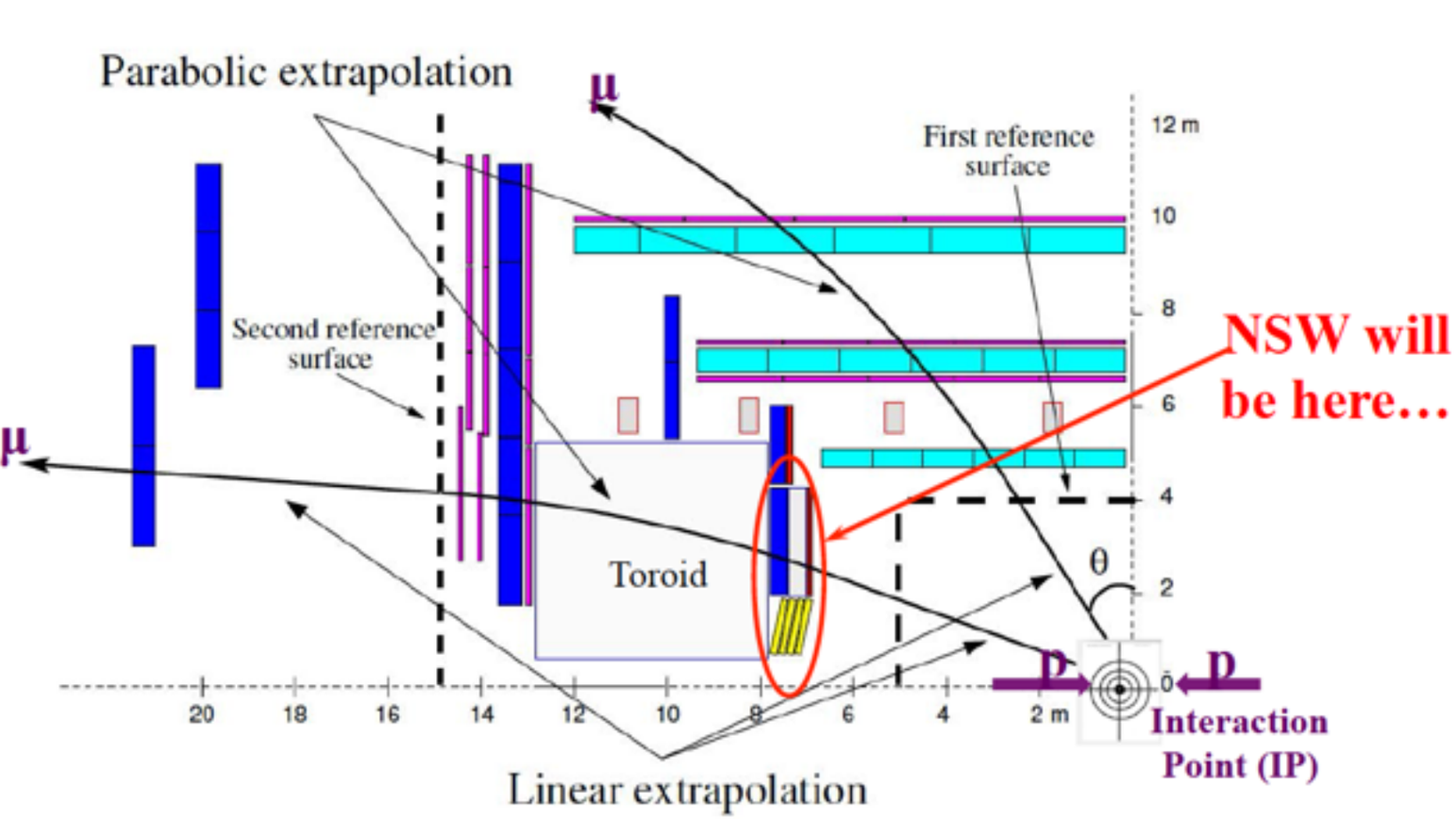
Problem: Monitored Drift Tubes in current muon end cap "small" wheel can't handle hit rates @ 3x design lumi: $3x10^{34}$ cm^{-2} s^{-1}

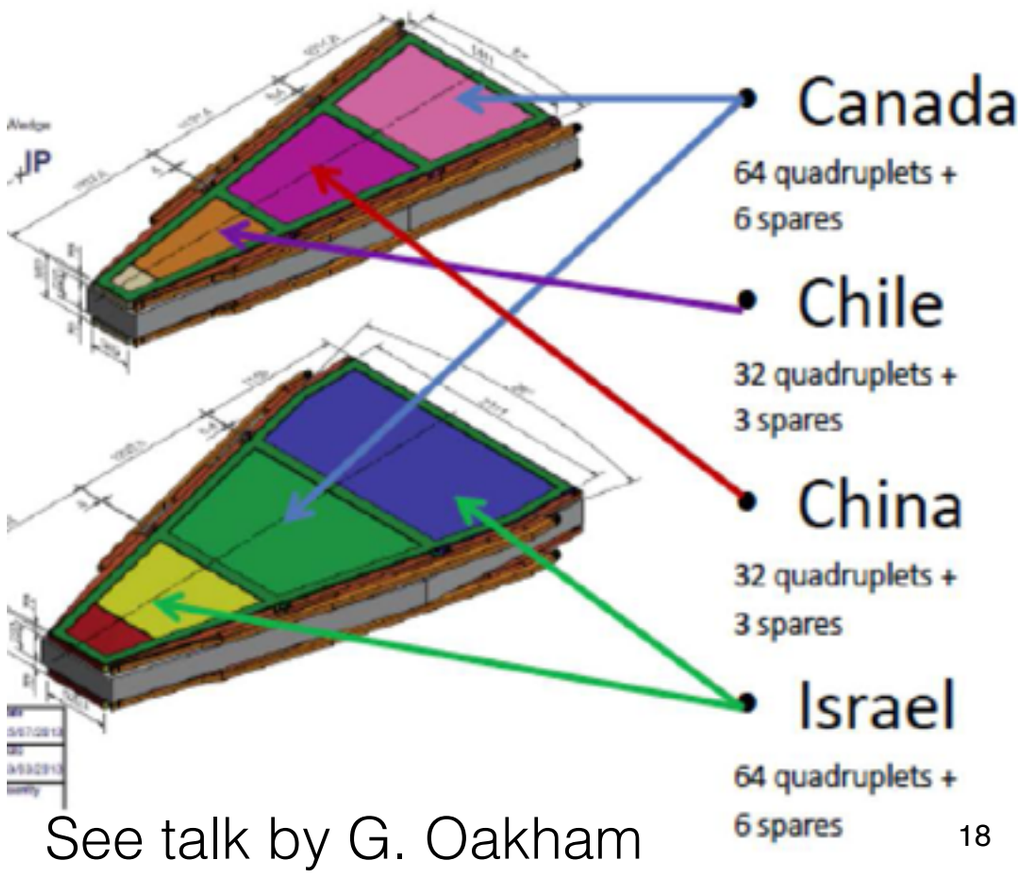
Solution: replace with MicroMegas and Thin Gap Chambers



Current small wheel

Canada will build 64 modules for NSW 2015-2016

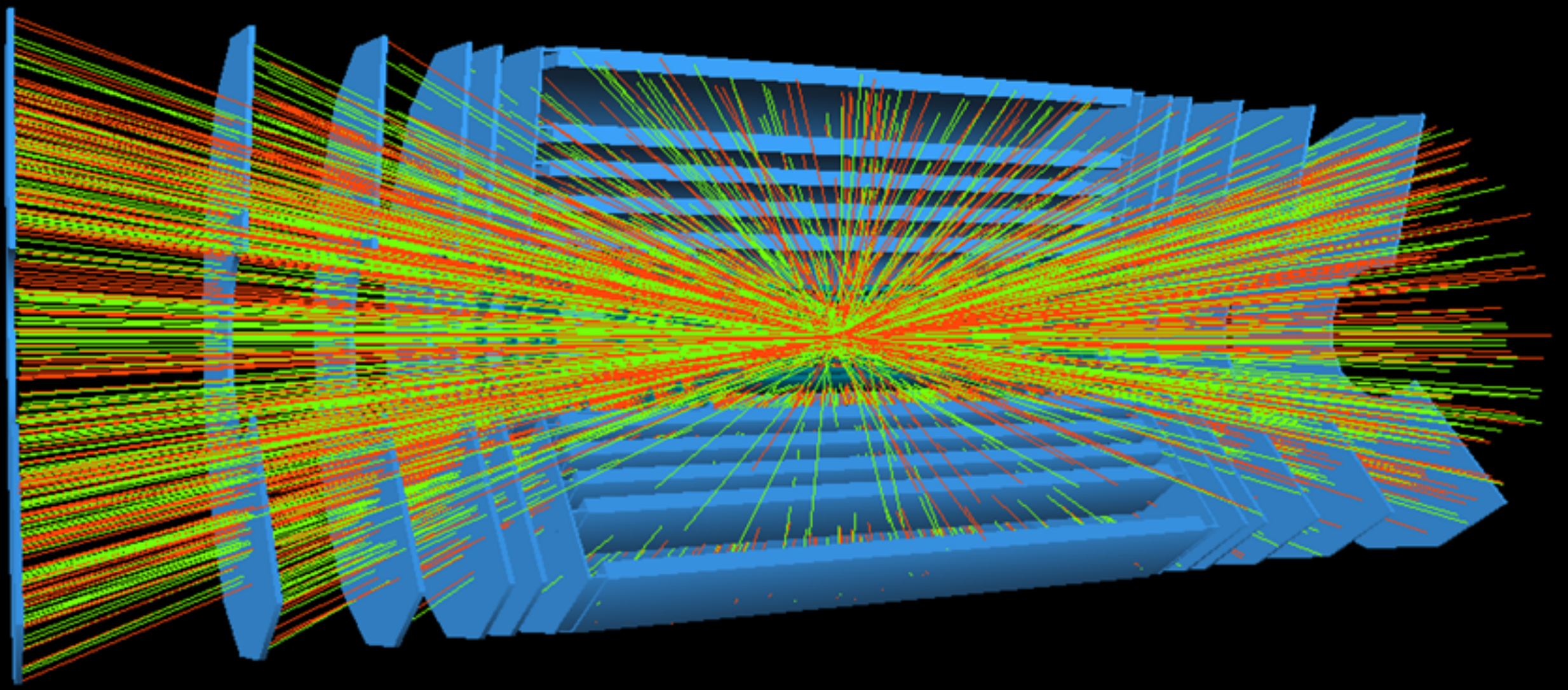




See talk by G. Oakham

ATLAS Phase-2 Upgrade

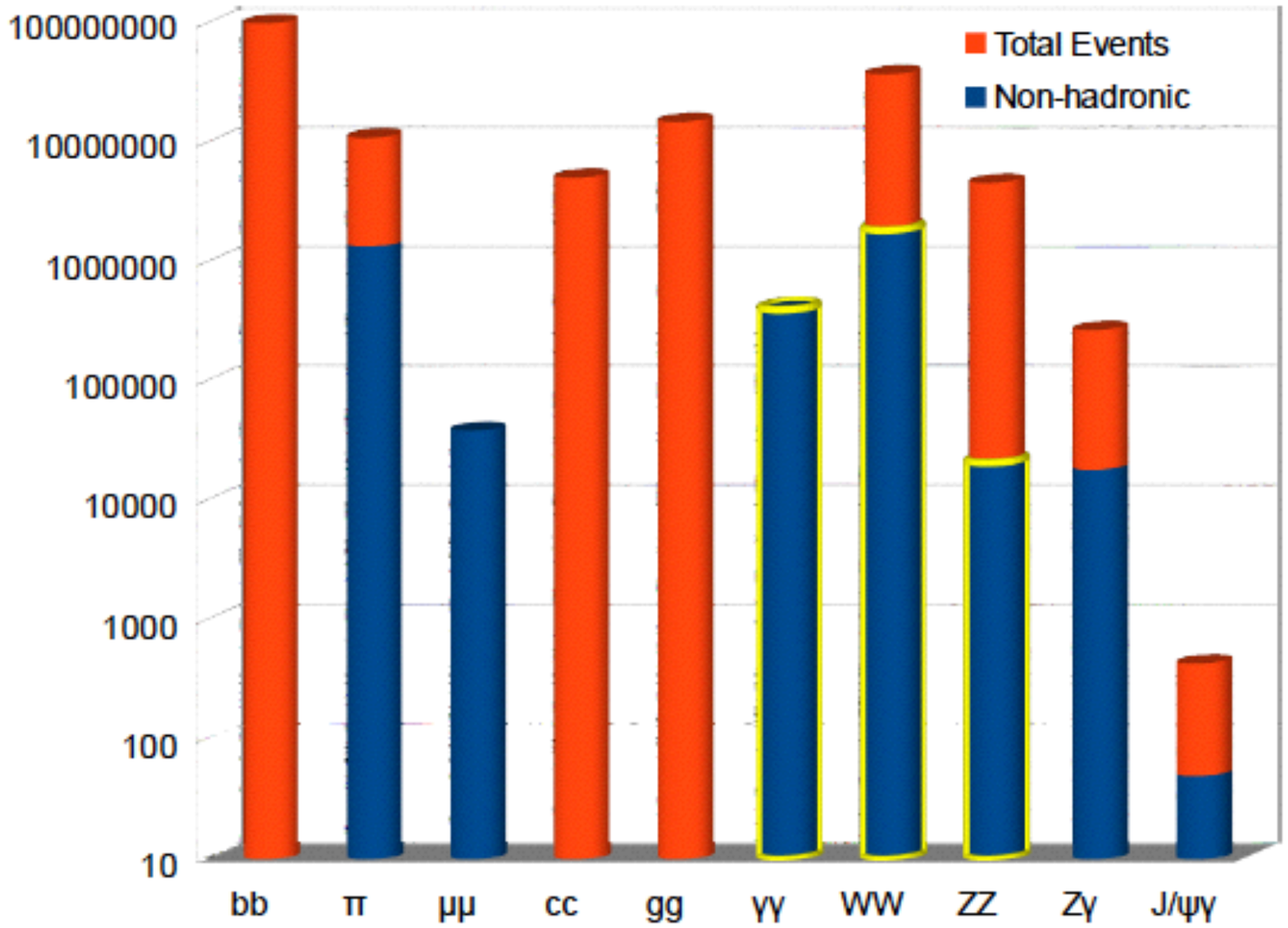
Replacement of ATLAS Inner Tracker with silicon strips & pixels:
Here 230 pileup events shown

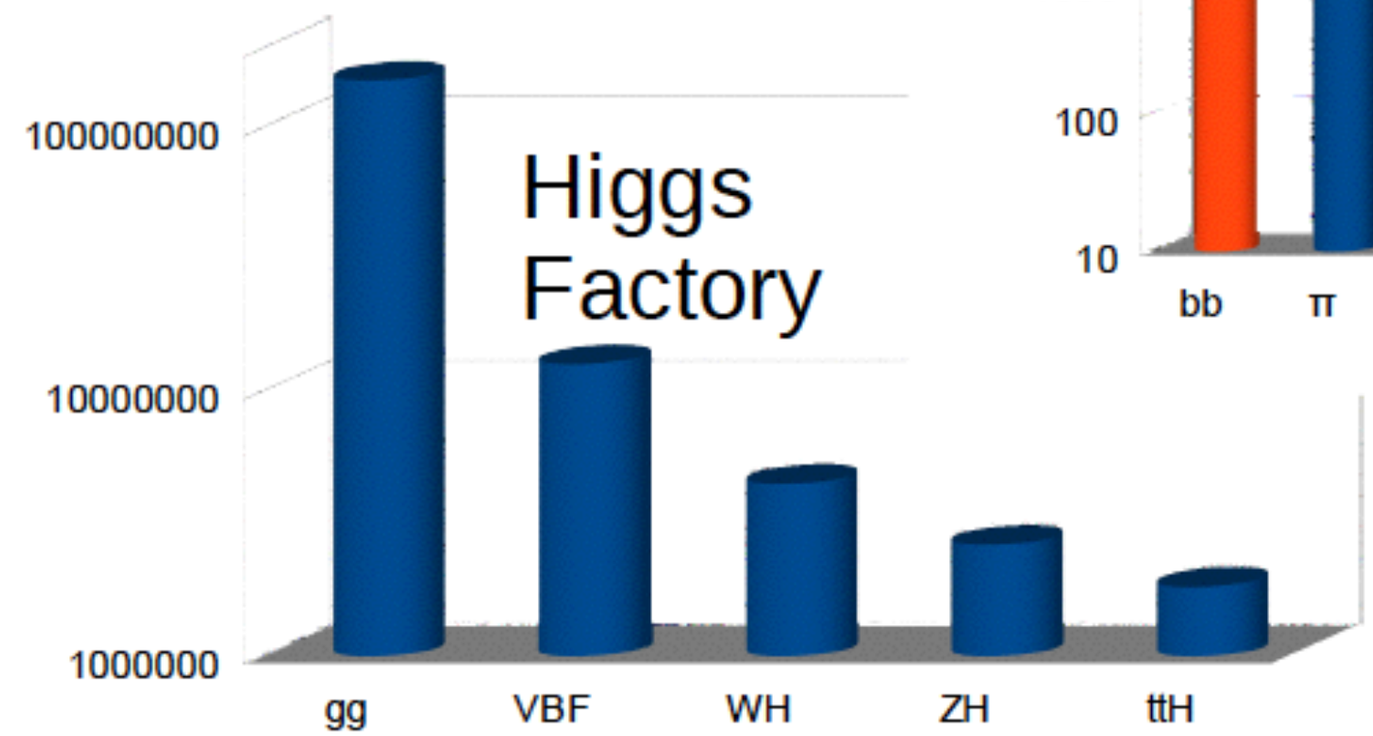


Interest in Canada for Phase-2 LAr FCal, electronics & Inner Tracker Upgrades

Higgs Potential at HL-LHC

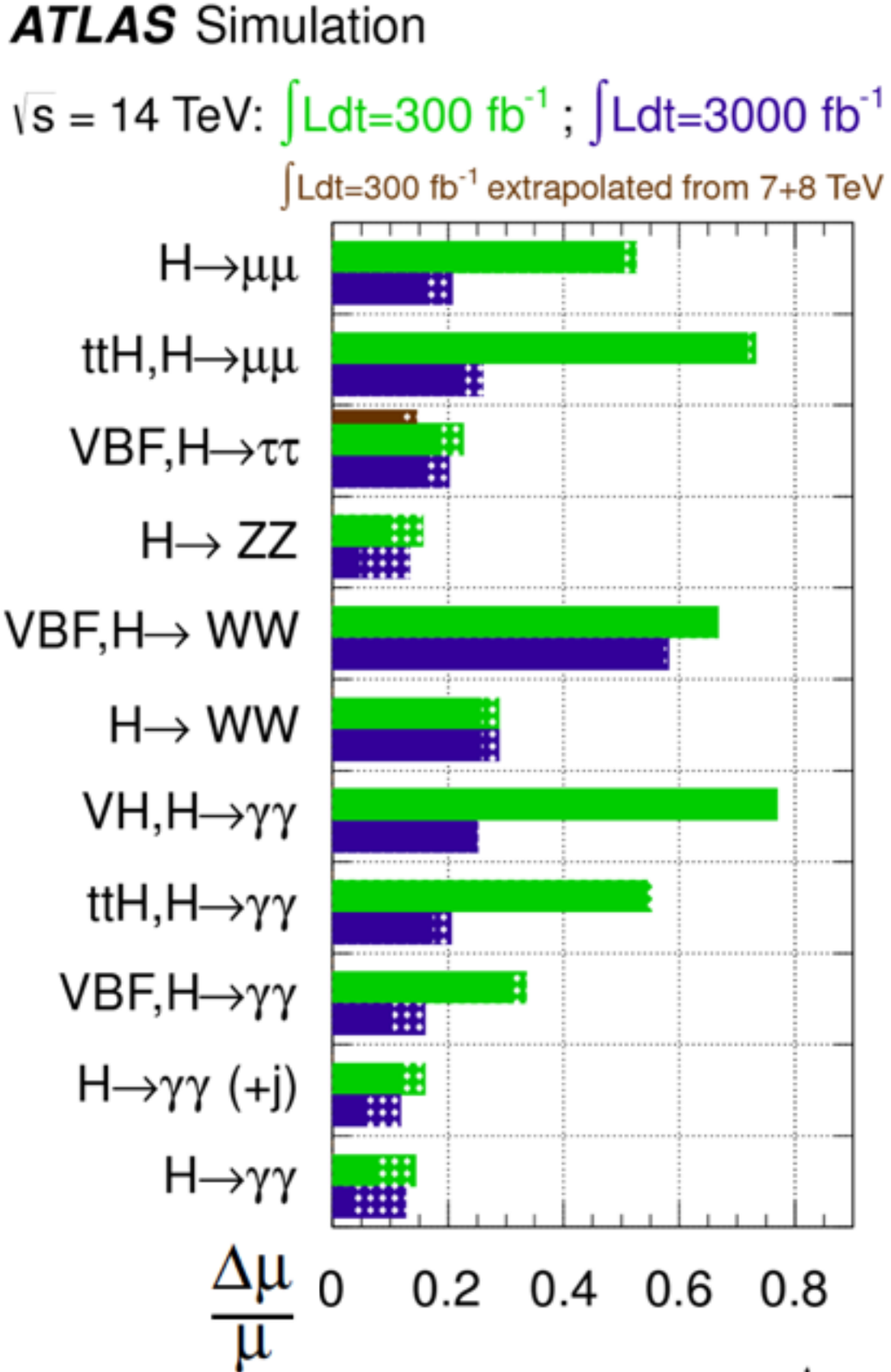
- Over 100M Higgs bosons
- 20K H→ZZ→llll
- 400K γγ
- 50 H→J/ψγ

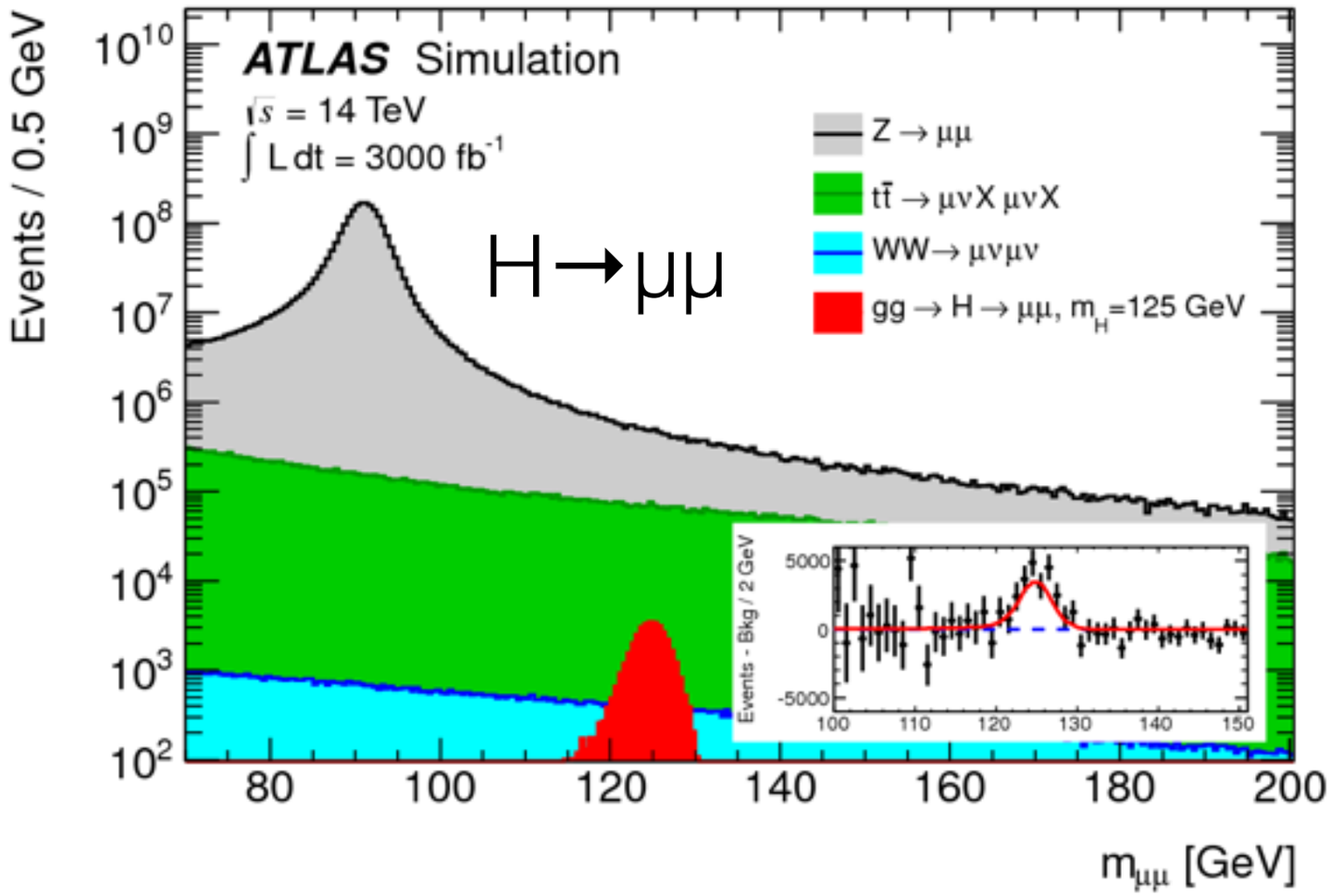




- Over 1M in all major production modes

Higgs Prospects @ HL-LHC





- Prospects for precision Higgs couplings measurements, deviation from SM?
- Higgs self-coupling λ_{HHH}? Challenging but being studied
- Higgs coupling to second-generation H→μμ

SUSY stop on the horizon?

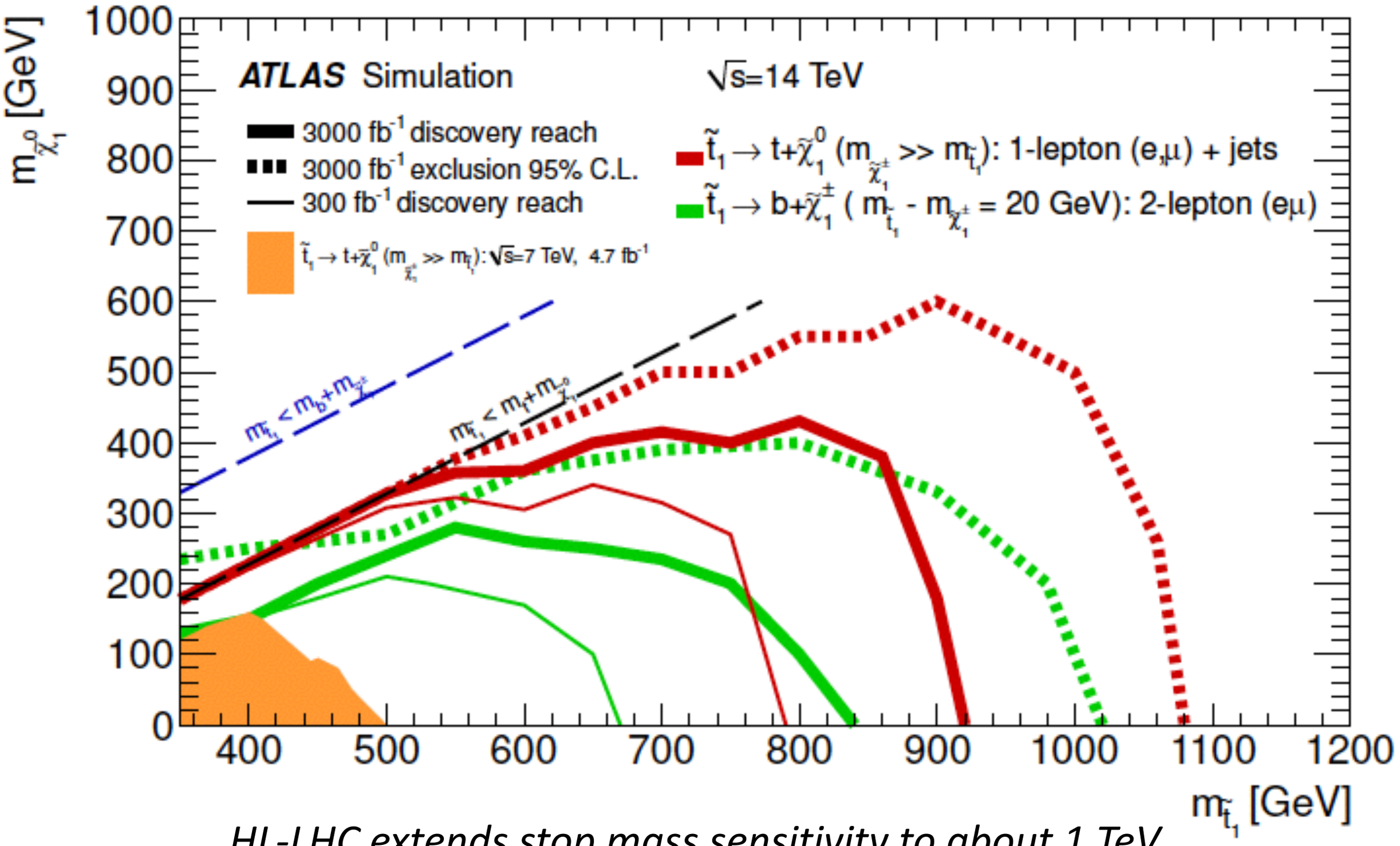
$\tilde{t}$

t

STOP

(Photo by RT, inspired by Giudice)

Stop Discovery Potential @ HL-LHC



HL-LHC extends stop mass sensitivity to about 1 TeV

Interactions: VIP Canada visits to CERN

- The Honourable Dr. Kellie Leitch, Minister of Labour and Minister of Status of Women, June 10, 2014
- Senior Management, Canada's Advanced Research and Innovation Network CANARIE, May 22, 2014
- Her Excellency Ms. Jennifer MacIntyre, Ambassador of Canada to Switzerland and Liechtenstein, May 14, 2014
- The Honourable Lisa Raitt, MP and Minister of Labour, June 18, 2013
- Dr. Paul Young, FRSC, Chair TRIUMF Board of Management &
  Dr. Gilles Patry, President and CEO Canadian Foundation for Innovation (CFI), Nov. 26-27, 2012
- Dr. Heidi-Christina Bandulet, Senior Programs Officer, CFI, March 22-23, 2012
- Ambassador Mrs. Roberta Santi, Bern, Feb. 2012, & March 2010.
- Mr. Joseph Daniel, Member of the Canadian House of Commons, November 2011.
- Dr. Danial Wayner, Vice President, Frontier Science, NRC, October 2011
- Mr. Konstantinos Georgaras, Director of Policy, International and Research Office, Canadian Intellectual Property Office, September 2011
- Dr. Kim Matheson, Vice President (Research and International) Carleton University, July 2011
- John McDougall, President, NRC, November 2010
- Mr. John Gero, Canadian Ambassador and Permanent Representative to the World Trade Organization, October 2009. Mr. Bruce Gitelman, Royal Canadian Institute for the Advancement of Science, October 2010
- Mr. Peter Allen, President, Mercator Investments Ltd., Council, CIAR/CIFAR, March 2010, also November 2007
- Commissioner Diana Nichols Nelson, Canadian Senior Trade Commissioner, Bern, March 2010, & October 2008
- Ambassador Robert Collette, Canadian Embassy, Bern, October 2008
- Mr. Mike Lazaridis, Research In Motion, October 2006, November 2003, & June 2001
- Dr. Martin Taylor, VP of Research, University of Victoria, member of TRIUMF Board of Management, May 2006
- Dr. Pierre Coulombe, President, National Research Council, October 2005
- Dr. Howard Burton, Executive Director, Perimeter Institute for Theoretical Physics, January 2003
- Dr. Thomas Brzustowski, President, NSERC, August 2002

+ ATLAS Experiment & Computing LHC Resource Review Board meetings twice / year (NSERC, NRC)

Example: NRC Visit to CERN

VISIT PROGRAMME

Dr Dan Wayner
Vice-President
Frontier Science
National Research Council
Canada

27 participants +IPP from across Canada

More information

10:00	Met by R. Teuscher at the Hotel Cris
10:25	Arrival through Gate A at the steps, *Parking space reserved in front of the bu*
10:30	Meeting with Canadian scientists orp *6th floor conference room, building 60 –*
11:30	Lunch at CERN cafeteria with R. Te
14:30	Welcome and general introduction to P. Jenni - R. Teuscher present *5th floor conference room, building 60 -*
14:55	Questions and answers
15:15	CERN transport from the steps, build
15:25	LHC superconducting magnet test ha
15:55	Transport from SM18 to Point 1, buil
16:05	ATLAS Visitor Centre (P. Jenni with *CERN photographer present*
16:45	Transport from Point 1, building 316
16:55	LHC Computing Grid Project presen *Openspace, ground floor, building 513*
17:40	Transport from building 513 to the st
17:50	Meeting with Director for Research *5th floor conference room, building 60 –*
18:30	End of visit

List of participants at 10:30

Name	Institute	Status
Geese, Zoltan	UBC	postdoc
Swedish, Stephen	UBC	student
Soni, Nitesh	Alberta	postdoc
Vives, Francesc	Alberta	postdoc
Saddque, Asif	Alberta	student
Cheatham, Sue	McGill	postdoc
Mantifel, Roger	McGill	student
Belanger-Champagne, Camille	McGill	postdoc
Giunta, Michele	Montreal	postdoc
Polifka, Richard	UofT	postdoc
Venturi, Nicola	UofT	postdoc
Ilic, Nikolina	UofT	student
Dhaliwal, Saminder	UofT	student
Rezvani, Reyhaneh	UofT	student
Bain, Travis	UofT	student
Tarrade, Fabien	Carleton	postdoc
Marchand, Jean-Francois	Carleton	postdoc
Koutsman, Alex	TRIUMF	postdoc
Kvita, Jiri	SFU	postdoc
Andres Tanasijczuk	SFU	postdoc
Ouellette, Eric	Uvic	student
Martyniuk, Alex	Uvic	postdoc
Marino, Christopher	Uvic	postdoc
Bernlochner, Florian	Uvic	postdoc
Canepa, Anadi	TRIUMF	Research Scientist
Stelzer-Chilton, Oliver	TRIUMF	Research Scientist
Vetterli, Mike	SFU / TRIUMF	Prof.

CERN participants

Prof. Sergio Bertolucci	Director for Research and Scientific Computing
Dr Peter Jenni	ATLAS Collaboration Former Spokesperson
Dr Robert (Bob) Jones	EU Projects Leader, Information Technology Department
Dr Louis Walckiers	Technology Department

CERN Users

Prof. Richard Teuscher	ATLAS Collaboration, IPP Research Scientist and University of Toronto

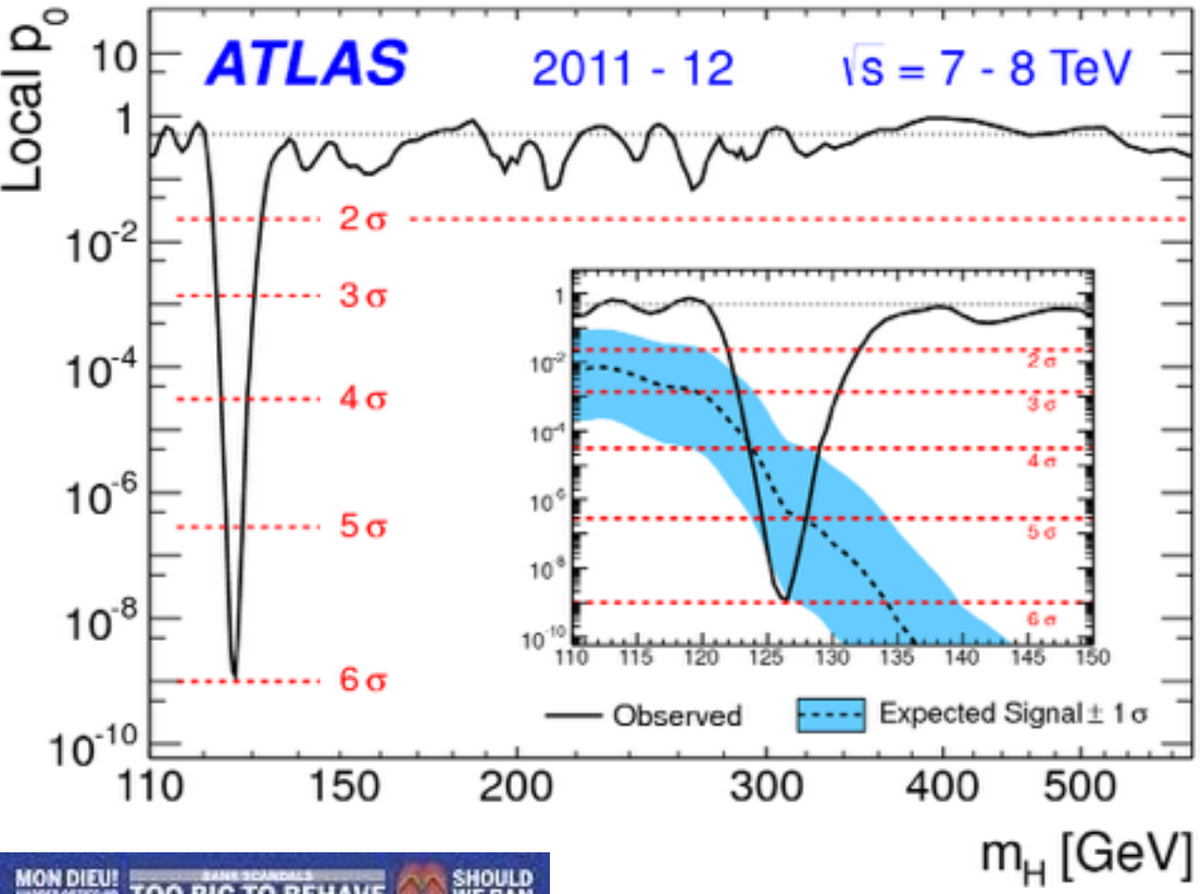
Report Summary:

A meeting with ATLAS Canada members at CERN in the morning, which went very well. Dr. Wayner later commented twice that he was impressed by the breadth of Canadian involvement in ATLAS, and of the international makeup of the group.

Canadian graduate students

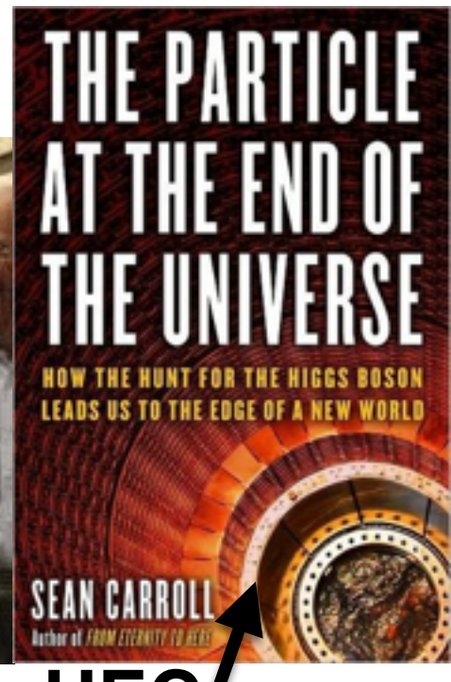
The Honourable Dr. Kellie Leitch, Minister of Labour and Minister of Status of Women, ATLAS, June 10, 2014

Canada & Higgs Discovery



Canadians leading in all stages of discovery from construction to data analysis:

- 1980's: Founding members of ATLAS
- 1990's: LAr design and construction
- 2000's: Shipment to CERN, installation underground
- 2005: Commissioning with cosmic rays
- 2008: First LHC beam
- 2010-2012: Data analysis
- 2012, July 4: Higgs discovery
- 2013: Nobel prize in physics
- 2014-2035: analysis and future upgrades



Summary

- **Successful completion of LHC Run-1:**
  > 2^8 physics papers, > 2^9 conference notes: see > 2^4 CAP talks!
- **Higgs discovery, 2013 Nobel prize in Physics**
- **Era of precision Higgs physics has begun**
- **Restart of LHC at 13 TeV in Spring 2015**
- **Window for new physics discovery?**
- **Long term project: High Luminosity LHC**
- **Canadians will continue to take on leading roles in ATLAS physics analysis, detector operation, upgrades, & promoting subatomic physics in Canada**

ATLAS Canada Presentations @ CAP 2014

Monday, 16 June 2014

1. Standard Model Measurements with the ATLAS Detector *30′*
   Matthew Scott Rudolph (University of Toronto (CA))

2. Global Sequential Calibration of jets at ATLAS *15′*
   Santiago Batista (University of Toronto (CA))

3. Measurement of the top quark polarization in semi-leptonically decaying top-antitop pairs with the ATLAS detector *15′*
   Garrin Mcgoldrick (University of Toronto (CA))

4. Higgs Particle Searches with ATLAS *30′*
   Doug Schouten (TRIUMF (CA))

Tuesday, 17 June 2014

5. Review of the current status of Higgs Properties *30′*
   Dr. Florian Urs Bernlochner (University of Victoria (CA))

6. Search for the Standard Model Higgs boson produced in association with top quarks in pp collisions at 8 TeV with the ATLAS detector at the LHC *15′*
   Steffen Henkelmann (University of British Columbia (CA))

7. Search for Standard Model Higgs boson production in association with a top quark pair in the four lepton signature with the ATLAS detector *15′*
   David Anthony Demarco (University of Toronto (CA))

8. Search for Supersymmetry at ATLAS *30′*
   Jean-Francois Arguin (Universite de Montreal (CA))

9. ATLAS Run1 Constraints on the Electroweak Sector of SUSY *15′*
   Zoltan Gecse (University of British Columbia (CA)

10. Search for Chargino and Neutralino Production in Final States with Three Leptons and Missing Transverse Momentum with the ATLAS detector in 20.3 fb^{-1} of sqrt{s}= 8 TeV pp collisions *15′*
    Matthew Gignac (University of British Columbia (CA))

11. Search for resonant VH production with a W or Z boson decaying leptonically *15′*
    Frederick Dallaire (Universite de Montreal (CA))

12. Search for Associated Higgs Boson Production in the WH→ WWW(∗)→ lvlvqq Decay Mode Using 20.3 fb−1of Data Collected with the ATLAS Detector at √s = 8 TeV *15′*
    Joseph Peter Kinghorn-Taenzer (University of Toronto (CA)

13. Cut-based analysis of the Z-associated Higgs-strahlung process Z(H->WW) using data from the ATLAS experiment and Monte Carlo simulations *15′*
    Aaron Arthur Liblong (University of Toronto (CA))

Wednesday, 18 June 2014

14. No Stone Left Unturned? Searches for New Physics with ATLAS *30′*
    Dr. Wojtek Fedorko (University of British Columbia)

15. The Search for a Heavy Higgs-like Boson in the WW(lvjj) Decay Channel with the ATLAS Detector *15′*
    Hass Abouzeid (University of Toronto (CA))

16. Search for new physics in the same-sign dilepton final states with the ATLAS detector at the LHC *15′*
    Kenji Hamano (University of Victoria (CA))

17. The Canadian contribution to the upgrades to the ATLAS experiment *30′*
    Gerald Oakham (Carleton University (CA))

18. Beam test of new ATLAS muon detectors at Fermilab *15′*
    Simon Viel (University of British Columbia (CA))

19. Track-based alignment of the ATLAS Inner Detector: New extensions and expected performance for the next physics data run *15′*
    Matthias Danninger (University of British Columbia)

20. Implementing Tracking with the ATLAS Diamond Beam Monitor *15′*
    Miriam Diamond (University of Toronto (CA))

Thursday, 19 June 2014

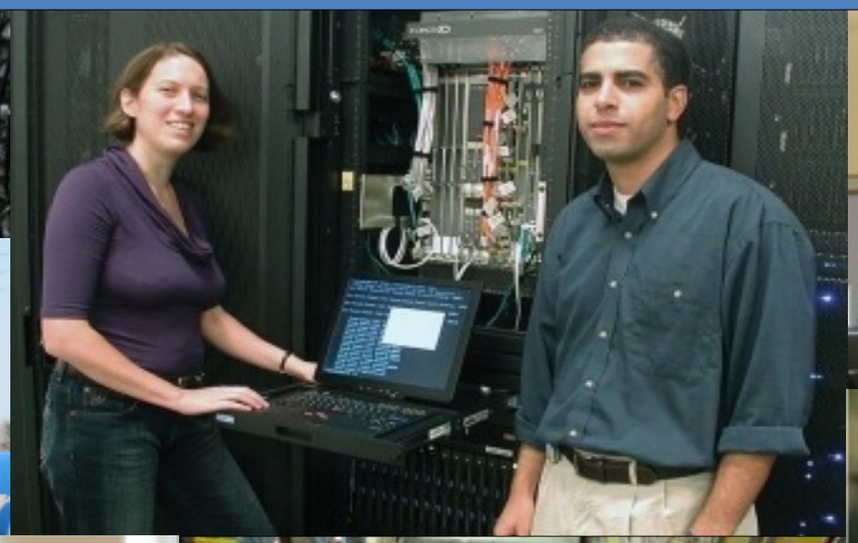
21. Poster: Testing of new ATLAS muon detectors at Fermilab's Test Beam Facility *2′*
    Stephen Albert Weber (Carleton University (CA))

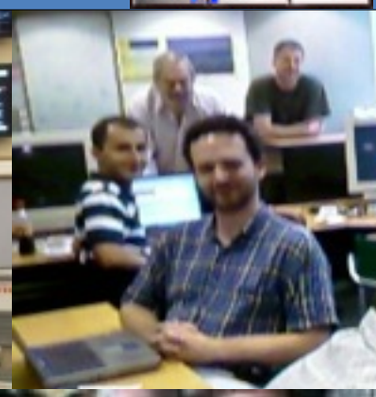
22. Poster: ATLAS Muon Chamber Ageing Studies *2′*
    Elise Gaia Devoie (TRIUMF (CA))

INSTITUTE OF PARTICLE PHYSICS

ATLAS Canada Snapshots











backup

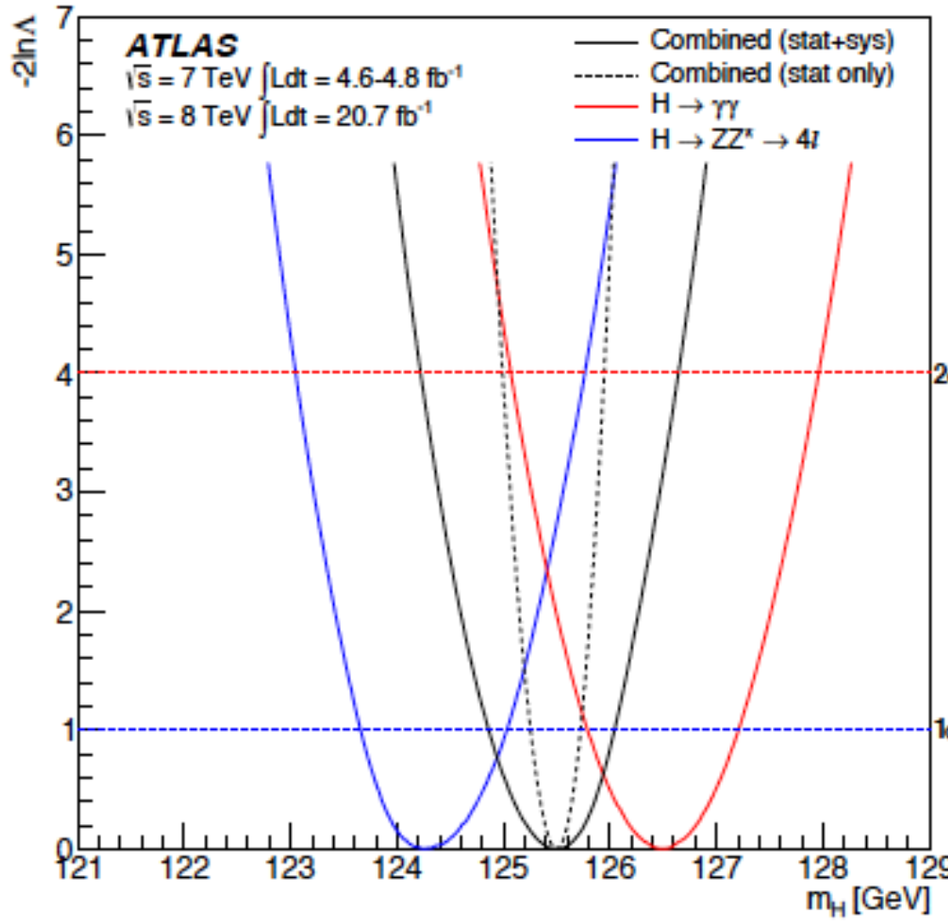
Physics

Mass Measurement

- mass measurement is performed in $ZZ \to 4\ell$ and $\gamma\gamma$ channels
- allow the signal strengths $\mu_{4\ell}$, $\mu_{\gamma\gamma}$ to float
  - best overall $m_H = 125.5 \pm 0.2\,(\text{stat})\,^{+0.5}_{-0.6}\,(\text{sys})$ GeV
  - combination shifts e/γ energy scale slightly, reduces $m_{\gamma\gamma}$ compared to standalone
- consistency of $\gamma\gamma$ and ZZ masses is at the 1.5% level

$$\Delta m_H = 2.3^{+0.6}_{-0.7}\,(\text{stat}) \pm 0.6\,(\text{sys})\ \text{GeV}$$

- **many** cross-checks performed, dedicated sub-group
- investigate systematics on e/γ scales with $Z, Z\gamma, J/\psi$ samples
- estimate effect of non-Gaussian behaviour for largest systematic uncertainties (e/γ scale, lepton ID), then consistency is at 8%

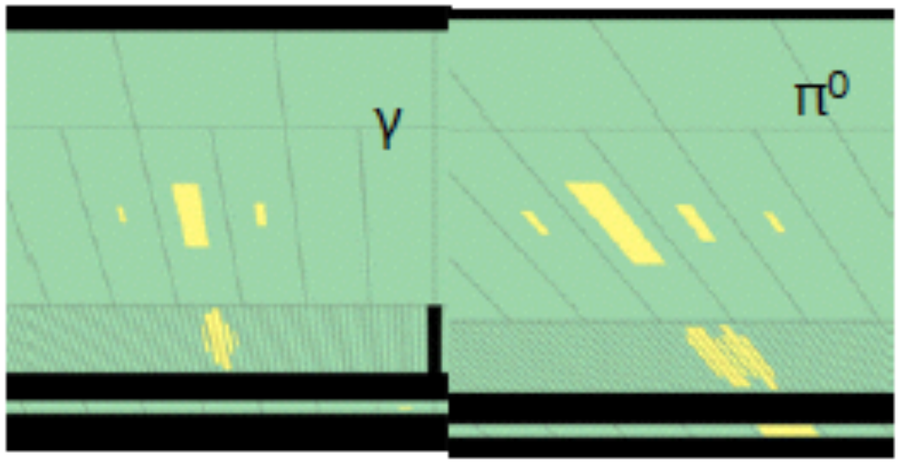


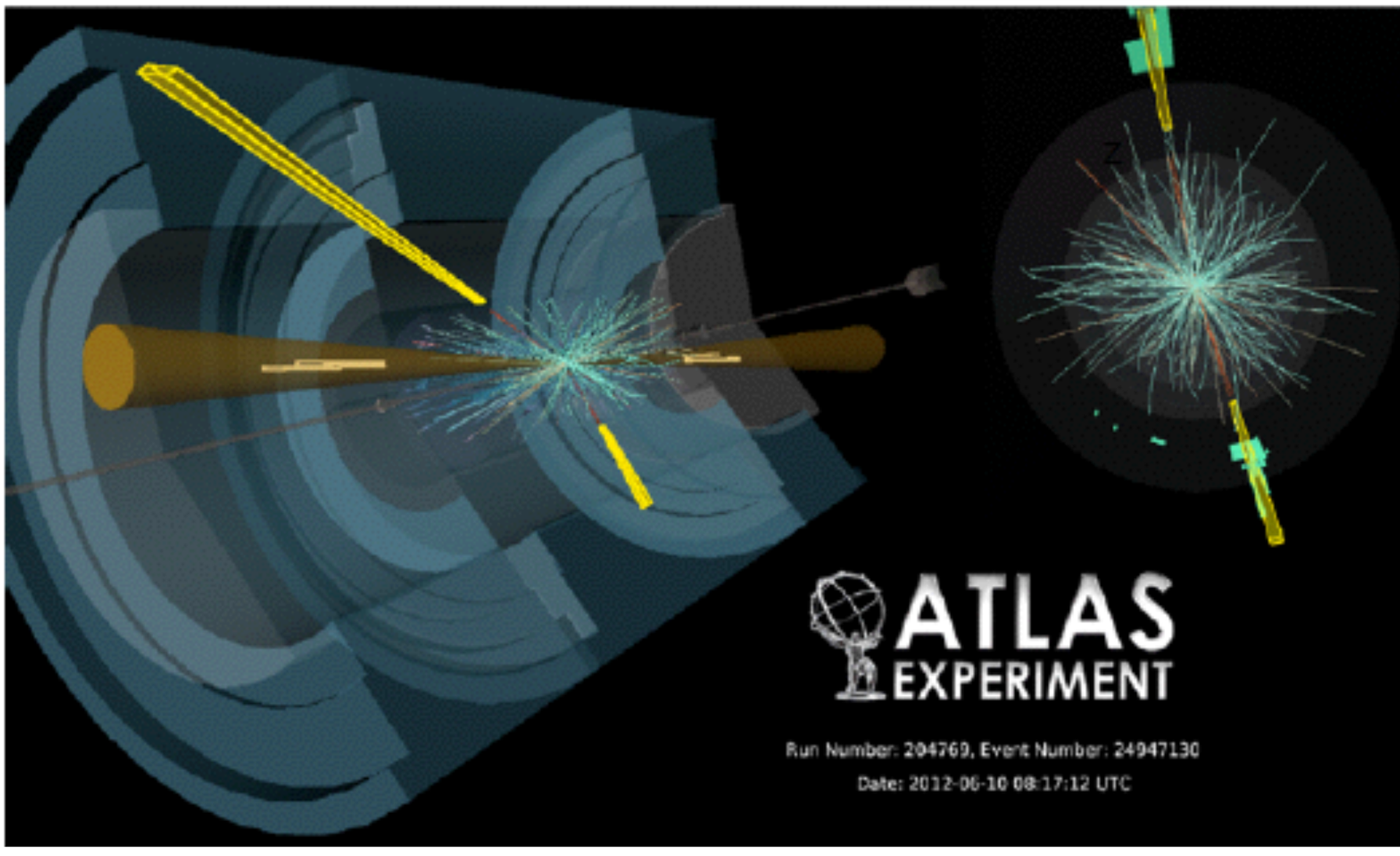
See talk by D.Schouten

$H \rightarrow \gamma\gamma$

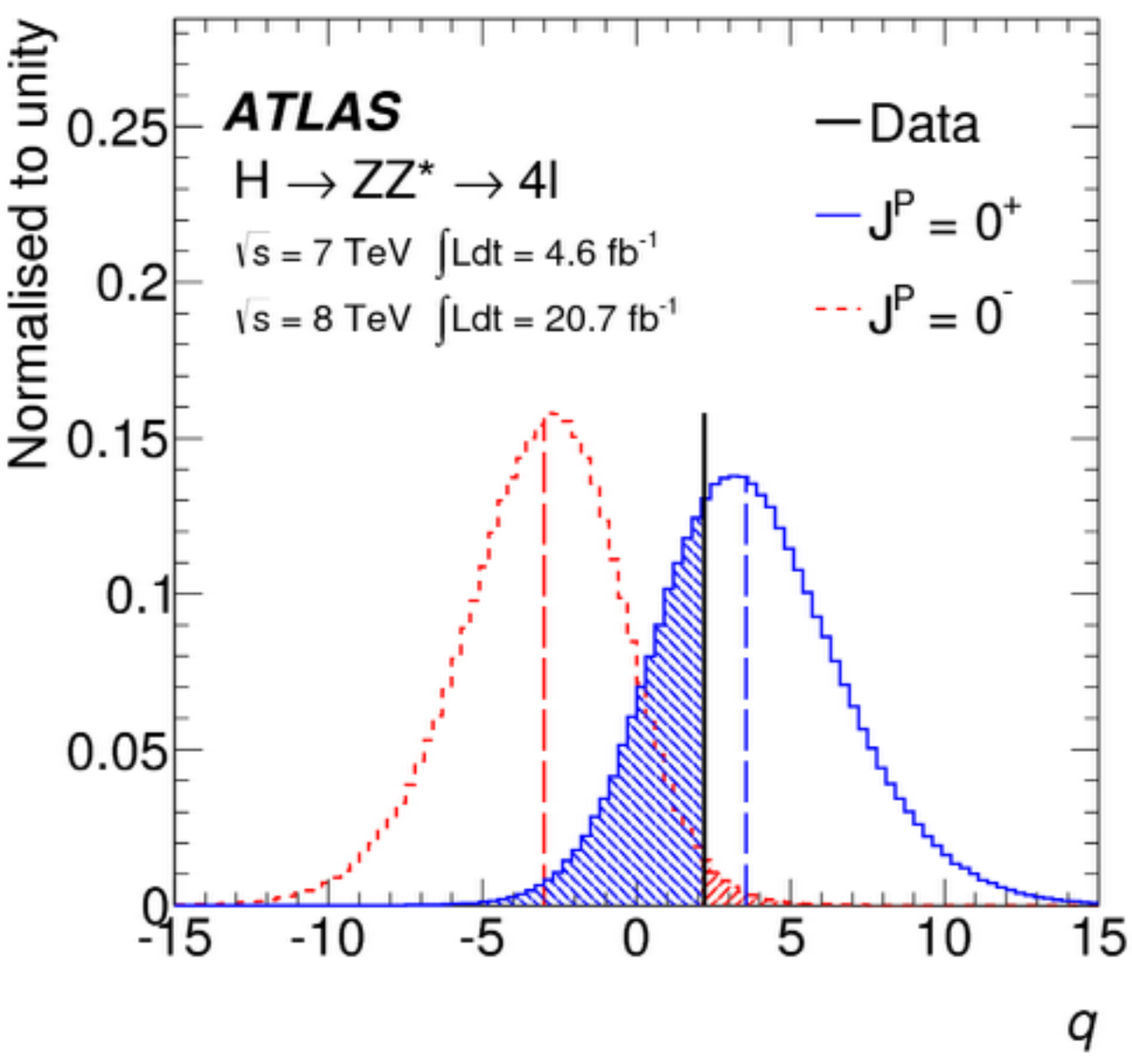
σ X BR ~ 50 fb @ 125.5 GeV

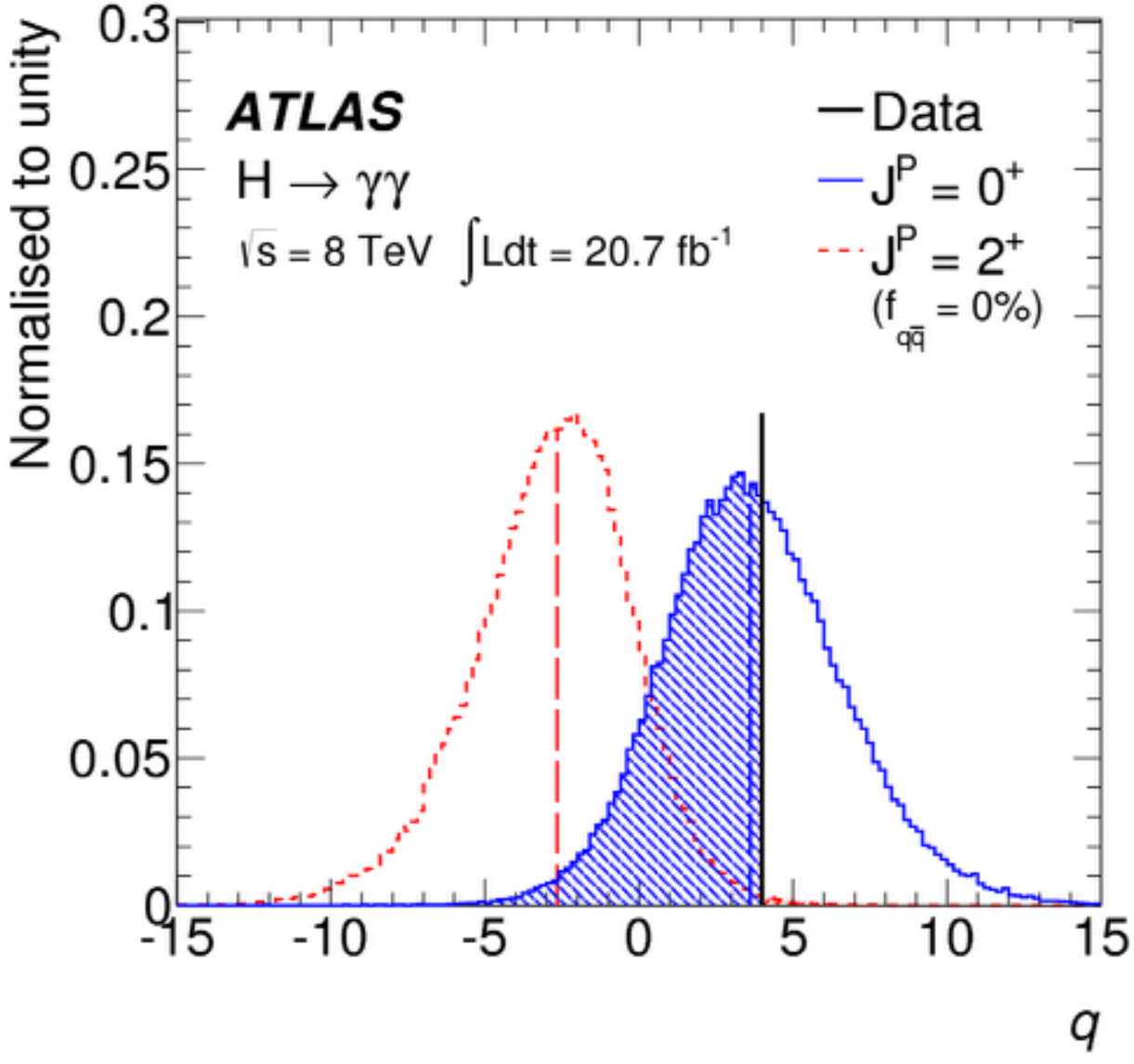
- Loop decay (W and top), low BR ~ 0.2%
- Simple topology
  - Two isolated energetic photons
- ...requiring excellent performance
- Large backgrounds
  - Excellent γ ID: 75% $\gamma\gamma$ after cuts
- Signal: narrow peak (good mass resolution)
  - S/B ~ 3%





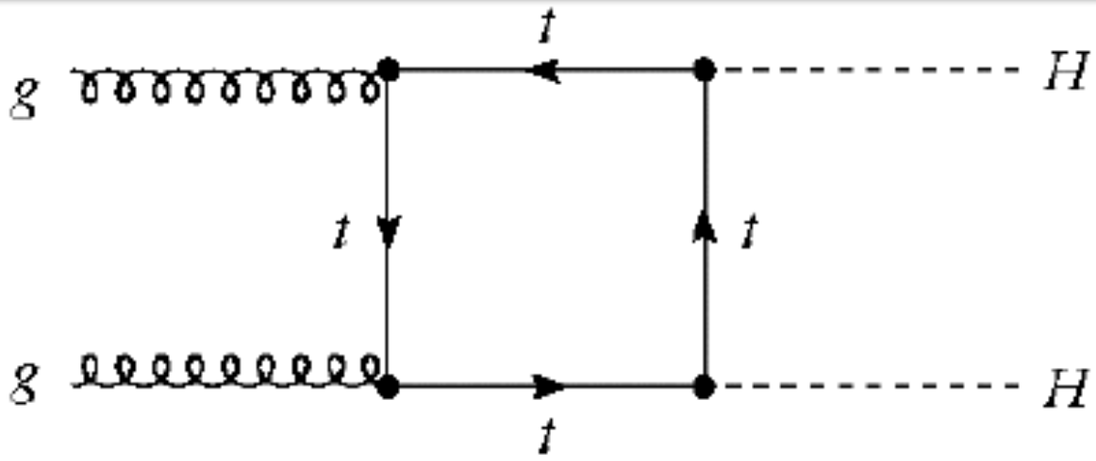
Higgs Spin

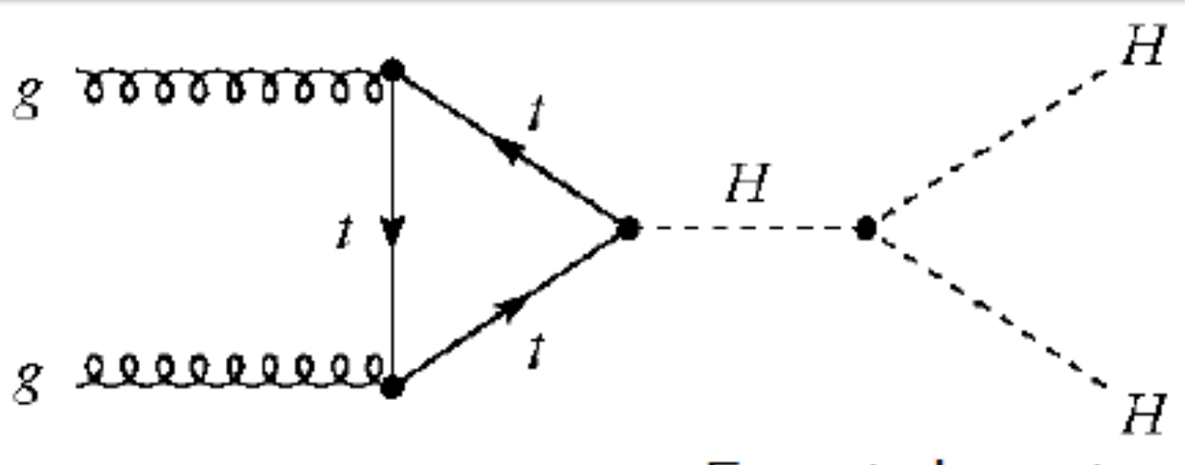




Alternate hypotheses to $J^P=0^+$ excluded at 97.8% CL

Higgs Boson Self Coupling at HL-LHC





- Needs observation of Higgs pairs
  - Expected σ_{HH}=40±3fb → 120K events
  - Finding one was tough with ~500K events
- But it is not enough
  - Both the above diagrams (and more) contribute
  - Negative interference :(
- Ongoing studies suggest some sensitivity
  - Low rate makes high demands on detectors & lumi
  - Theoretical studies suggest possible: 1309.6318

Expected events

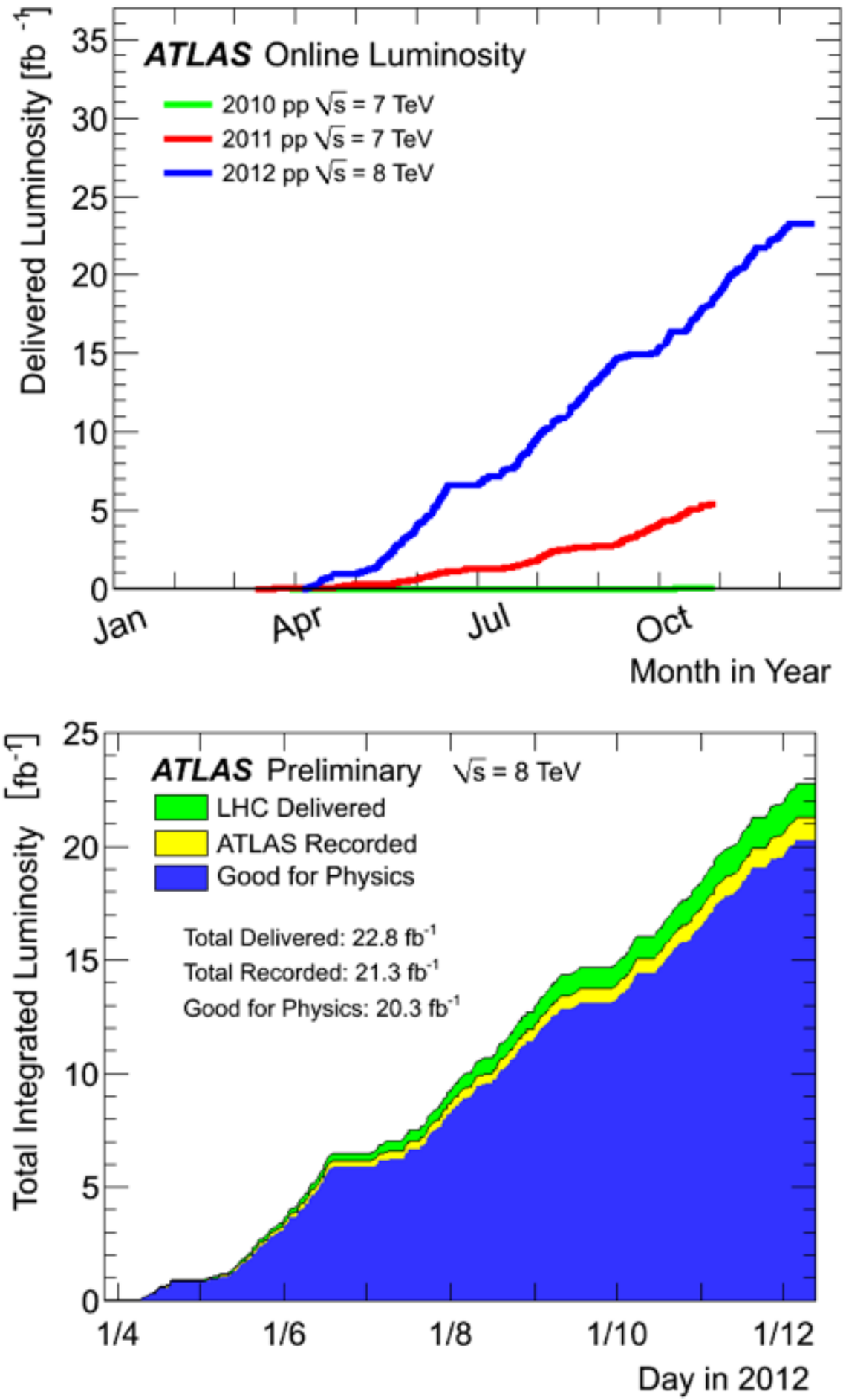
bbWW	30000
bbττ	9000
WWWW	6000
γγbb	320
γγγγ	1

Operations

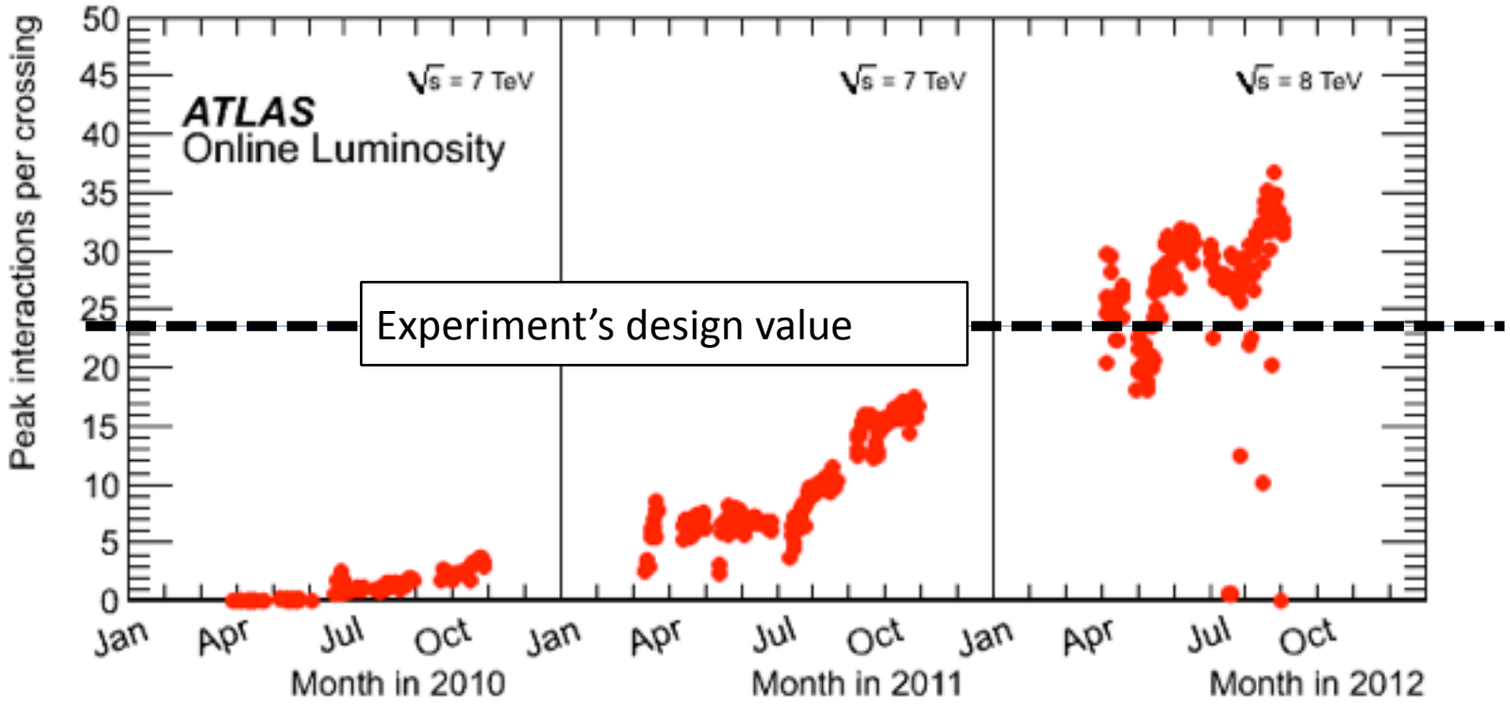
Run-1 Data

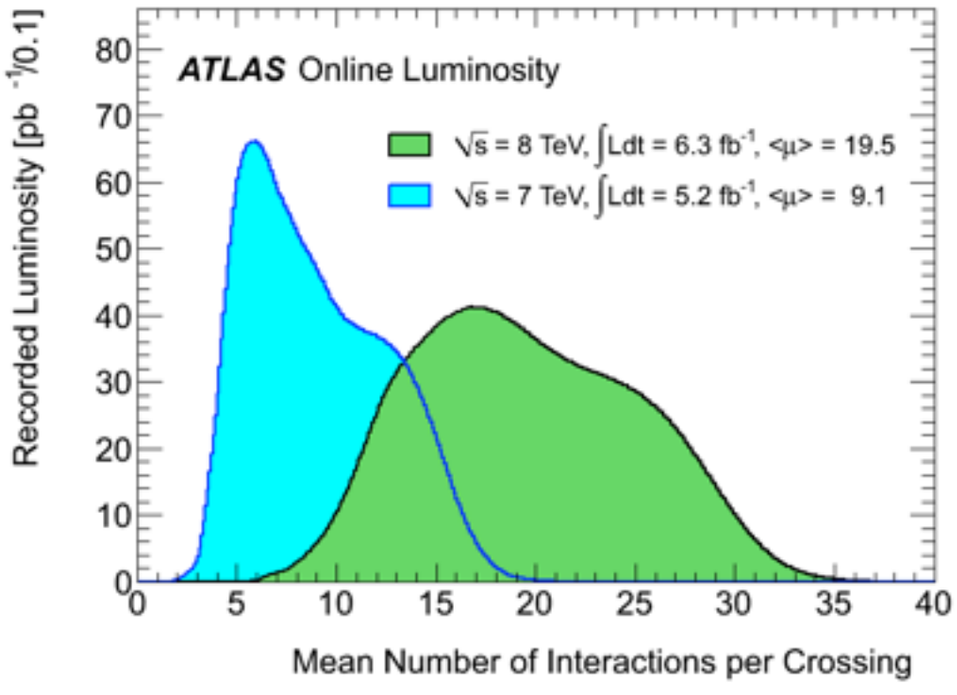
- LHC Run-1 (2010-2013) ended on Feb. 14, 2013
- ATLAS recorded 93.5% of the integrated luminosity delivered in 2013/2013
- Good quality data: 95.8% used for physics analyses

Year:	√s (TeV) pp [Pb-Pb]	Recorded Lumi Pp [Pb-Pb]
2010	***7 [2.76]***	***45 pb***
2011	***7 [2.76]***	***5.35 fb***
2012 / 2013	***8 [5 p-Pb]***	***21.7 fb [29.8 nb***

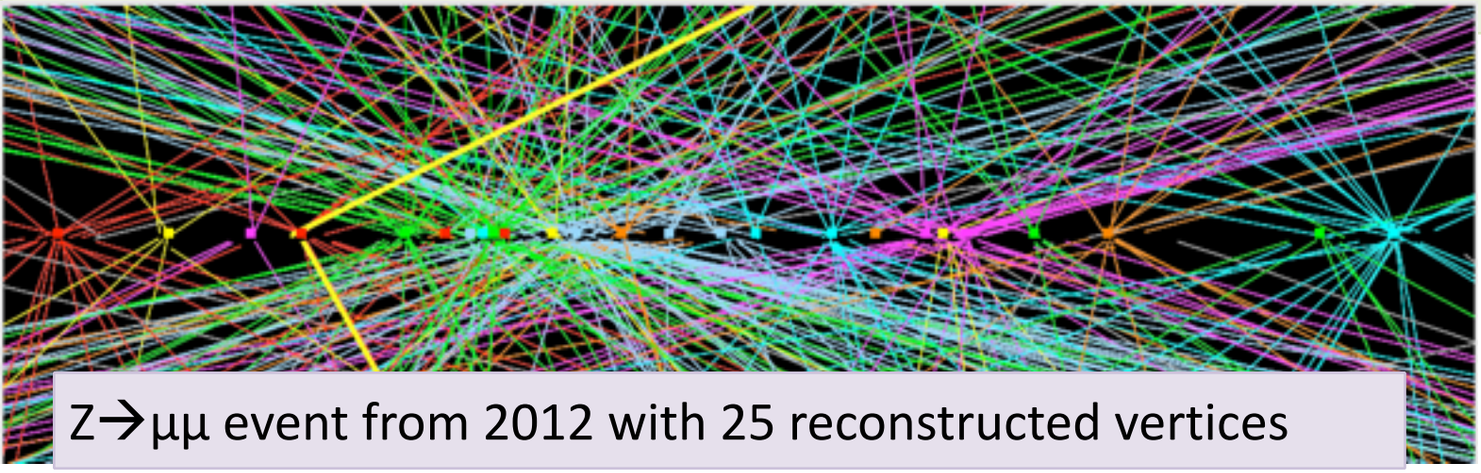


The Big Challenge: Pile-Up

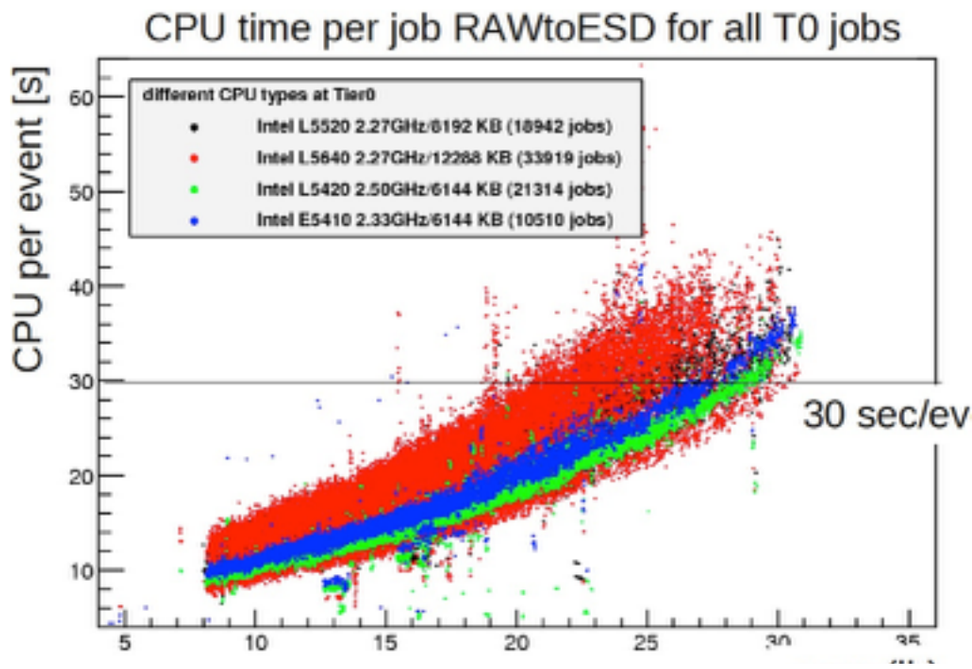




- Ran with 50ns bunch spacing (instead of 25ns)
  - → double pile-up for same luminosity
- Had to be fought and mitigated at all levels:
  - Trigger, reconstruction of physics objects, isolation cuts, etc.
  - Data processing: CPU time for reconstruction…



Z→μμ event from 2012 with 25 reconstructed vertices

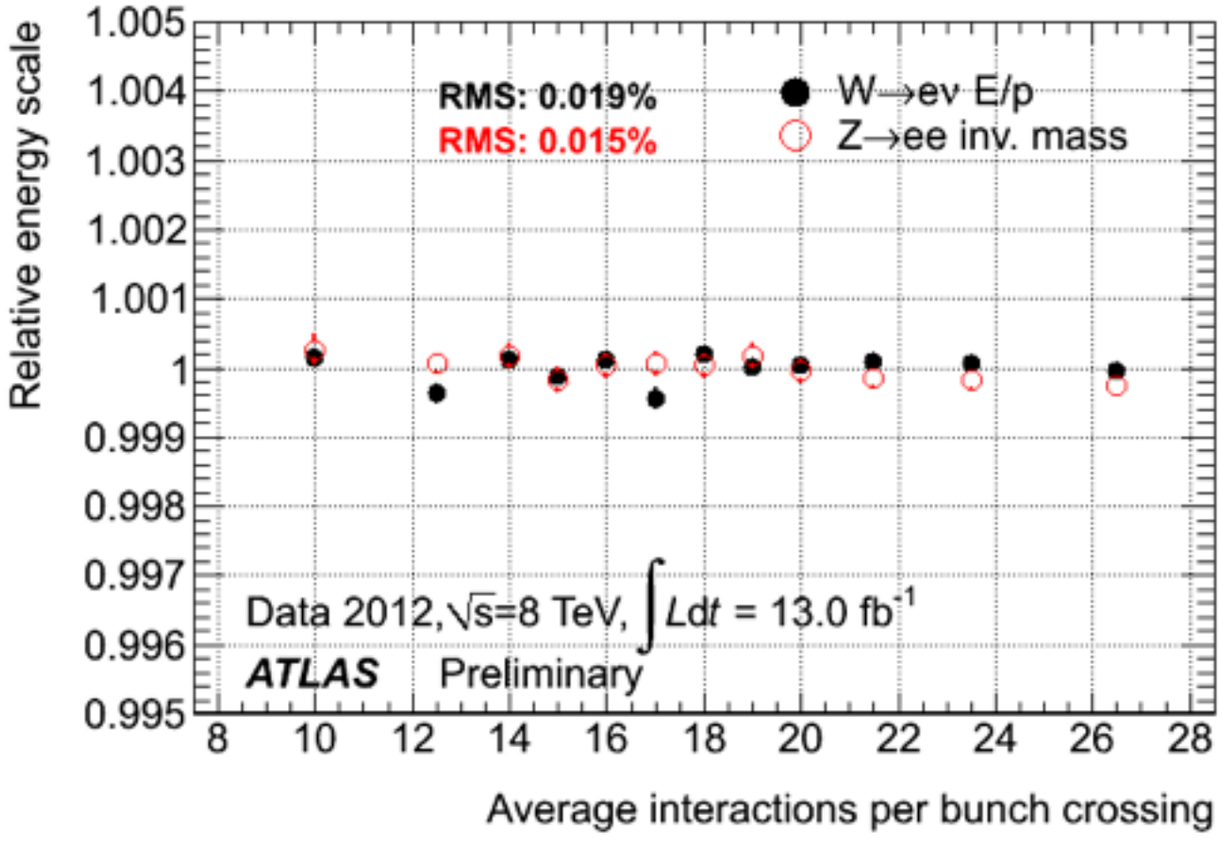


Average number of interactions per bunch crossing

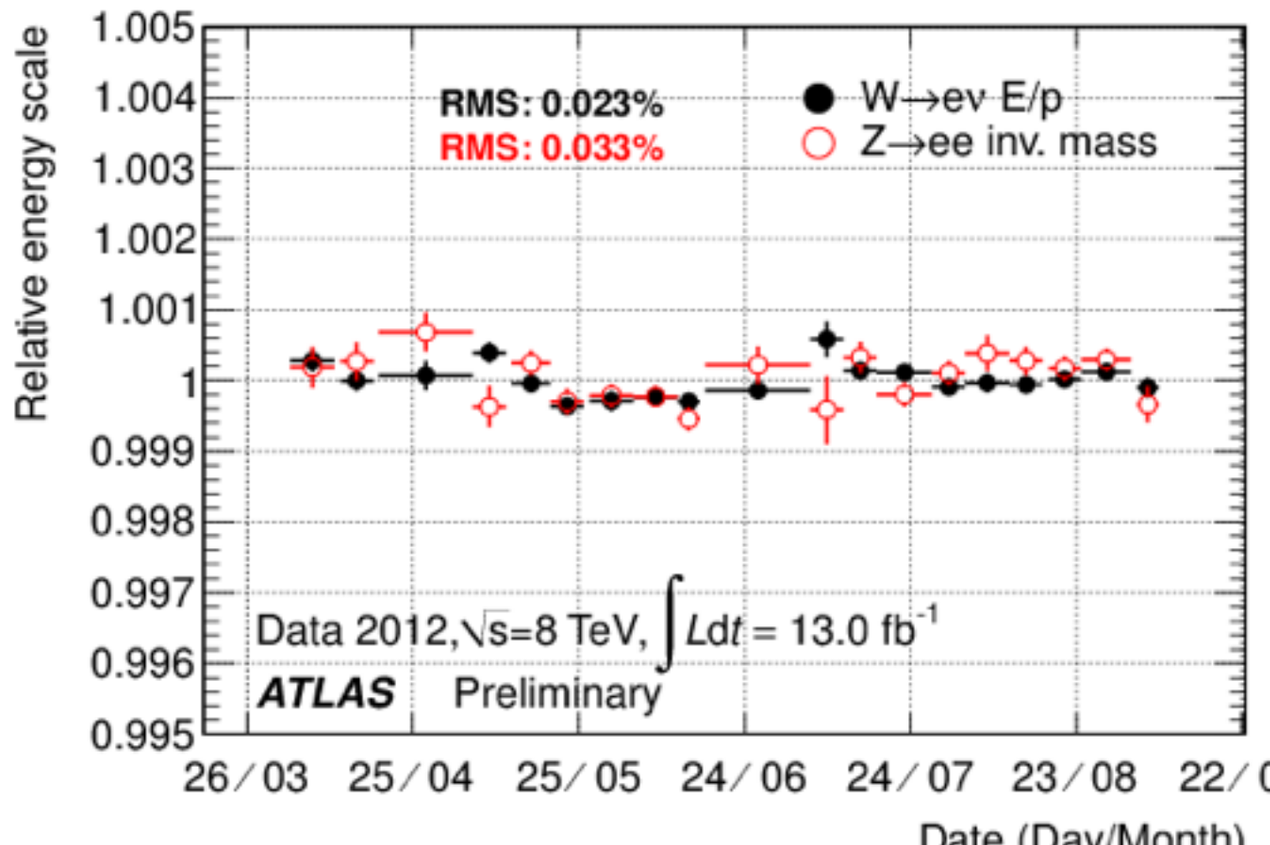
Calorimeter Performance & Pileup

Study energy scale by looking at:

- Calorimeter energy divided by momentum from ID electrons in W→ev
- Invariant mass of electrons in Z→ee



Stability of the energy scale is on per mil level as a function of time and pileup

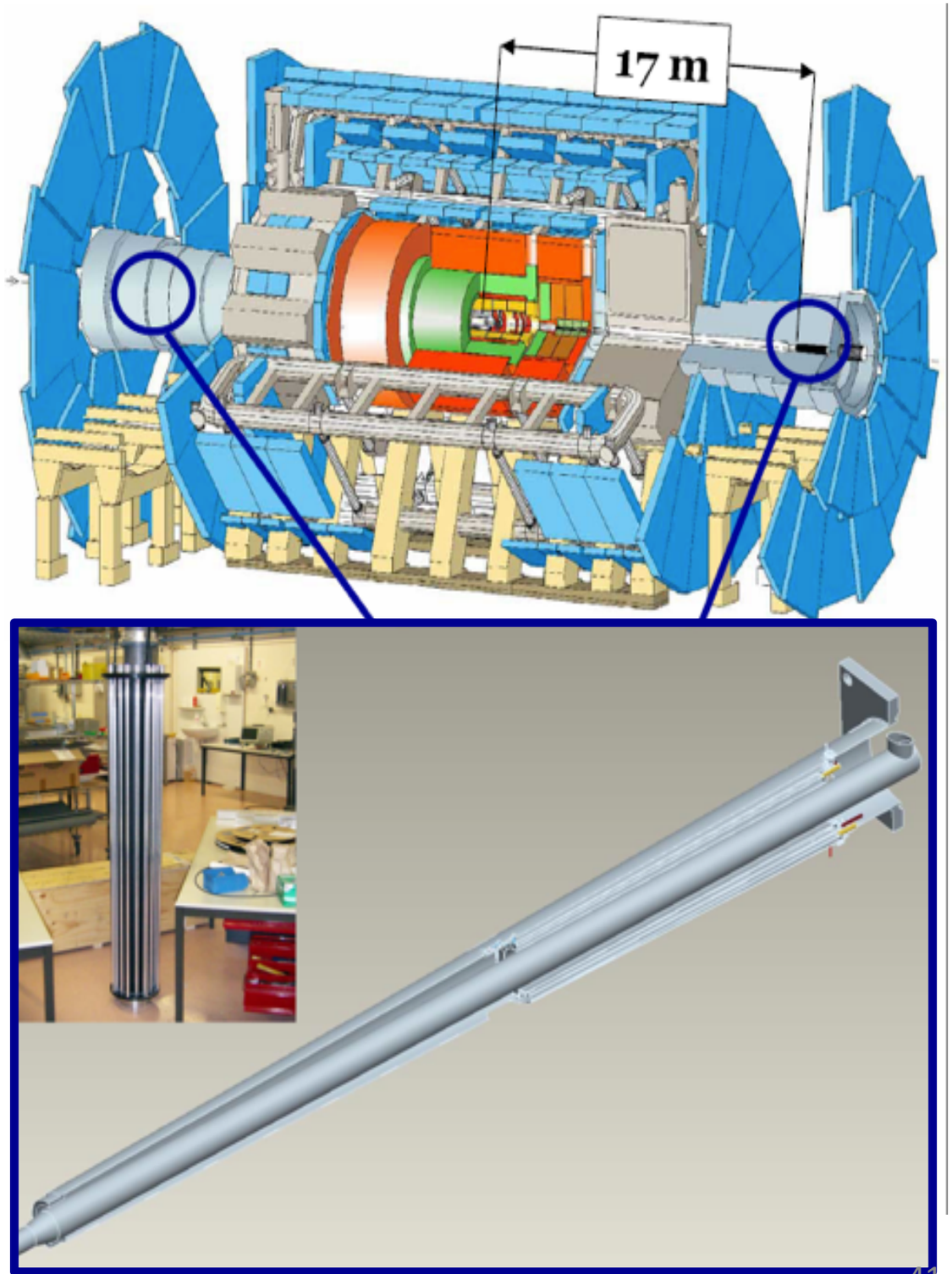


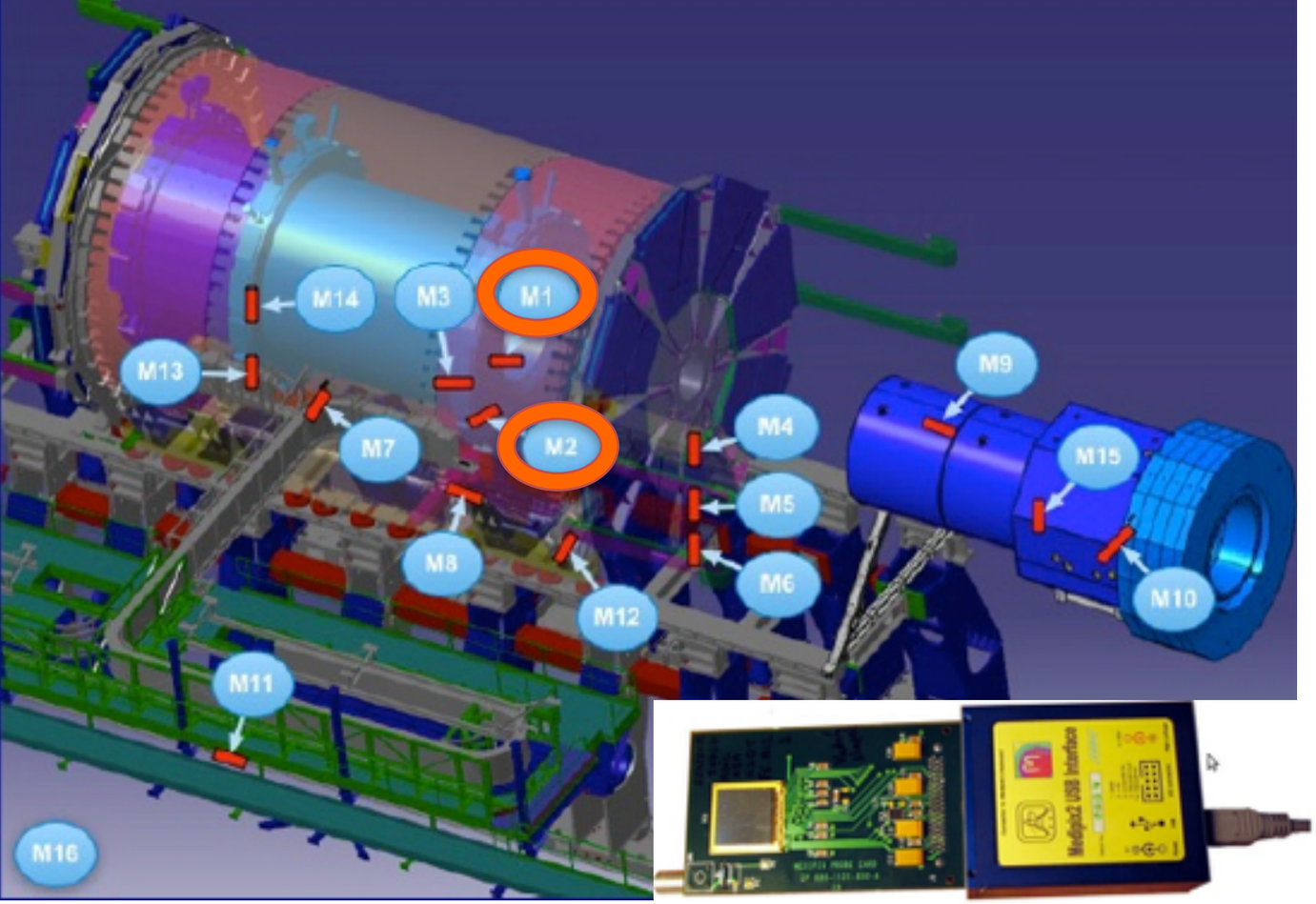
Electron energy response stability with pileup in 2012 data (13 fb^{-1}).

→ Canadians also developing tools at trigger level for pileup mitigation (use of tracks, calor subtraction schemes, object-based MET trigger...)

LUCID Luminosity Cerenkov Integrating Detector

- LUCID: ATLAS detector dedicated to Luminosity measurement
- placed around the beam pipe inside the forward shielding at ± 17 m
- LUCID was proposed, designed, & largely constructed by ATLAS Canada
- It was the first detector to report LHC beam “splashes” in 2008
- After calibration, it measures the absolute luminosity with an accuracy of O(3%)
- Luminosity is a key quantity in all ATLAS physics analyses





MediPix (MPX)

- 16 MPX detectors are placed in strategic locations in the ATLAS detector and underground cavern
- Real-time monitoring of charged particles, photons, and neutrons
  - Simulation validation
  - Activation measurement
  - Luminosity cross-checks
- Canada: 1 faculty, 2 students

MPX Si detectors (256×256 pixels, each pixel 55×55×300 μm³ size) Five tasks fulfilled from an operational point of view (real-time):

1- Measurement of the radiation field inside the ATLAS detector volume (including neutrons, thermal neutrons, fast neutrons)

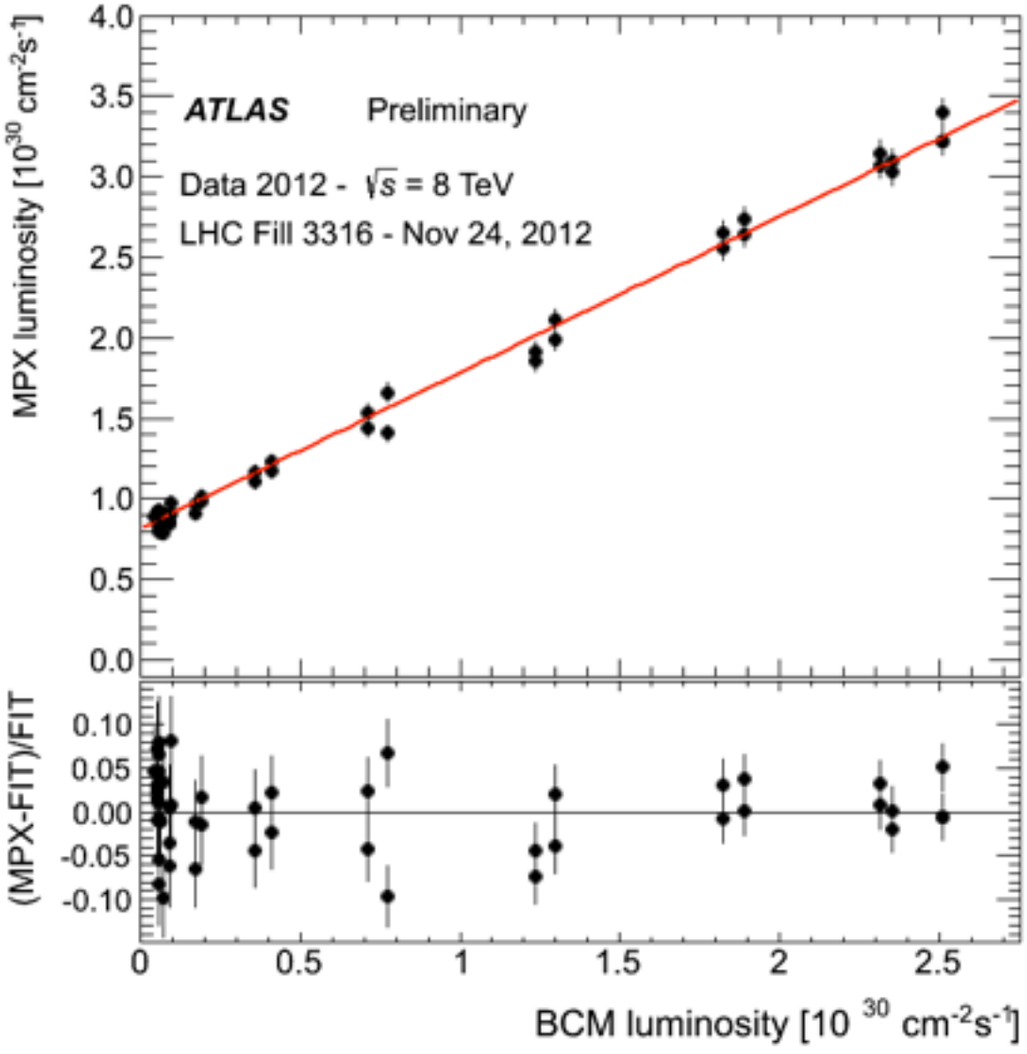
2- Measurement of background radiation in the experimental hall and in the detector surroundings. Comparison of simulated background (FLUGG/ G CALOR) with MPX data. Important for upgrades / High Luminosity LHC.

3- Measurement of the real performance of the different subdetectors (e.g., particle/ energy leakage, punch through, etc.).

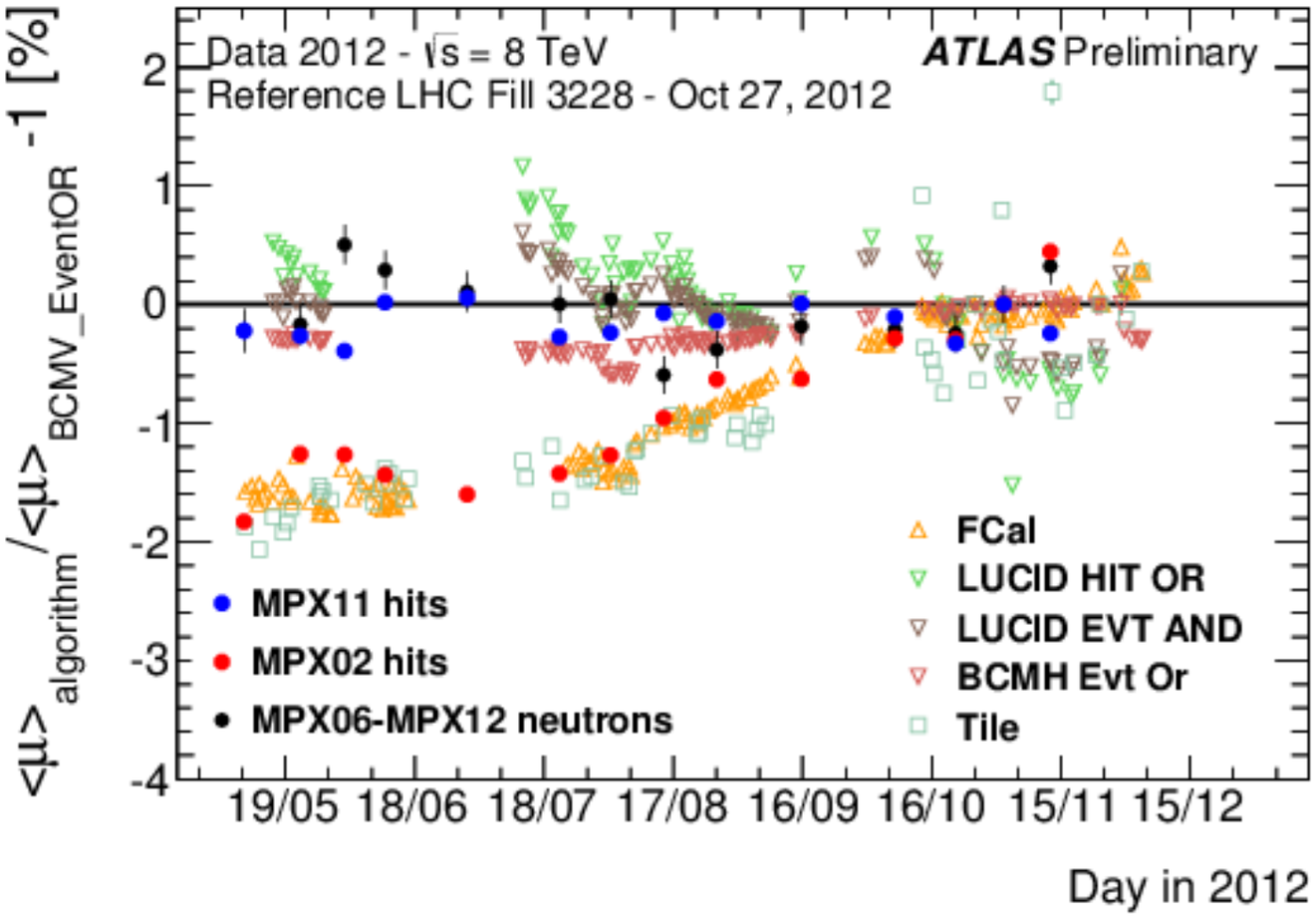
4- Measurement of luminosity (including luminosity monitoring, vdM luminosity calibration scan,…).

5- Measurements of activation of the environment in underground cavern UX15 & underground electronics service room USA15.

MPX / LUCID / BCM / FCal



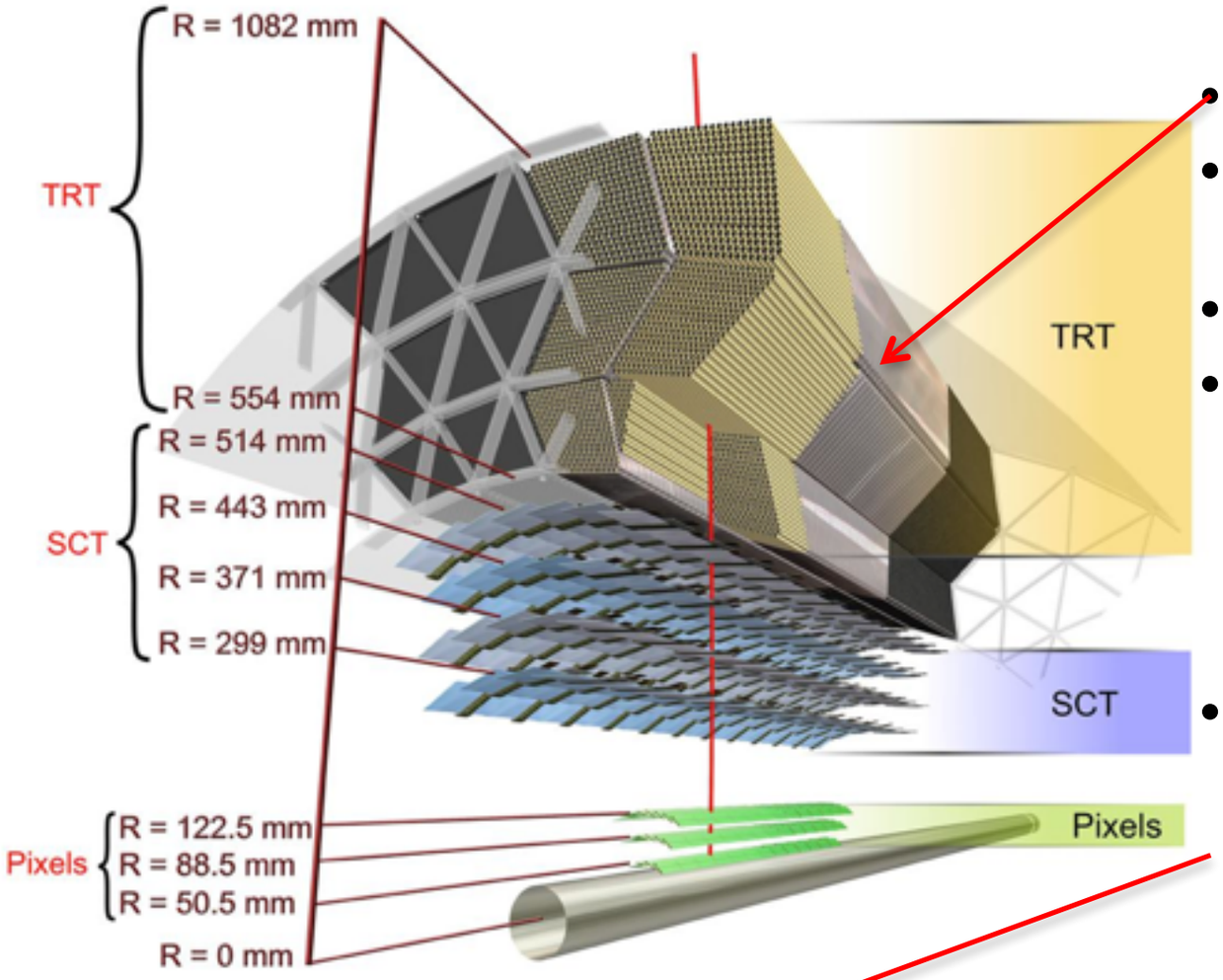
MPX01 hit luminosity vs. BCM luminosity for the last horizontal Nov. 2012 vdM scan.



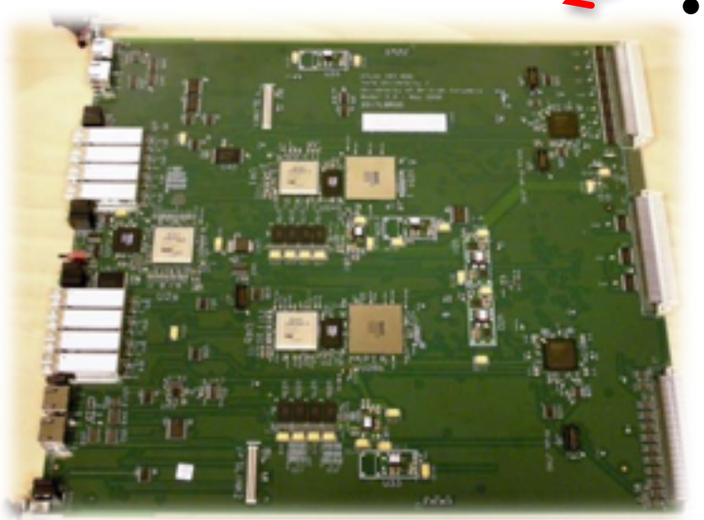
Fractional deviation in the number of interactions per bunch crossing (averaged over all colliding bunch pairs), obtained using MPX, LUCID, FCal vs BCM

Combined Luminosity uncertainty: 2011: 1.8%, 2012: **2.8%** (was 3.6%)

Transition Radiation Tracker (TRT)



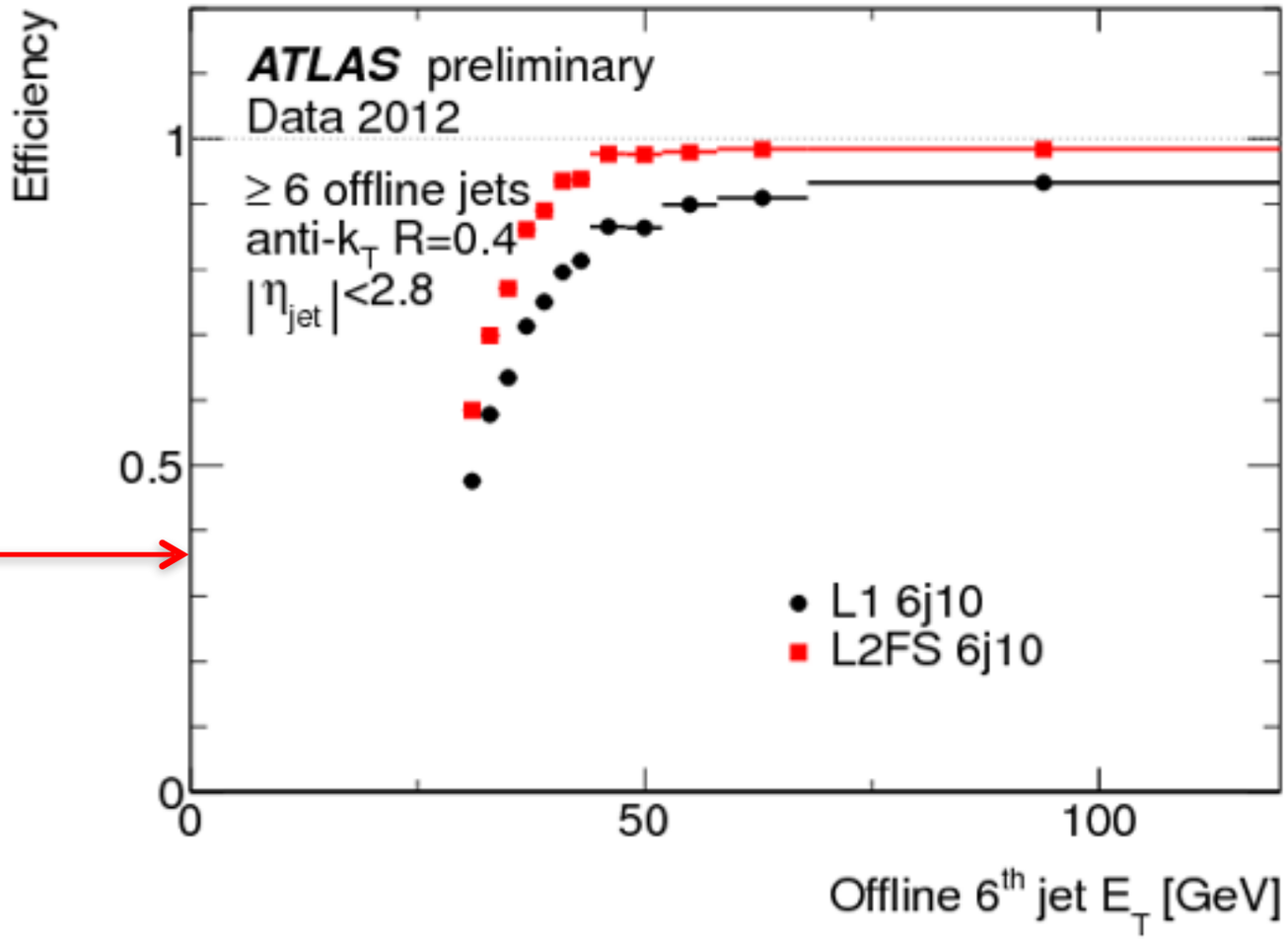
- Drift-tube straws filled with Xe gas for tracking
- Radiator foils for electron identification by transition radiation
- Stable operation in 2012 (99.5 % DQ eff.)
- In 2012 TRT gas system developed leaks of Xe (in exhaust circuit)
  - Did not affect physics performance, but $
  - Repaired May-June'13 accessible leaks
  - Study performance of Ar/Xe mixture
- Canada: Focus on back-end readout electronics, 100 VME boards
  - Data error checking, buffering, compression



- Canada: 2 faculty, 2 postdocs, 4 students, activities include:
  - TRT & Inner Detector Shifts at CERN
  - Optimization studies of TRT reconstruction software for future LHC operation at 25 ns
  - Tuning TRT digitization MC, faster TRT calibration software
  - Design of TRT monopole trigger
  - Firmware for 100 kHz Level 1 trigger rate with shortened data readout

Trigger / DAQ

- DAQ and HLT at performance limits in 2012
  - Peak Level-2: 6.5 kHz
  - Physics to tape: 600 Mb/s
- Strong Canadians presence (5 faculty, 4 postdocs, 7 Ph.D. students):
  - Jet trigger
  - Trigger rate presenter
  - Trigger core software
  - Trigger tool
  - Trigger shifter
  - Trigger performance paper
  - MET signature group
  - MET trigger monitoring
  - MET trigger paper… ++



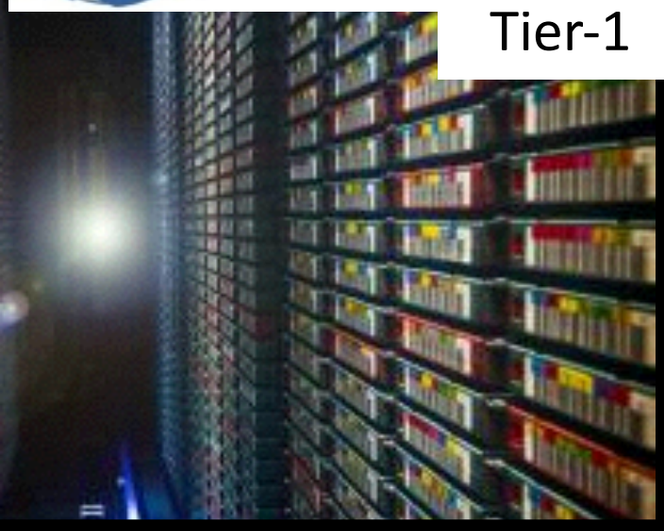
Efficiency for L1 (sliding window) and L2 full readout (anti-kT R=0.4) jets to satisfy a 6 jet trigger for $|\eta| < 2.8$, $E_T > 30$ GeV

CERN and Worldwide LHC Computing Grid

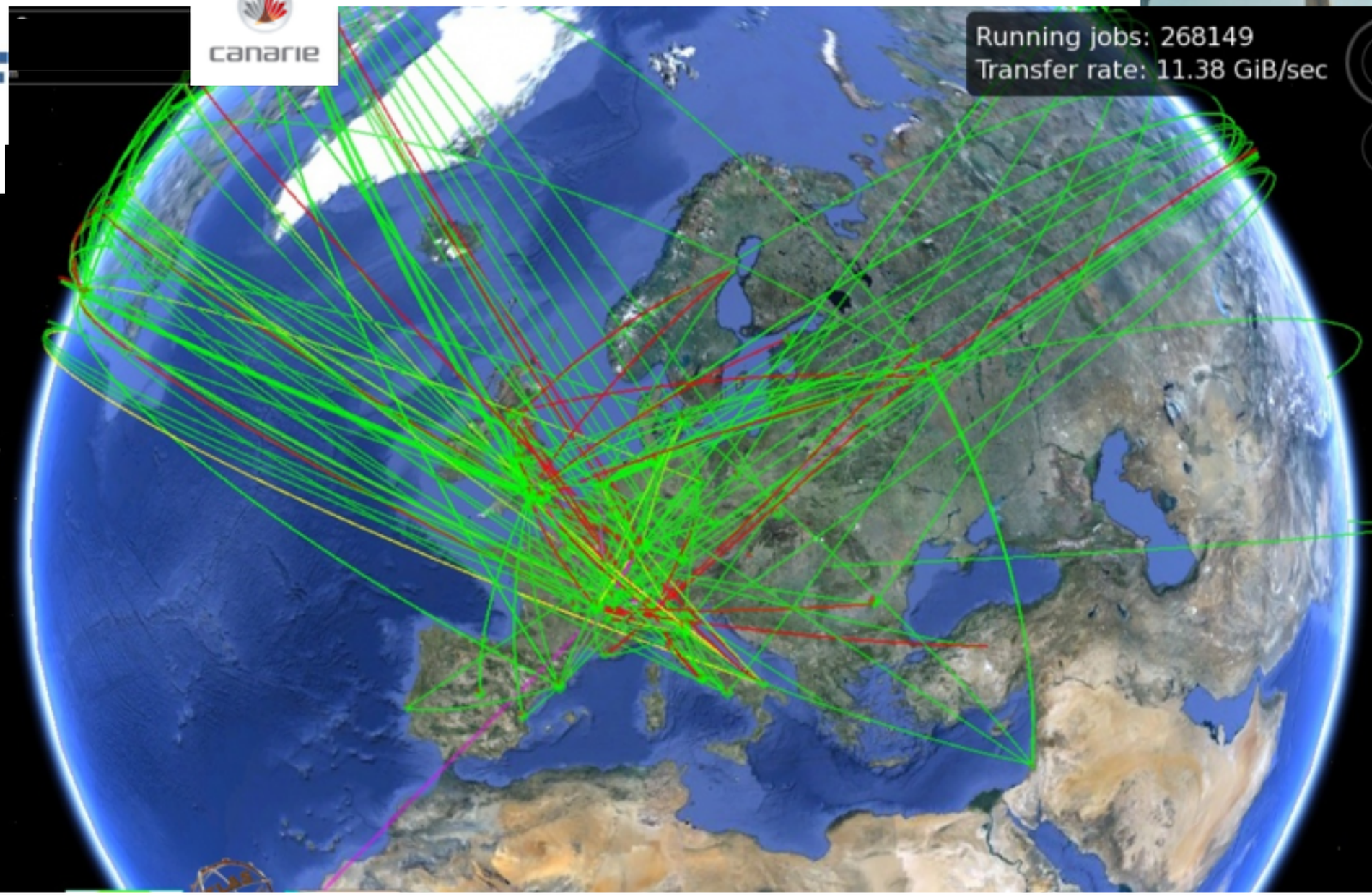
- Canada hosts one of 10 worldwide Tier-1 data centres at TRIUMF, Vancouver
- 3 000 000 GB / year → stack of DVD's **high as CN tower** every 4 months…

TRIUMF

Tier-1



canarie



Tier-2 west & east

SciNet

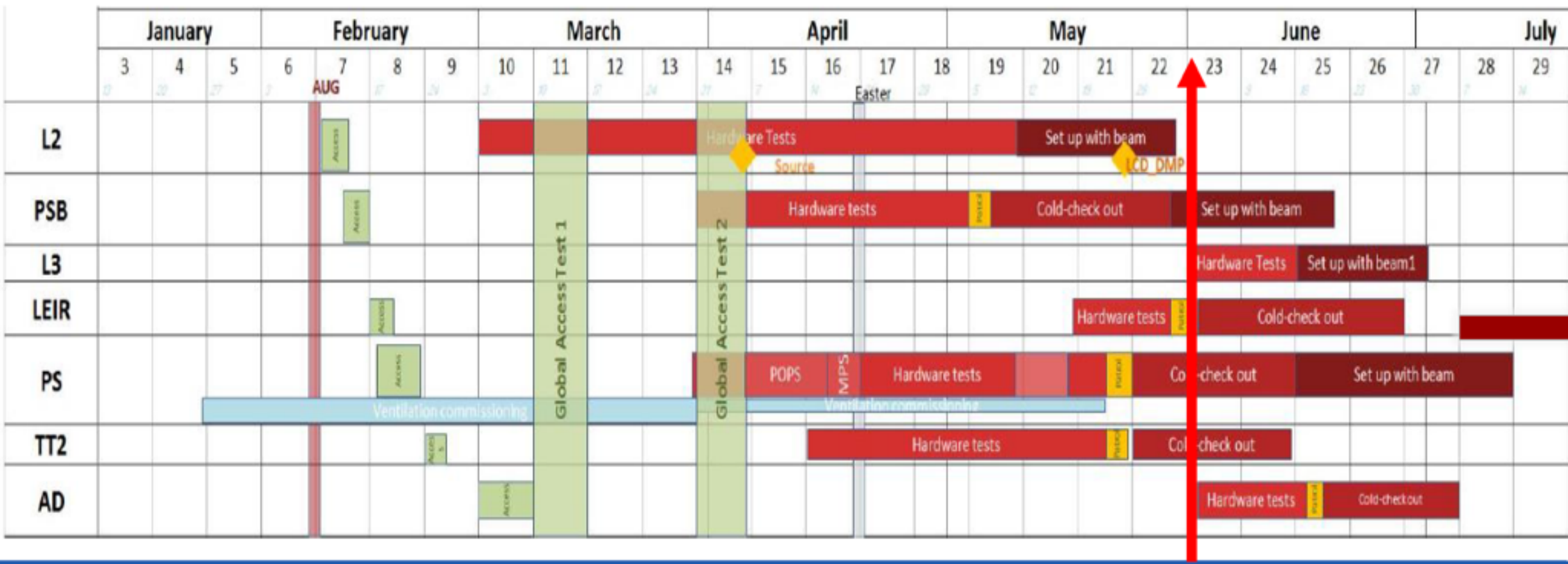
Canada's most powerful supercomputer

CBC News : Jun 18, 2009

LHC Injectors start-up

LHC-injectors … getting ready for beams

- PSB &PS : hardware tests started in April
- Cold check-out phases well advanced
- SPS: powering tests will start by end of June



LS1 and Upgrade

LAr Operations during Shutdown LS1

- Continue LAr running when possible
  - HV system off, readout ON
  - Keep runs (calibration, cosmic-ray muon, …) going when possible
  - 100 kHz tests
- Milestone weeks from Feb ‘14
  - Re-integrate subdetectors
- Cosmic ray runs from end ‘14
- Continue experience with operation team for 2015
- Canadians continue operations on / under ground

Canadian graduate student at work in ATLAS underground in Fall 2013

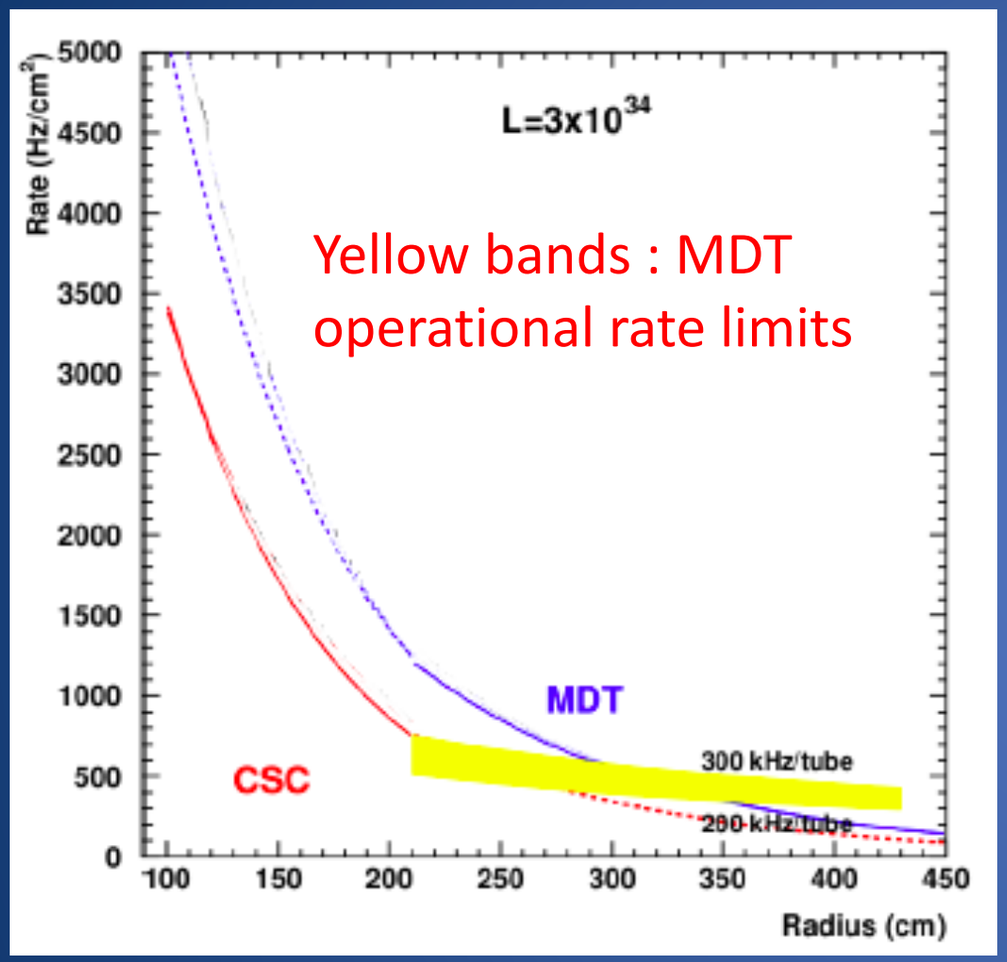
- LAr HV System in counting room

(*he put on his helmet after)

Upgrades: NSW Tracking

The Problem:

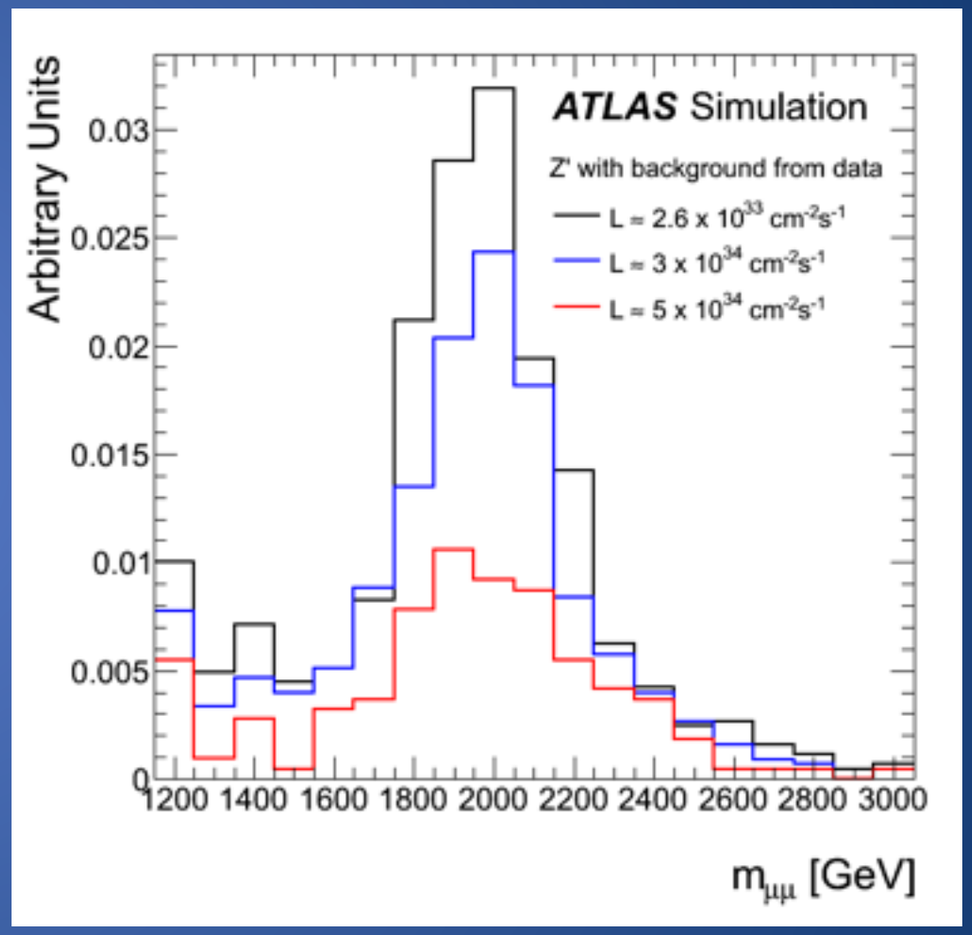
expected hit rates at $3x10^{34}$



- MDT Hit efficiency much reduced in EI at high luminosity
- Track Segment required in the EI station to measure momentum

The Effect:

Simulated Z' (2TeV) at luminosities of 0.2, 3, $5x10^{34}$ - 2 muons in End Cap



The Solution :

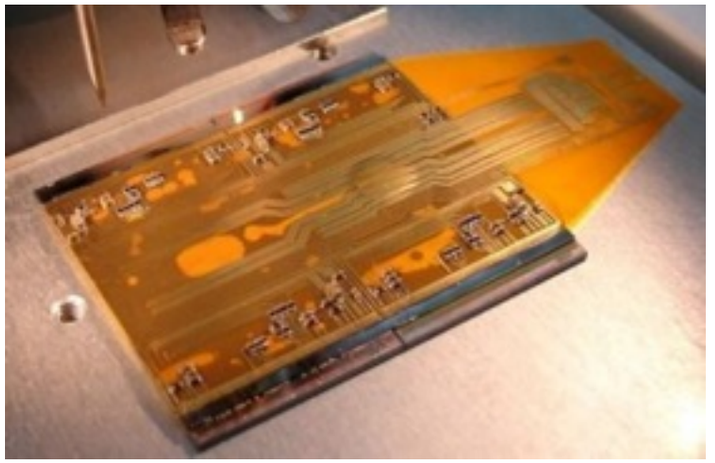
- high precision high granularity detectors for efficient tracking and triggering at high luminosity: Micromegas and sTGC

New ATLAS Tracking Detector (ITK)

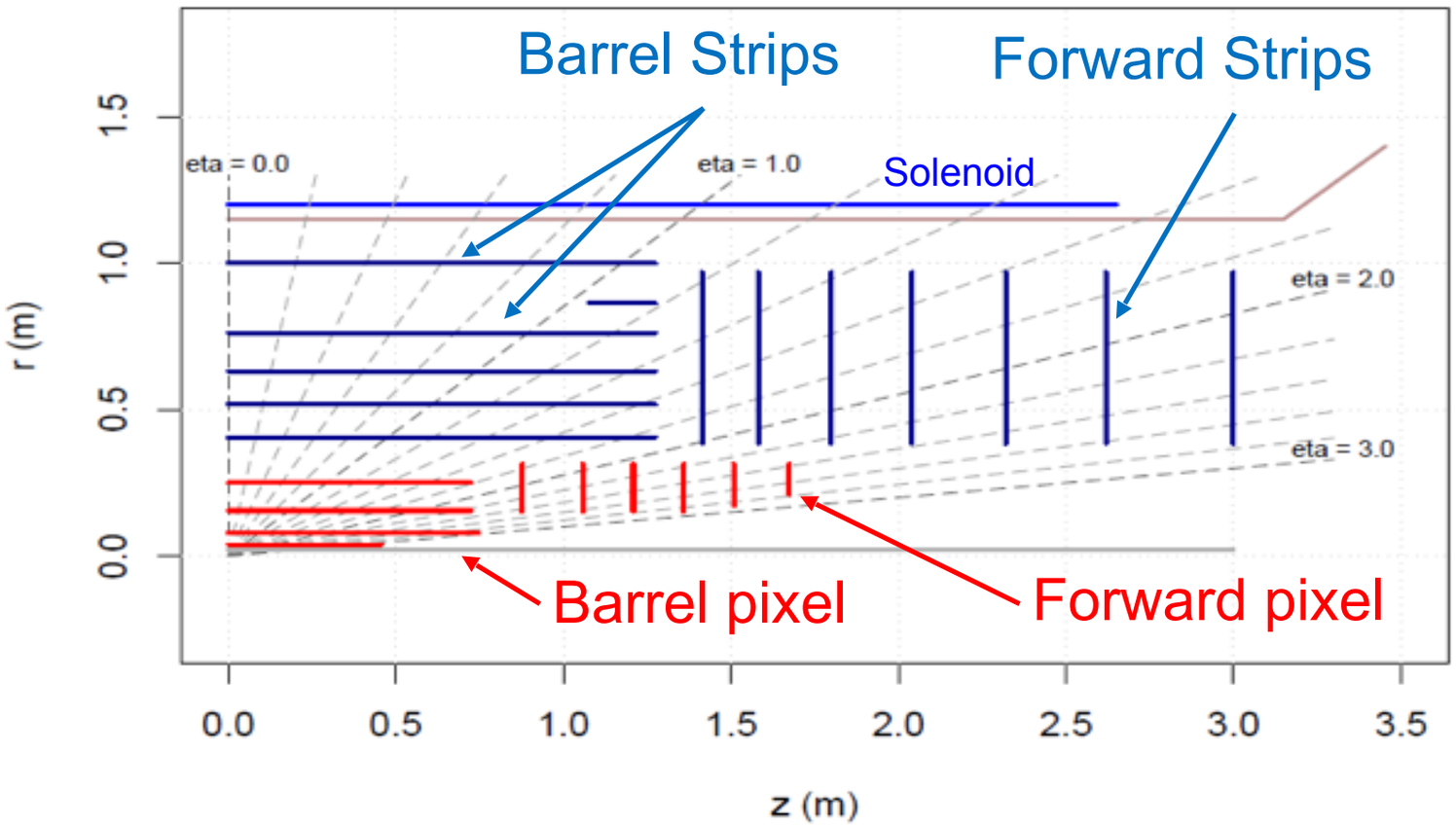
- Current Inner Detector (ID)
  - Designed to operate for 10 years at L=1x10^{34} $cm^{-2}s^{-1}$ with pileup of 23 events / crossing, trigger rate at Level-1 of 100kHz
- Limiting factors at HL-LHC
  - Bandwidth saturation 500 kHz (Pixels, SCT)
  - Too high occupancies (SCT, approaching 100% for TRT)
  - Radiation damage (Pixels (SCT) designed for 400 (700) fb^{-1})

Microstrip Stave Prototype

Quad Pixel Module Prototype



Layout new (all Si) ATLAS Inner Tracker for HL-LHC



New ITK: pixel and microstrip sensors.

ATLAS Canada

ATLAS Canada

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Carleton UNIVERSITY

McGill

Université de Montréal

SIMON FRASER UNIVERSITY

UNIVERSITY OF TORONTO

UBC

University of Victoria

UNIVERSITÉ YORK UNIVERSITY

TRIUMF

ATLAS CANADA

- **150 Canadian researchers and technical staff**
- **Includes over 70 graduate students**
- **39 faculty incl. 4 CRC Chairs**
- **9 leading Canadian Universities and the TRIUMF laboratory in Vancouver.**

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- ATLAS Canada Deputy Spokesperson: Prof. Richard Teuscher, IPP / University of Toronto, teuscher@physics.utoronto.ca

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Michel Vetterli	SFU/TRIUMF
Manuella Vincter	Carleton/CRC
Andreas Warburton	McGill

ATLAS Canada in the press…

canada.com

Tiny particles,
U of A physicist

ASTROPHYSICS
HIGGS & KISSES

The Atlas Experiment:
BIG data and the hunt for the God Particle

orion
Ontario's backbone of innovation

University of Victoria smashes data transfer record
At the Supercomputing Conference 2012 (SC2012) held Nov 12 - 16th, an international effo
University of Victoria, the U
gigabits per second, nearly

April 05, 2013
CERN offers UN advice on bringing women into science

Higgs boson: University of Toronto plays
role in "God particle" discovery, expected
Probing into the heart of matter
OTTAWA -- Part of the search for a type of matter that hum
Carleton University -- but it's a bit messy with runaway bolts
BY THE VANCOUVER SUN

Higgs boson discovery confir

Subatomic 'God particle'
By Emily Chung, CBC News Posted: Mar

Découverte d'une particule qui pourrait être le boson de Higgs
Mise à jour le mercredi 4 juillet 2012 à 21 h 00 HAE Radio-Canada avec Reuters, Agence France-Presse et La Presse Canadie

Canadian contributors get bang out of particle detector's launch
BY THE OTTAWA CITIZEN SEPTEMBER 10, 2008

Front cover and year-end review of Maclean's magazine, interviews on CBC news, The Nature of Things with David Suzuki, Quirks and Quarks, CTV, The Discovery Channel - Daily Planet, Toronto Star, Hamilton Spectator, Radio Canada, Montreal Gazette, Edmonton Journal, The Globe and Mail, Vancouver Sun, Ottawa Citizen, Youtube, UNESCO report 2013 …