ATLAS EXPERIMENT AT LHC AND UPGRADE PROGRAM

YURI KULCHITSKY

INSTITUTE OF PHYSICS, NATIONAL ACADEMY OF SCIENCES, MINSK, BELARUS

JINR, DUBNA, RUSSIA

ON BEHALF OF THE ATLAS COLLABORATION

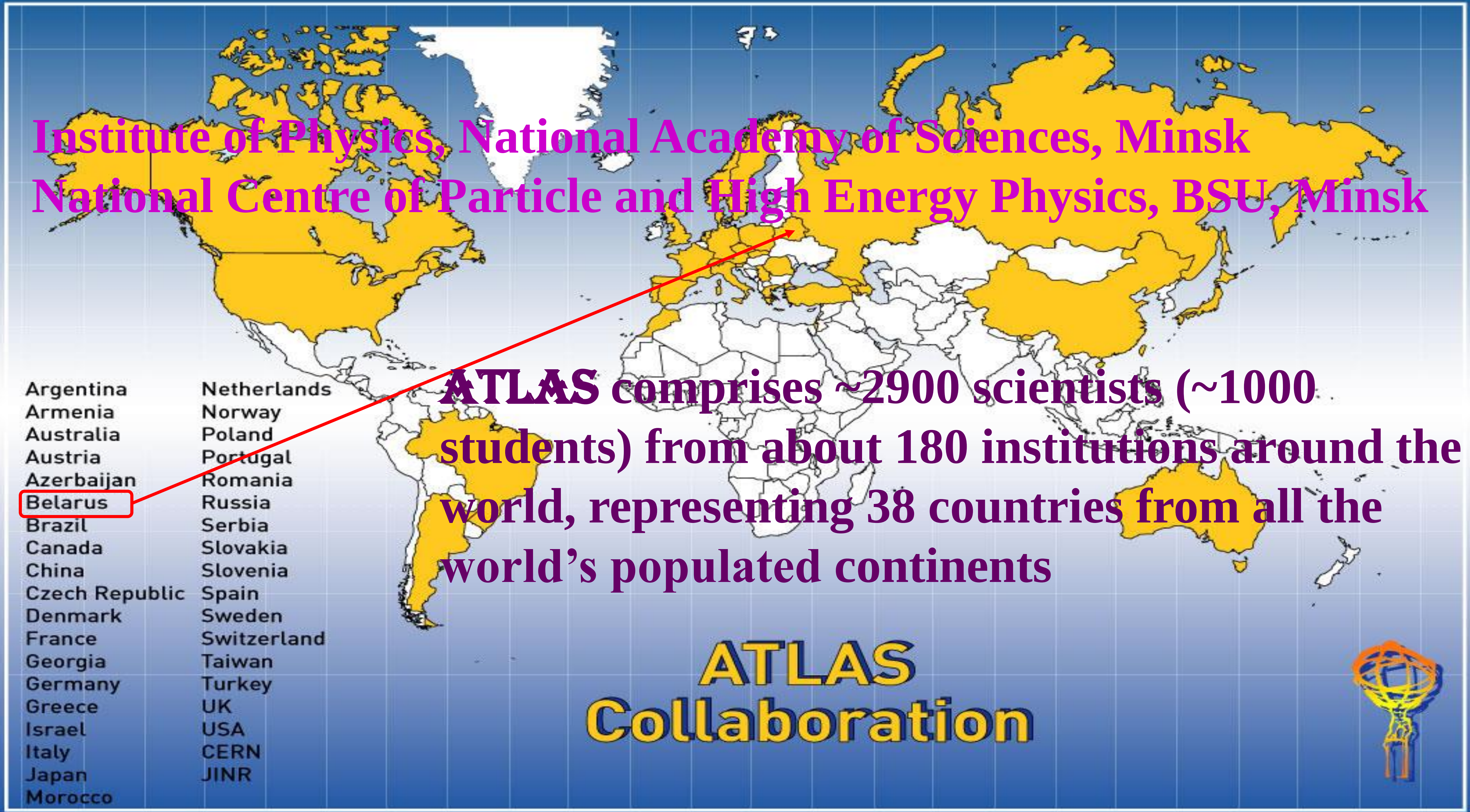
WORKSHOP

"LHC DAYS IN BELARUS",

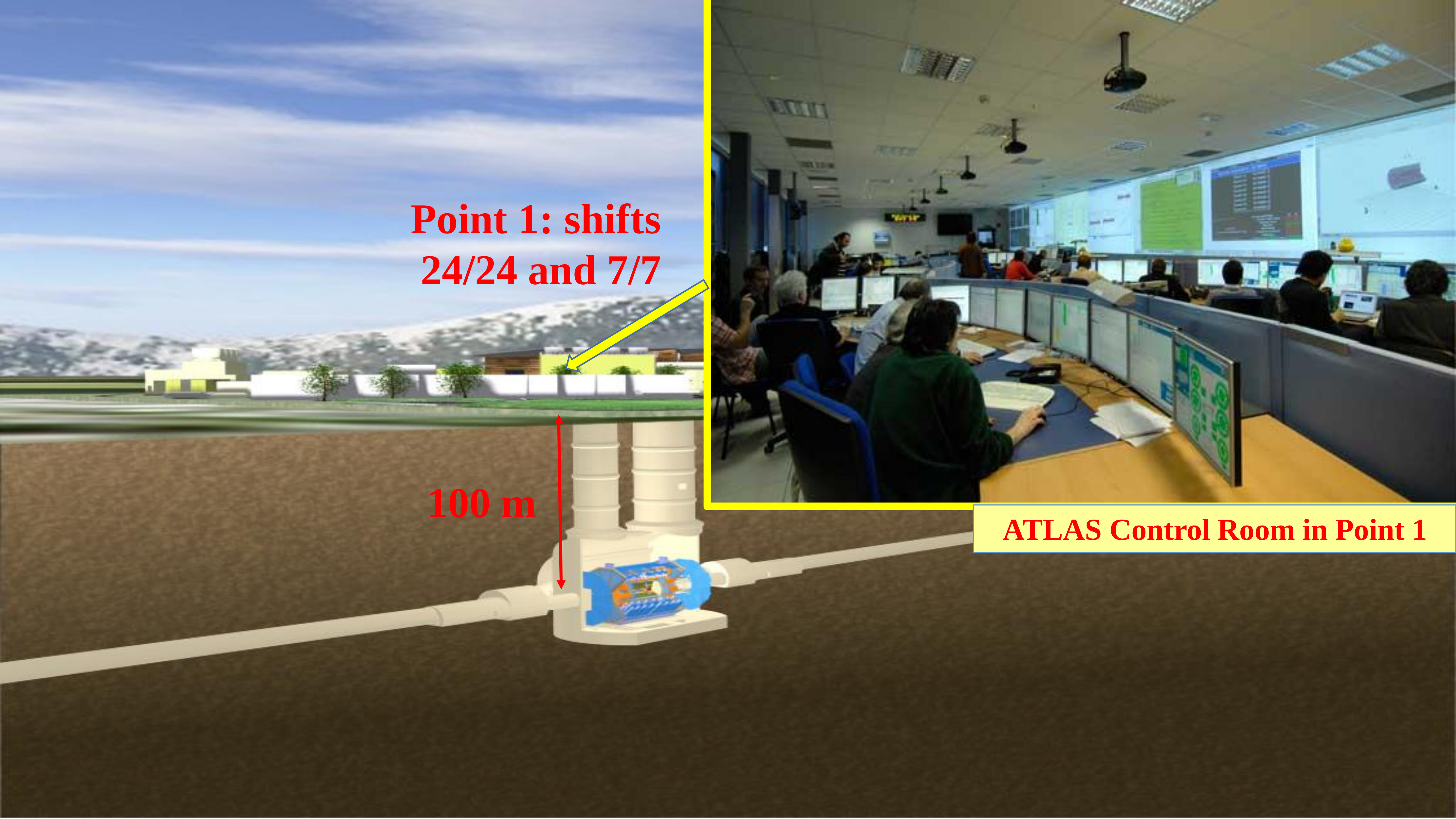
INSTITUTE FOR NUCLEAR PROBLEMS

OF BELARUSIAN STATE UNIVERSITY,

MINSK, BELARUS, 17 – 18 JANUARY 2017


Institute of Physics, National Academy of Sciences, Minsk
National Centre of Particle and High Energy Physics, BSU, Minsk
ATLAS comprises ~2900 scientists (~1000 students) from about 180 institutions around the world, representing 38 countries from all the world's populated continents
Argentina
Armenia
Australia
Austria
Azerbaijan
Belarus
Brazil
Canada
China
Czech Republic
Denmark
France
Georgia
Germany
Greece
Israel
Italy
Japan
Morocco
Netherlands
Norway
Poland
Portugal
Romania
Russia
Serbia
Slovakia
Slovenia
Spain
Sweden
Switzerland
Taiwan
Turkey
UK
USA
CERN
JINR
ATLAS
Collaboration

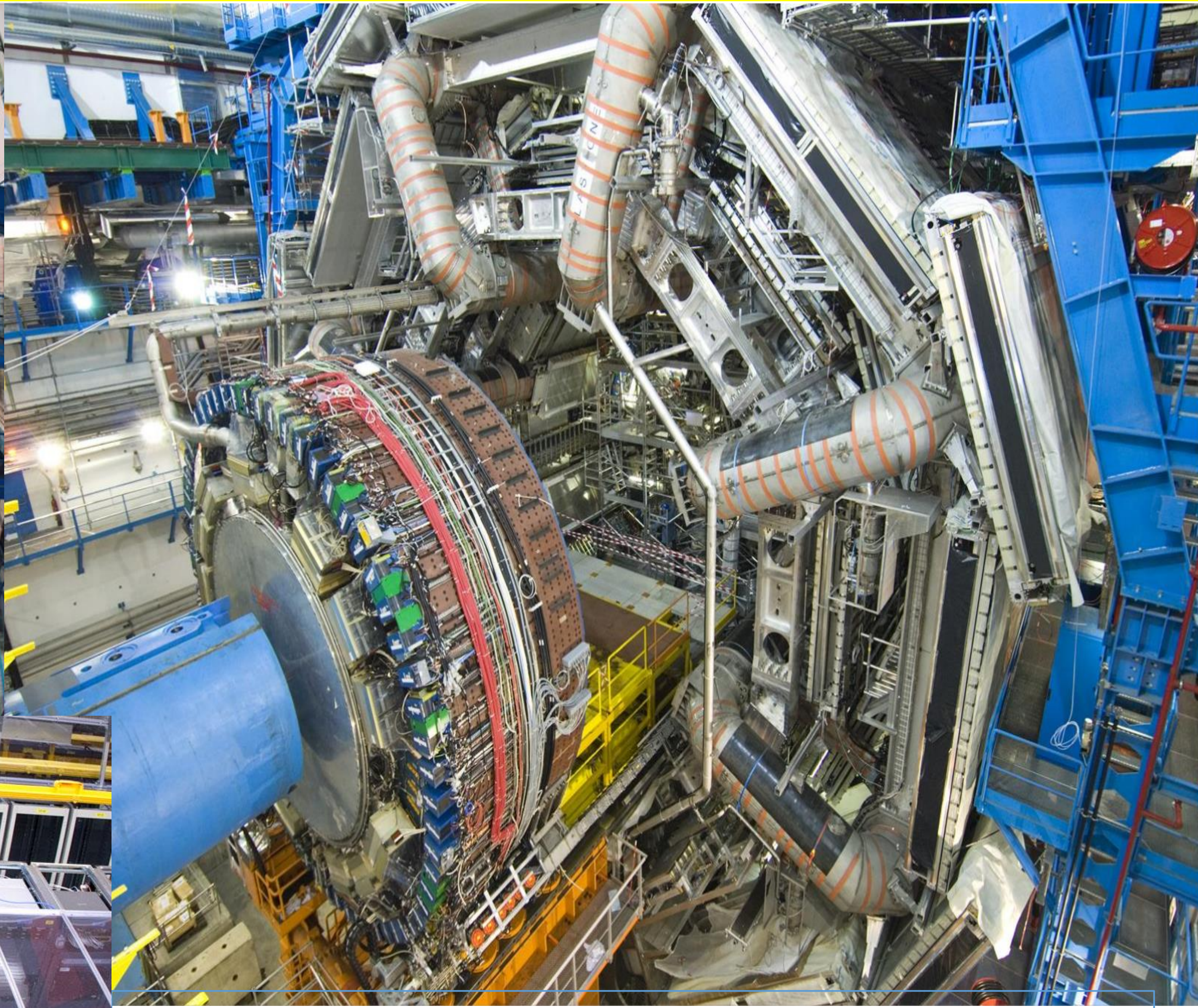
Large Hadron Collider
CMS
p
p
LHCb
ATLAS
ALICE


Point 1: shifts
24/24 and 7/7
100 m
ATLAS Control Room in Point 1

ATLAS 2004 – 2007

ATLAS cavern February 2004

ATLAS Computer system



ATLAS cavern February 2007

A TOROIDAL LHC APPARATUS (ATLAS) TODAY

Muon spectrometer

(*μ Trigger/tracking and Toroid Magnets*)

Precision Tracking:

- **MDT** (Monitored Drift Tubes)
- **CSC** (Cathode Strip Chambers) |η| >2.4

Trigger:

- **RPC** (Resistive Plate Chamber) barrel
- **TGC** (Thin Gas Chamber) endcap

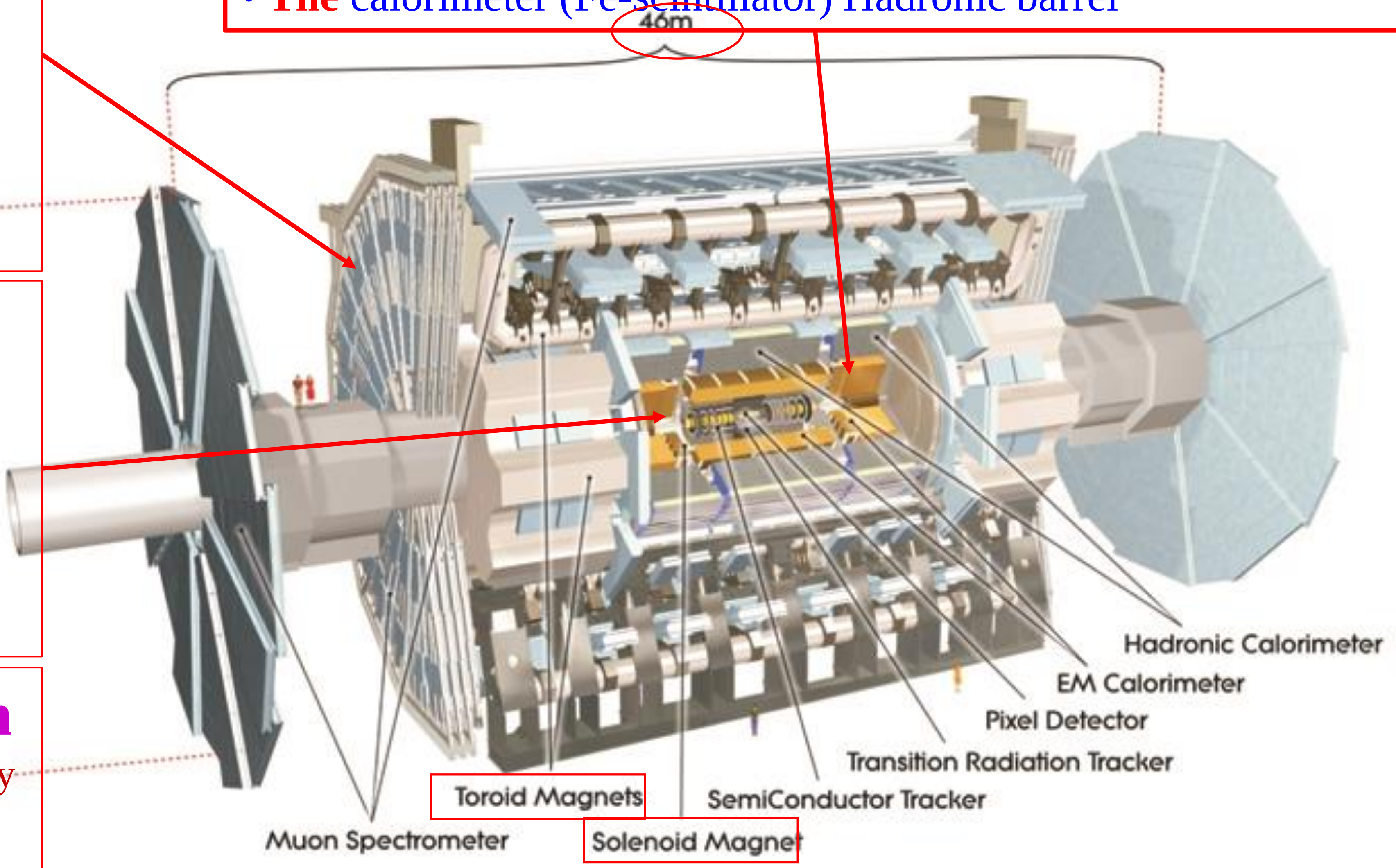
Calorimeter: EM and Hadronic energy

- **Liquid Ar** (LAr) EM barrel and End-cap & Hadronic End-cap
- **Tile** calorimeter (Fe-scintillator) Hadronic barrel

Inner Detector (ID)

Tracking; 2T Solenoid Magnet

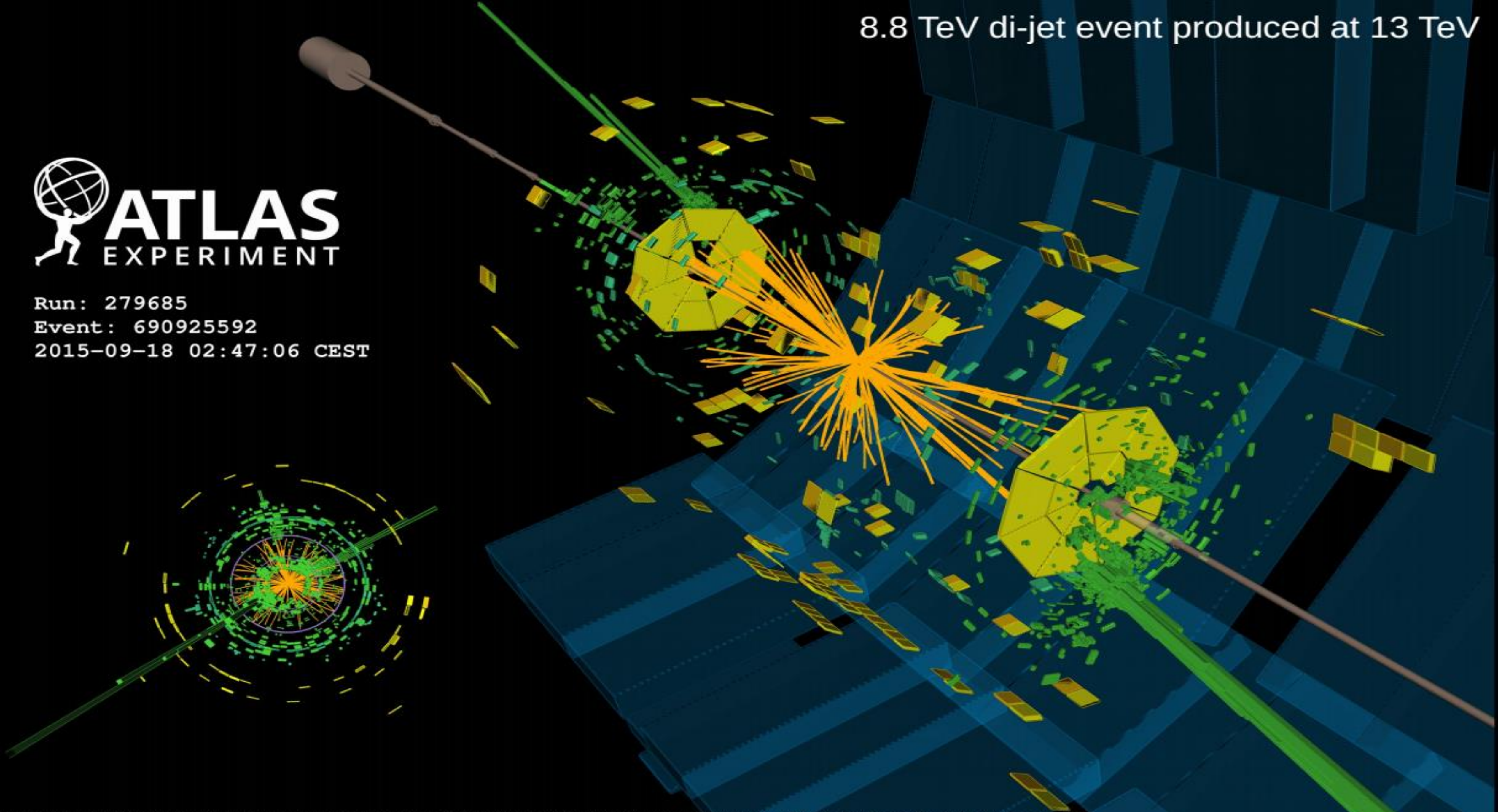
- **Silicon Pixels** 50 x 400 μm^2
- **Silicon Strips** (SCT) 40 μm rad stereo strips
- **Transition Radiation Tracker** (**TRT**) up to 36 points/track



Two Level Trigger system

- **L1 – hardware**: **100 kHz, 2.5 μs** latency
- **HLT – farm**: merge the former **L2** and **Event Filter 1.5 kHz, 0.2 s** latency

8.8 TeV di-jet event produced at 13 TeV

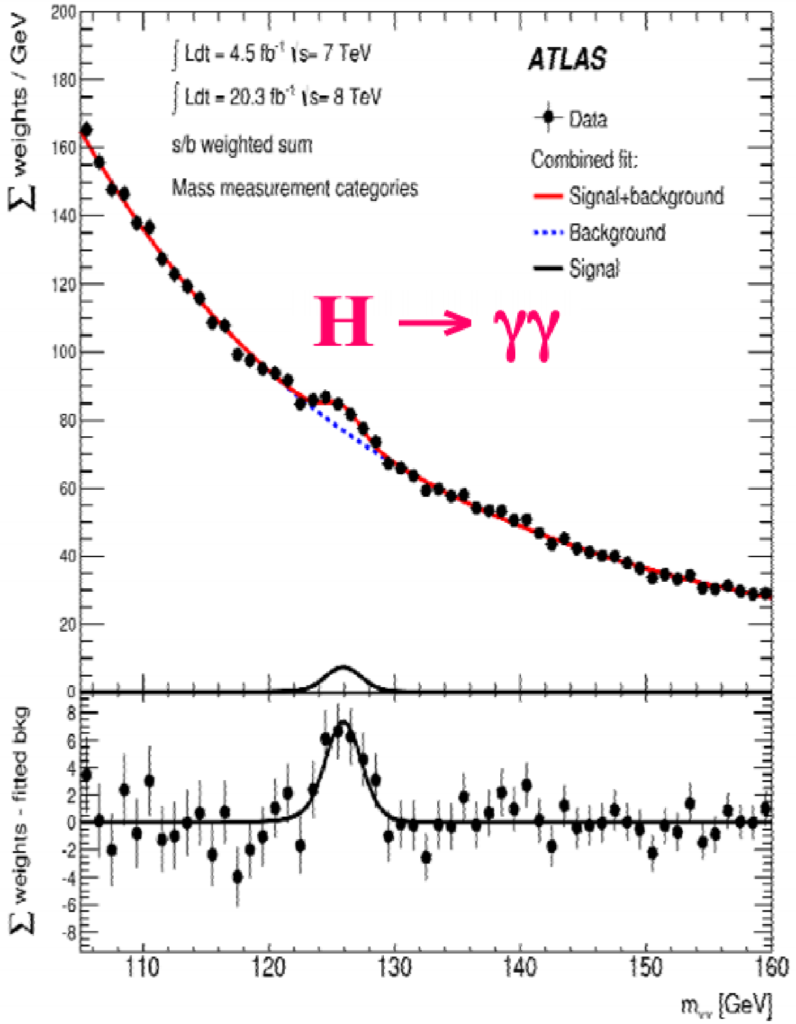


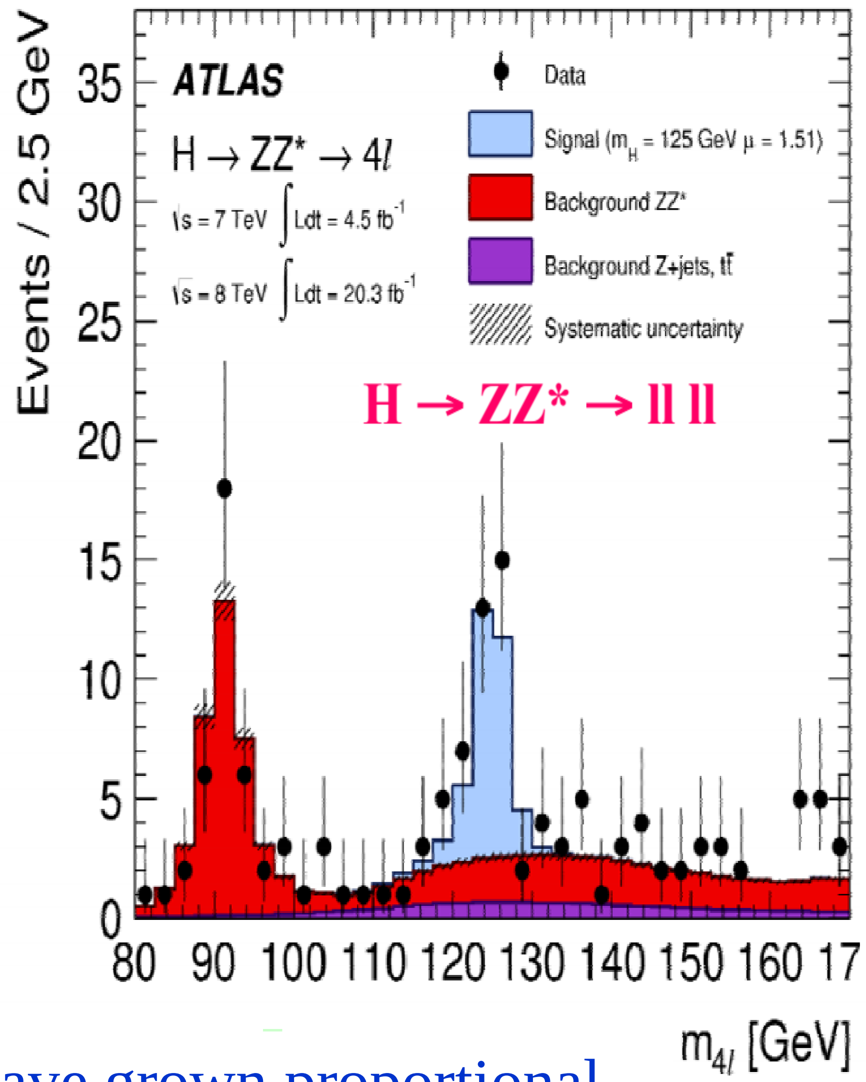
A high-mass dijet event. This event was collected in September 2015: the two central high-pT jets have an invariant mass of 8.8 TeV, the highest-pT jet has a pT of 810 GeV, and the subleading jet has a pT of 750 GeV. The missing ET for this event is 60 GeV.

HIGGS BOSON

PRD 90, 052004 (2014)

Chin. Phys. C, **38**, 090001 (2014) and 2015 update





H^0 $J = 0$

Mass $m = 125.09 \pm 0.24$ GeV

H^0 Signal Strengths in Different Channels

See Listings for the latest unpublished results.

Combined Final States $= 1.17 \pm 0.17$ (S = 1.2)

$WW^* = 0.81 \pm 0.16$

$ZZ^* = 1.15^{+0.27}_{-0.23}$ (S = 1.2)

$\gamma\gamma = 1.17^{+0.19}_{-0.17}$

$b\bar{b} = 0.85 \pm 0.29$

$\mu^+\mu^- < 7.0$, CL = 95%

$\tau^+\tau^- = 0.79 \pm 0.26$

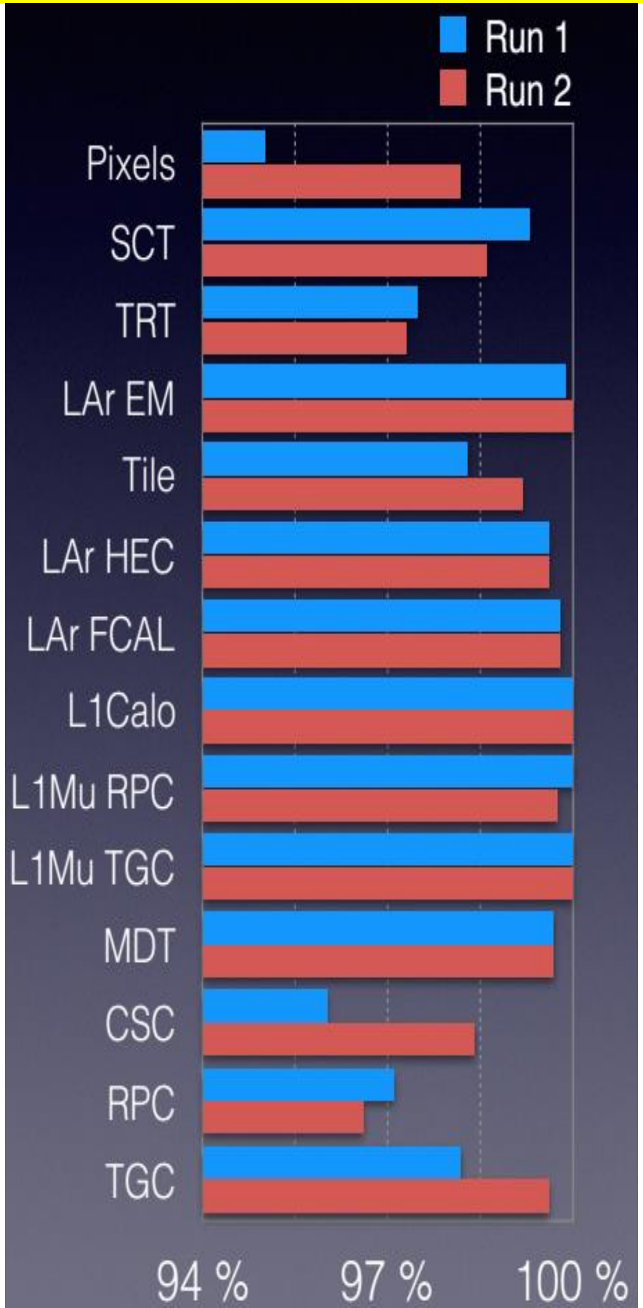
$Z\gamma < 9.5$, CL = 95%

$t\bar{t}H^0$ Production $= 2.5^{+0.9}_{-0.8}$

Unit	Symbol	cm^2
femtobarn	fb	10^{-39}
attobarn	ab	10^{-42}

The peaks in the discovery channels have grown proportional to the luminosity. They are not statistical fluctuations.

ATLAS DETECTOR PERFORMANCE



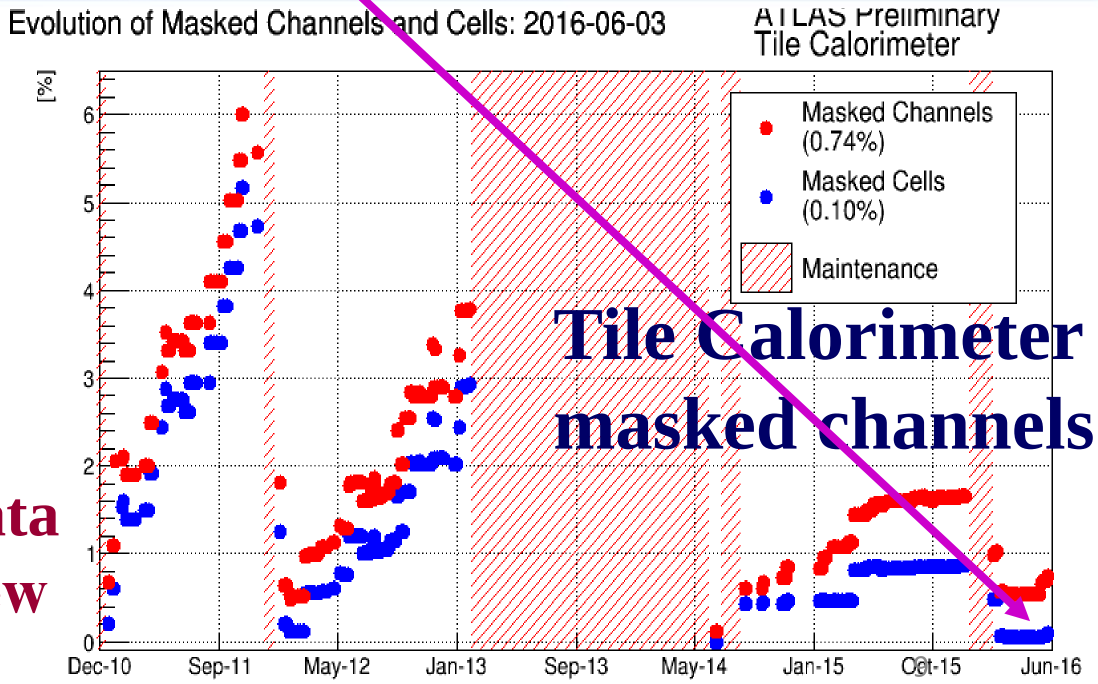
ATLAS pp 25ns run: August-November 2015

Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
93.5	99.4	98.3	99.4	100	100	100	100	100	100	97.8

All Good for physics: 87.1% (3.2 fb^{-1})

Luminosity weighted relative detector uptime and good data quality (DQ) efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at $\sqrt{s}$=13 TeV between August-November 2015, corresponding to an integrated luminosity of 3.7 fb^{-1}. The lower DQ efficiency in the Pixel detector is due to the IBL being turned off for two runs, corresponding to 0.2 fb^{-1}. Analyses that don't rely on the IBL can use those runs and thus use 3.4 fb^{-1} with a corresponding DQ efficiency of 93.1%.

- Overall smooth operation
- Constant live fraction of channels
- Important re-commissioning with data
- Learned to operate "a new detector"



Tile Calorimeter masked channels

LHC & ATLAS TIMELINE

2009 — Run 1

LHC startup, √s 900 GeV

Total L1A rate limited to ≈100 kHz until LS3

$\sqrt{s}$ = 7 - 8 TeV, L ~ 2×10^{33} cm^{-2}s^{-1}, *BS = 50/25 ns*

~10 fb^{-1}

2013–2014 — S1

Go to design energy, nominal luminosity

2016 → Run 2

Enhancements to trigger and detector

$\sqrt{s}$ = 13 - 14 TeV, L ~ 1×10^{34} cm^{-2}s^{-1}, *BS = 25 ns*

~50 fb^{-1}

2019–2020 — S2

Injector and LHC Phase-1 upgrade to full design luminosity

Run 3

Mainly more trigger upgrades

$\sqrt{s}$ = 14 TeV, L ~ 2×10^{34} cm^{-2}s^{-1}, *BS = 25 ns*

~300 fb^{-1}

2024–2026 — S3

HL-LHC Phase-2 upgrade, crab cavities

Run 4 — **2035**

Major upgrades for HL-LHC

$\sqrt{s}$ = 14 TeV, L ~ $5\text{-}7\times10^{34}$ cm^{-2}s^{-1}, *BS = 25 ns*

~3000 fb^{-1}

Detector challenges:

- ***x10 more radiation*** (~10^{16}neq/cm^2; 10 MGy)
- ***x10 more pile-up***

Run1: *<μ>=20;*
$\langle n_{PU}$(jets p_T>30 GeV)$\rangle$~0.04

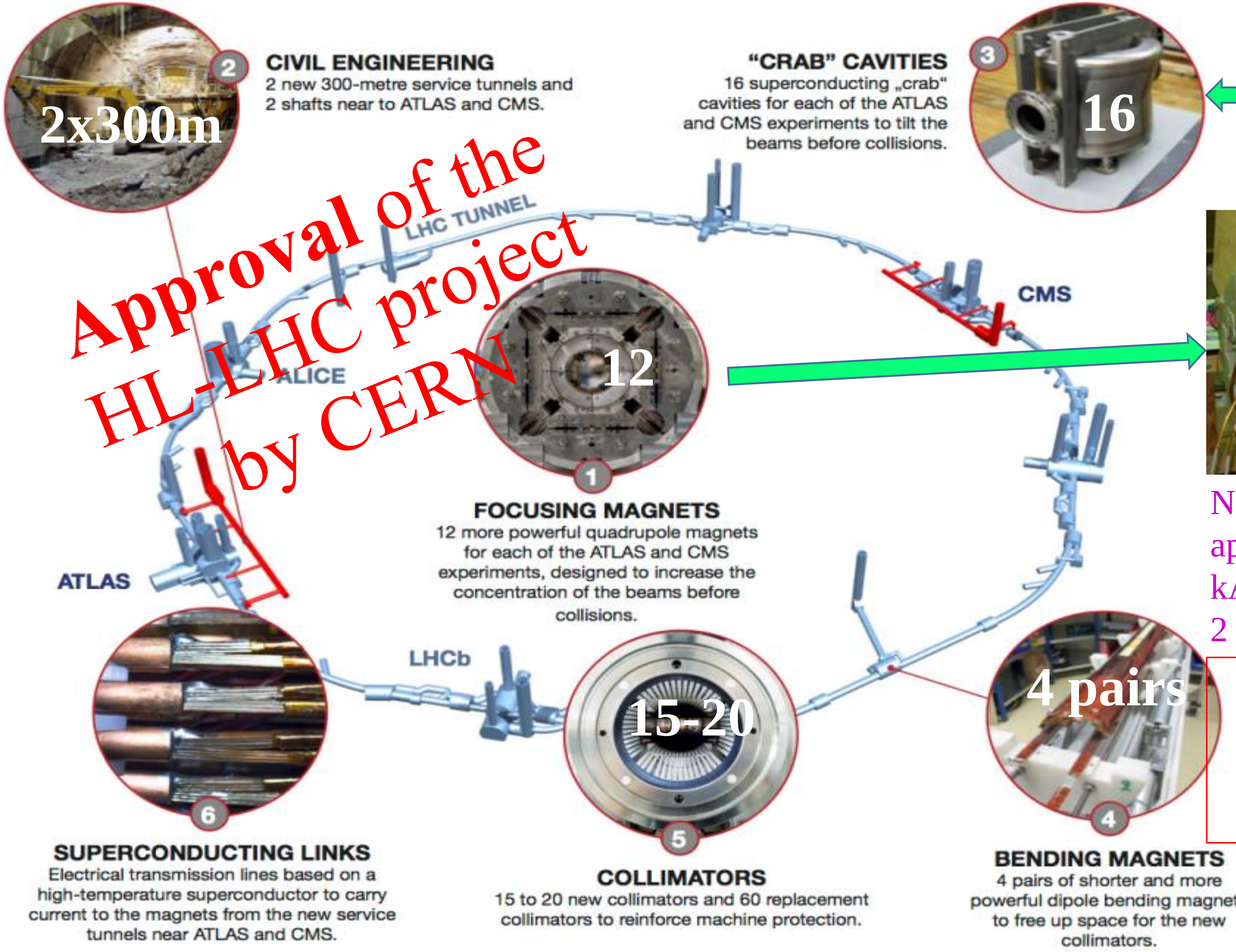
HL-LHC: *<μ>=200;* ***(increase in 10)***
$\langle n_{PU}$(jets p_T>30 GeV)$\rangle$~7.4
(increase in 185)

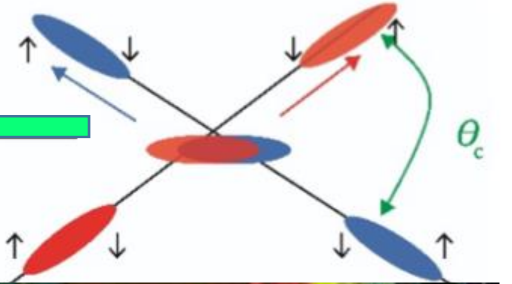
ATLAS Upgrades needed to:

- ***Keep performance***
- ***Trigger rates acceptable with low p_T thresholds***
- ***Pile-up mitigation up to large η is needed!***

The LHC and its HL-LHC phase are CERN's flagship project for the next 20 years
→ crucial for the future of the Organization and particle physics worldwide !

HL-LHC MAIN UPGRADE COMPONENTS



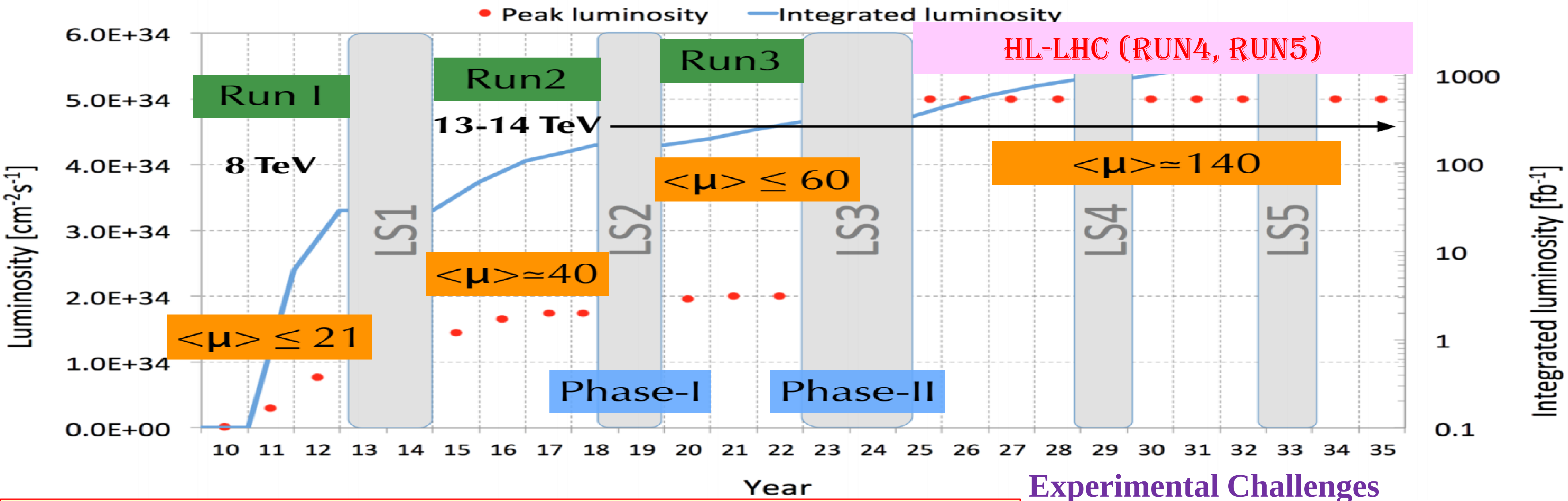


Nb_3Sn quadrupole model (1.5 m long, aperture = 150 mm) reached current of 18 kA (nominal: 16.5 kA) at FNAL.
2 coils from CERN + 2 coils from US.

"Next 10 years dominated by construction of HL-LHC (950 MCHF), which will be realised within a constant CERN Budget"
CERN Director General 23/06/2016

End 2015: Nb_3Sn dipole (1.8 m) reached 11.3 T (> nominal) without quenches.

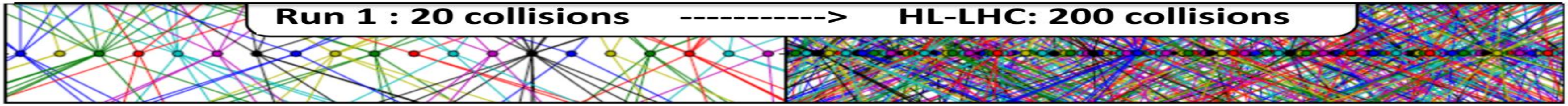
HL-LHC PROJECT TIMELINE



- **HL-LHC** will ***start in mid-2025*** after ~2.5 years of shutdown
- Levelled Luminosity of **$5\cdot10^{34}$ cm^{-2} s^{-1}.** Maximum Lumi **~$7\cdot10^{34}$ cm^{-2} s^{-1}**
- **Average number of pile-up** interactions per bunch crossing **<μ> ≃ 140**
- **Expect to collect** ~300 fb^{-1} with LHC and **~3000 fb^{-1} with the HL-LHC**

Experimental Challenges

- High pile-up ⇒ *detector and trigger improvements needed*
- High radiation level ⇒ *detector damage*
- **Goal:** *keep detectors performance at the same level as today*



PHYSICS MOTIVATION AT HL-LHC

Electroweak symmetry Breaking

1. **Higgs precision measurements** (coupling and spin-CP quantum numbers)
2. **Higgs rare and invisible decays** (H->μμ , H->Zγ,…)
3. **Top Yukawa coupling** (SH)
4. **Higgs self coupling**

THE NAME OF THIS GAME IS PRECISION

Beyond the Standard Model

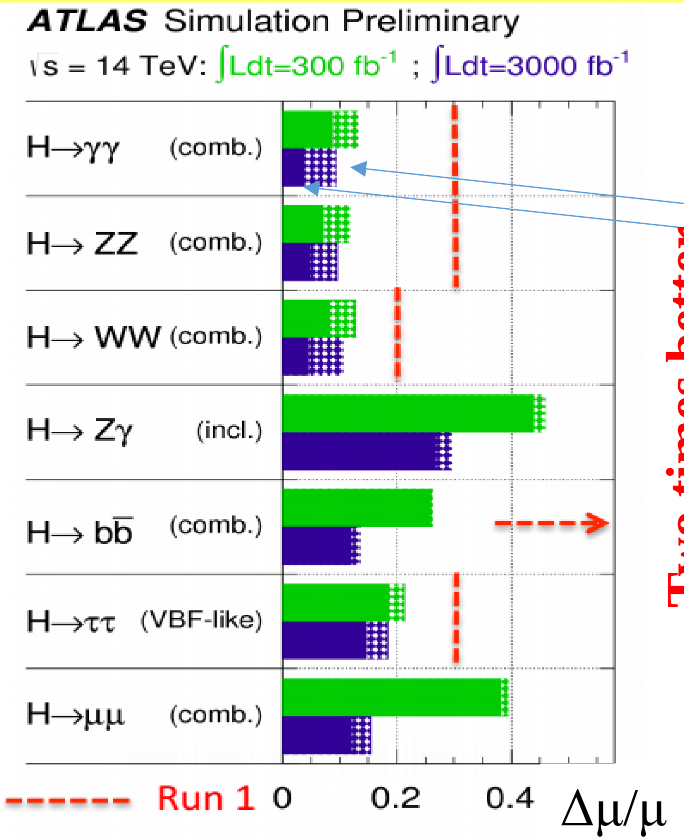
- **Higgs sector** (search for deviations from SM)
- **Dark matter**
- **SUSY**
- **Exotics**

HIGGS PRESISSION MEAGUREMENT ATL-PHYS-PUB-2014-016

At HL-LHC:

- **100 million** SM Higgs bosons
- **~4-5%** precision for main channels
- **~10-20%** precision for rare modes
- will be able to quantify **small deviations from the SM**
- **3-4 times** more sensitivity in direct searches for additional Higgs bosons than at LHC

Yuri Kulchitsky



Two times better signal strength precision

Signal strength precision Δμ/μ *				
H→	L = 300 fb-1 (run 3)		L = 3000 fb-1 (LH-LHC)	
	w/o theory Δ (%)	w/ theory Δ (%)	w/o theory Δ (%)	w/ theory Δ (%)
γγ	9	13	4	9
WW	8	13	5	11
ZZ	7	11	4	9
bb	26	26	12	14
ττ	18	21	15	19
Zγ	44	46	27	30
μμ	38	39	12	16

* $\mu = \sigma \times BR_{obs} / \sigma \times BR_{SM}$

EXOTIC & SUSY MOTIVATION AT HL-LHC

ATL-PHYS-PUB-2013-003, ATL-PHYS-PUB-2014-007

ATLAS Mass reach for Exotic signatures

ATLAS @14 TeV	Z' → ee SSM 95% CL limit	g_{KK} → t t RS 95% CL limit	Dark matter M* 5σ discovery
300 fb^{-1}	6.5 TeV	4.3 TeV	2.2 TeV
3000 fb^{-1}	7.8 TeV	6.7 TeV	2.6 TeV

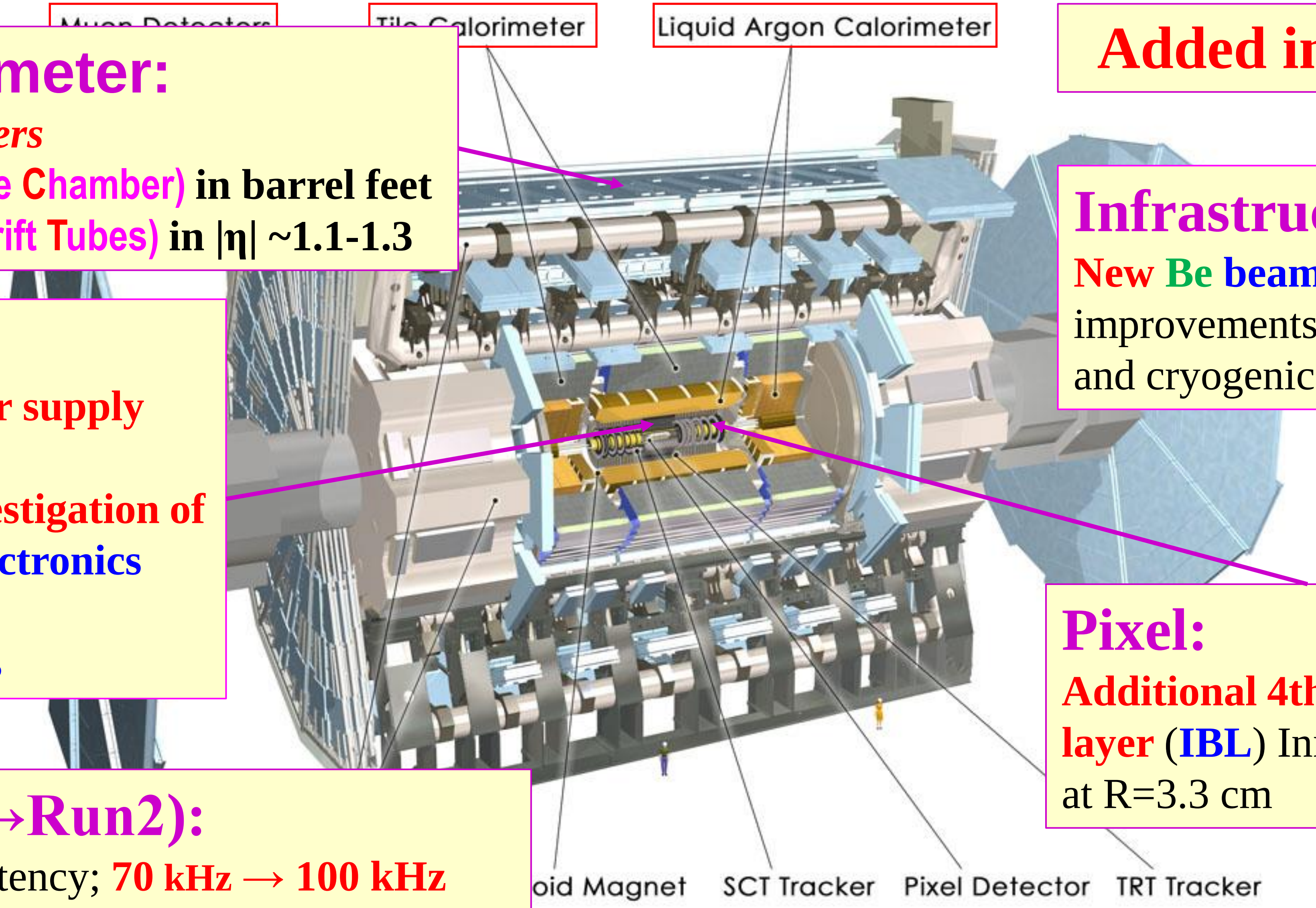
ATL-PHYS-PUB-2013-011, ATL-PHYS-PUB-2014-010, ATL-PHYS-PUB-2015-032

ATLAS Mass reach for SUSY particles

ATLAS projection	gluino mass	squark mass	stop mass	sbottom mass	χ_1^+ mass WZ mode	χ_1^+ mass WH mode
300 fb^{-1}	2.0 TeV	2.6 TeV	1.0 TeV	1.1 TeV	560 GeV	None
3000 fb^{-1}	2.4 TeV	3.1 TeV	1.2 TeV	1.3 TeV	820 GeV	650 GeV

Significant increase in mass reach for Exotics and SUSY signatures at HL-LHC (3000 fb^{-1})

ATLAS PHASE 0 UPGRADES (2013-2014)



Added in Phase 0

Muon spectrometer:

- *More muon chambers*
  RPC (Resistive Plate Chamber) in barrel feet
- MDT (Monitored Drift Tubes) in |η| ~1.1-1.3

Calorimeters:

- LAr and Tile power supply replacements
- Test beams for investigation of new FE and BE electronics
- New *MBTS*
- New lumi detectors

Infrastructure:

New Be beam pipe, improvements to magnet and cryogenic systems

Pixel:

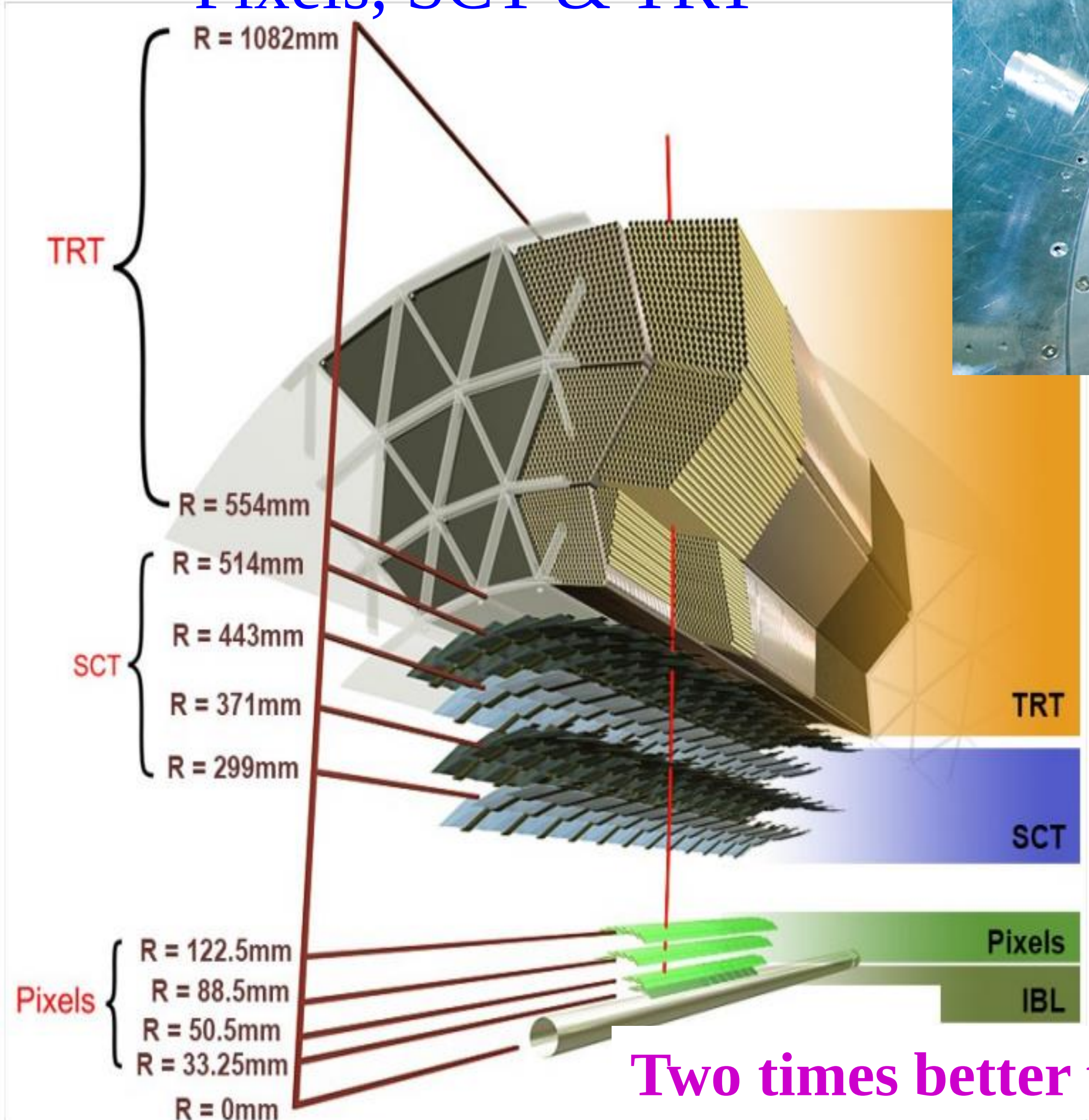
Additional 4th silicon pixel layer (IBL) Innermost layer at R=3.3 cm

Trigger (Run1→Run2):

- L1 (HW): 2.5 μs latency; 70 kHz → 100 kHz
- HLT/Event Filter (Software): 600 Hz → 1 kHz

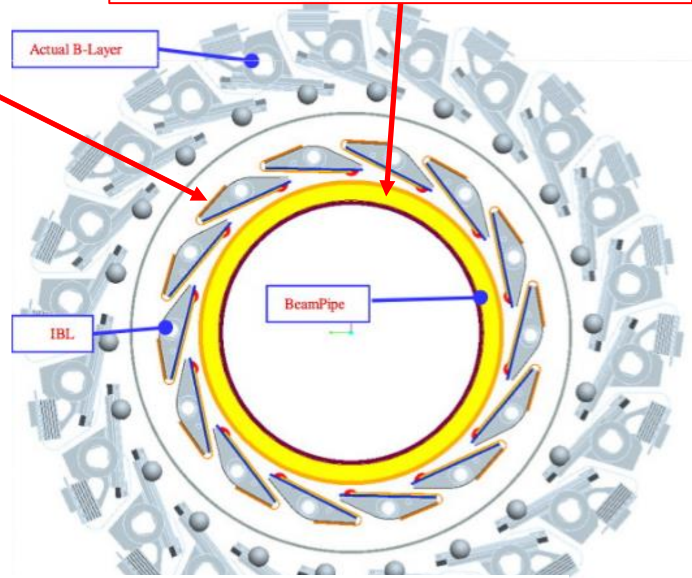
INNER DETECTORS (ID)

ATLAS tracking detectors:
Pixels, SCT & TRT

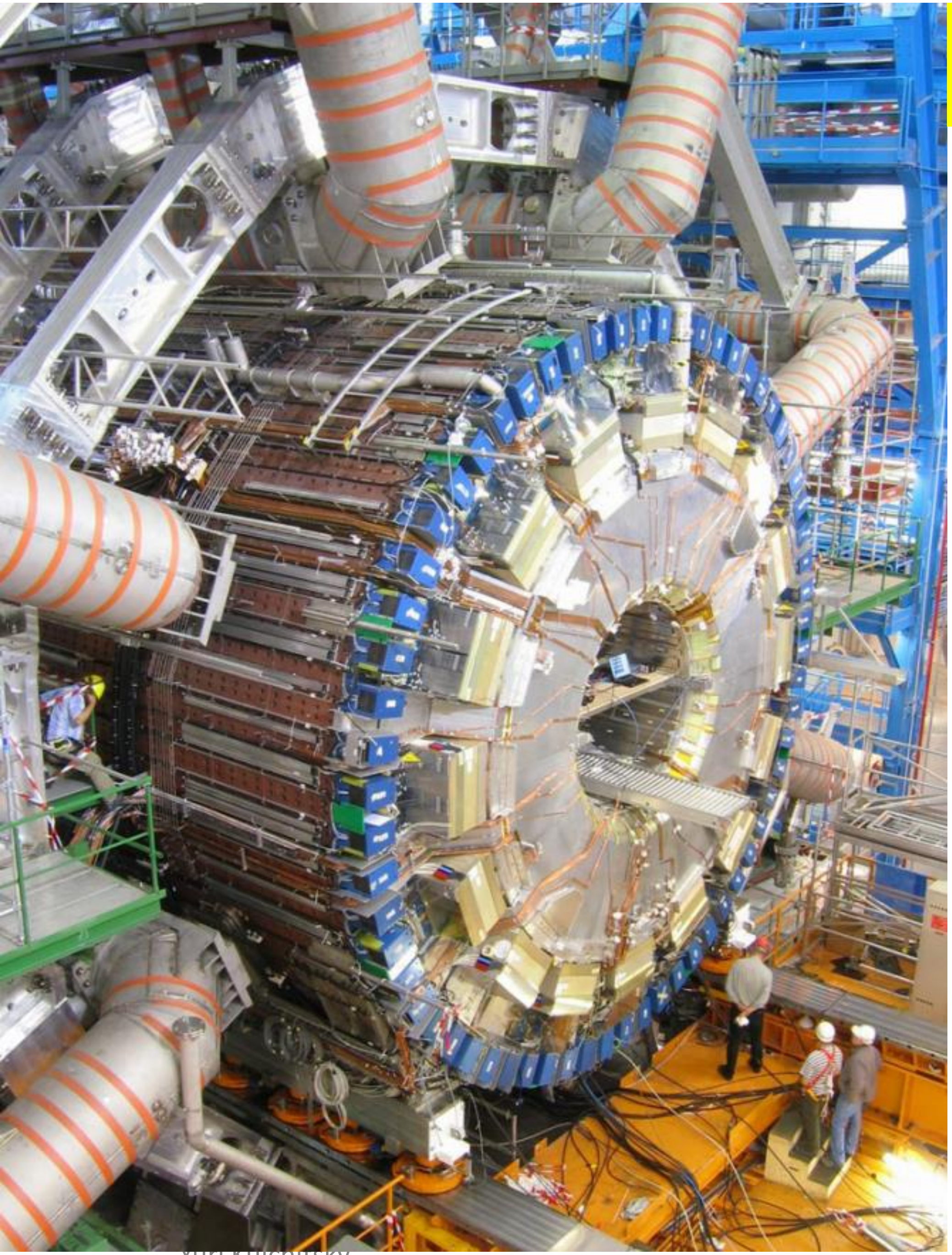


- **New innermost 4-th layer** for the Pixel detector [**IBL** = Insertable B-Layer]
- Required complete removal of the ATLAS Pixel volume
- IBL fully operational

New Be beam pipe

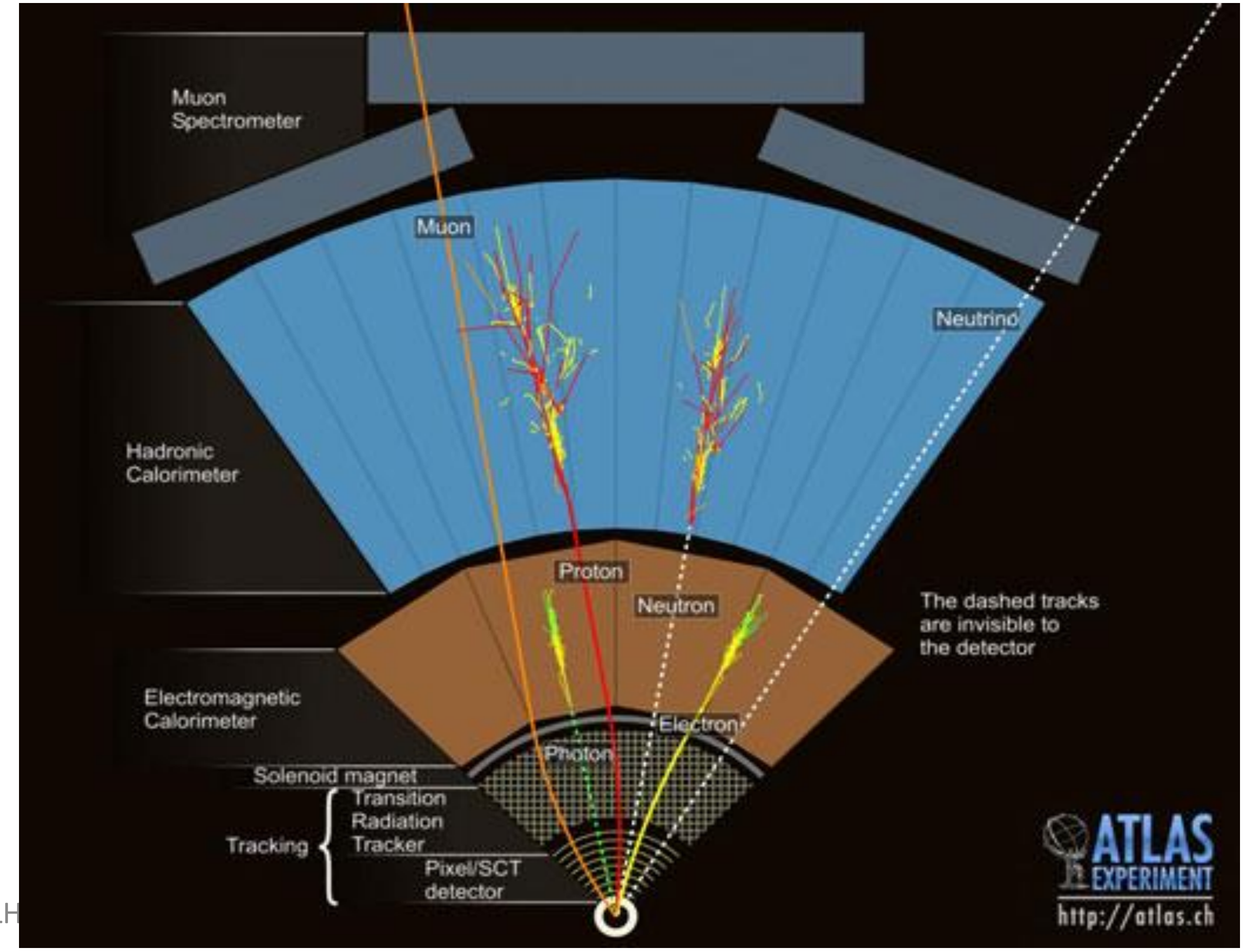


Two times better tracks impact parameters resolution at 13 TeV!



CALORIMETERS

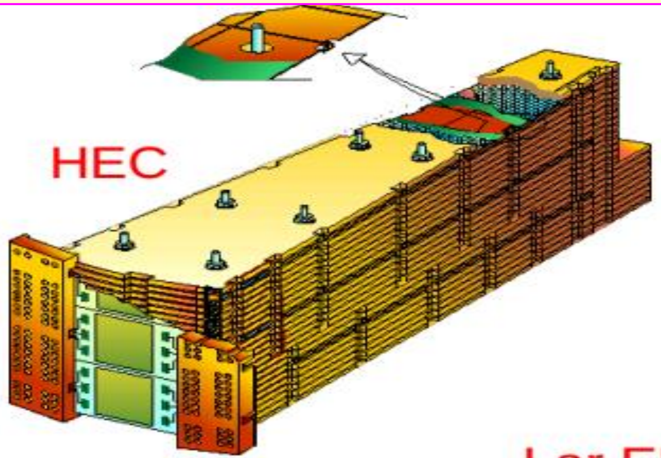
- Very stable performance
- Improved stability of new Tile power supplies
- Good operation efficiency: 99.4% LAr and 100% Tile
- LAr using 4 sample readout to achieve 100 kHz



ATLAS CALORIMETERS

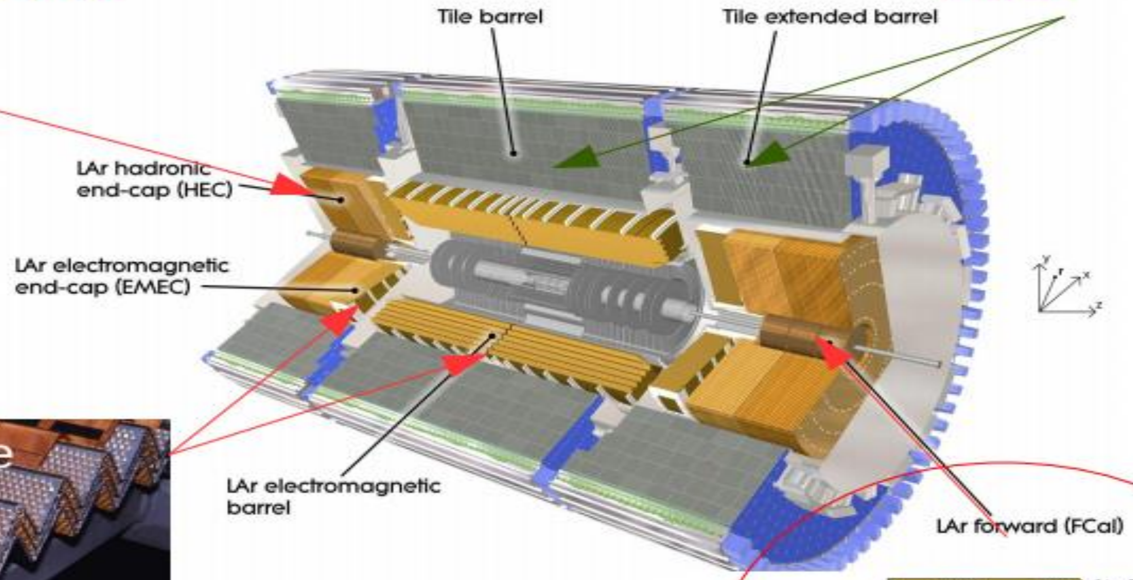
New for Calorimeters: LAr and Tile power supply replacements

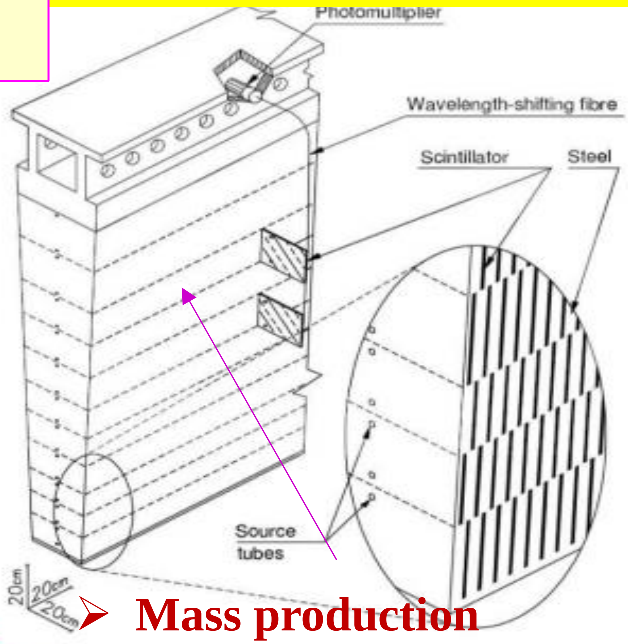
HEC



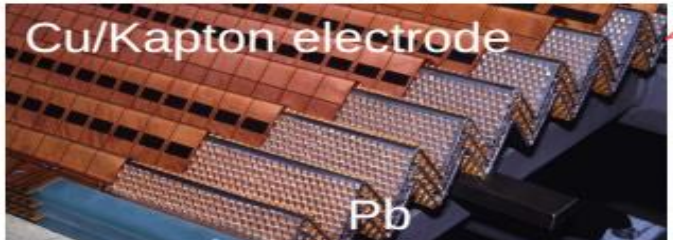
LAr

Tile

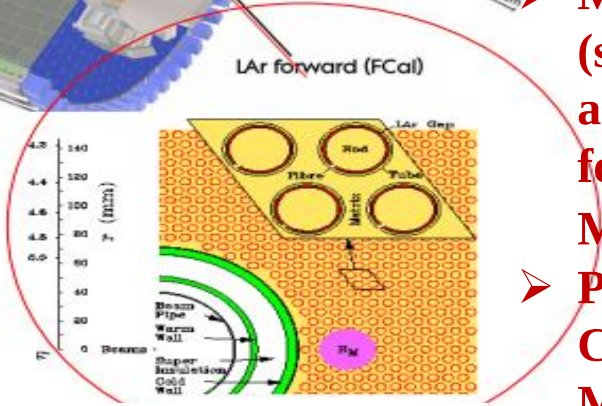




Lar EM



FCAL



- Mass production (stamping) of master and spacer iron plates for Tile Calorimeter Modules in Minsk.
- Production of Tile Calorimeter Barrel Modules in JINR
- Transportation of TileCal Barrel Modules from Dubna to CERN by JINR.

ATLAS Calorimeters:

- ✓ Very hermetic
  - ❖ Gaps partially instrumented
  - ❖ Small dead regions which did not significantly impact physics
- ✓ Excellent shower containment
- ✓ Fine granularity
- ✓ Good resolution and small noise

Test beam study **of new FE and BE electronics for Tile and Lar calorimeters**

ATLAS TileCal Testbeam SETUP 2015/17

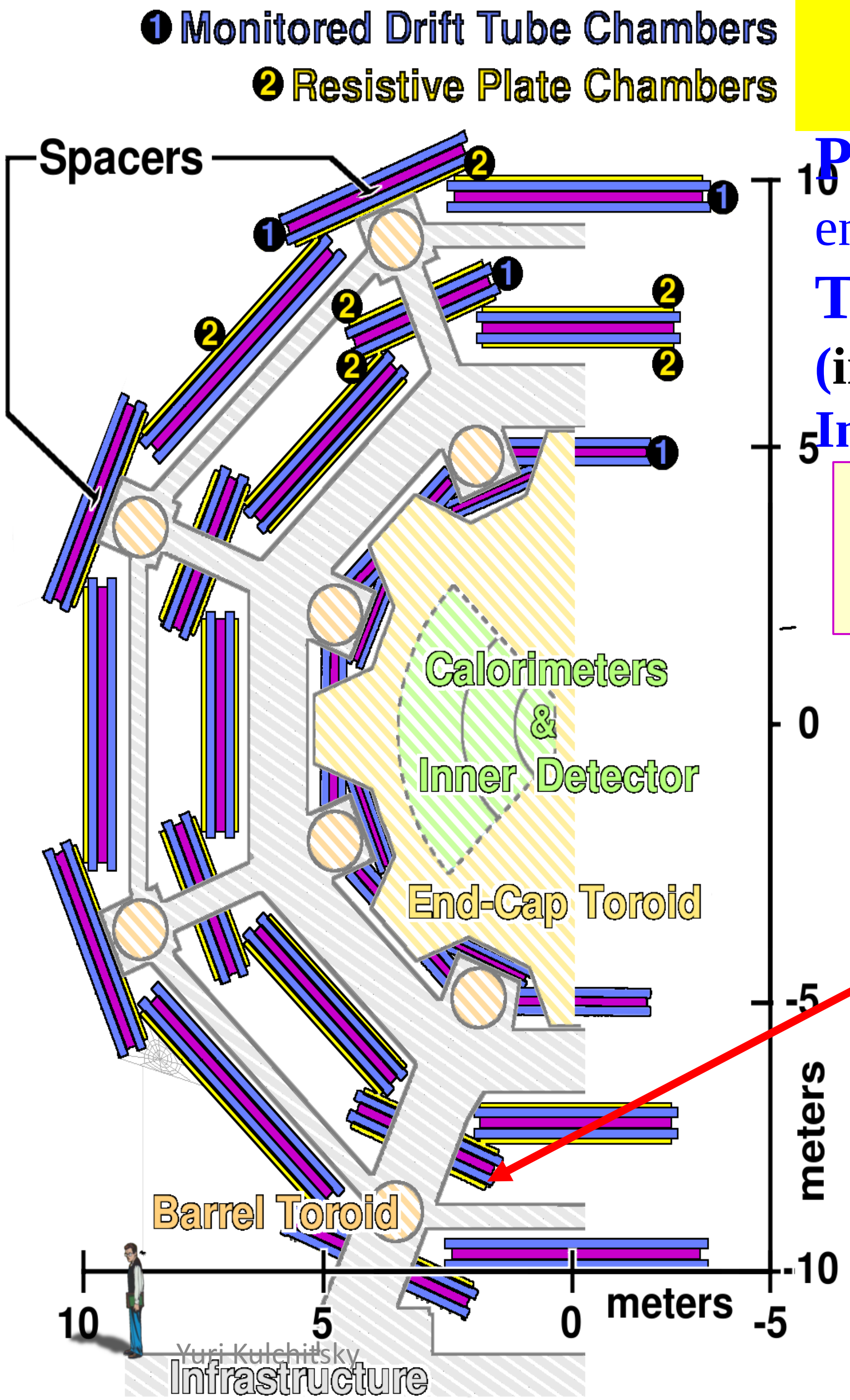
ATLAS MUON DETECTOR (MD)

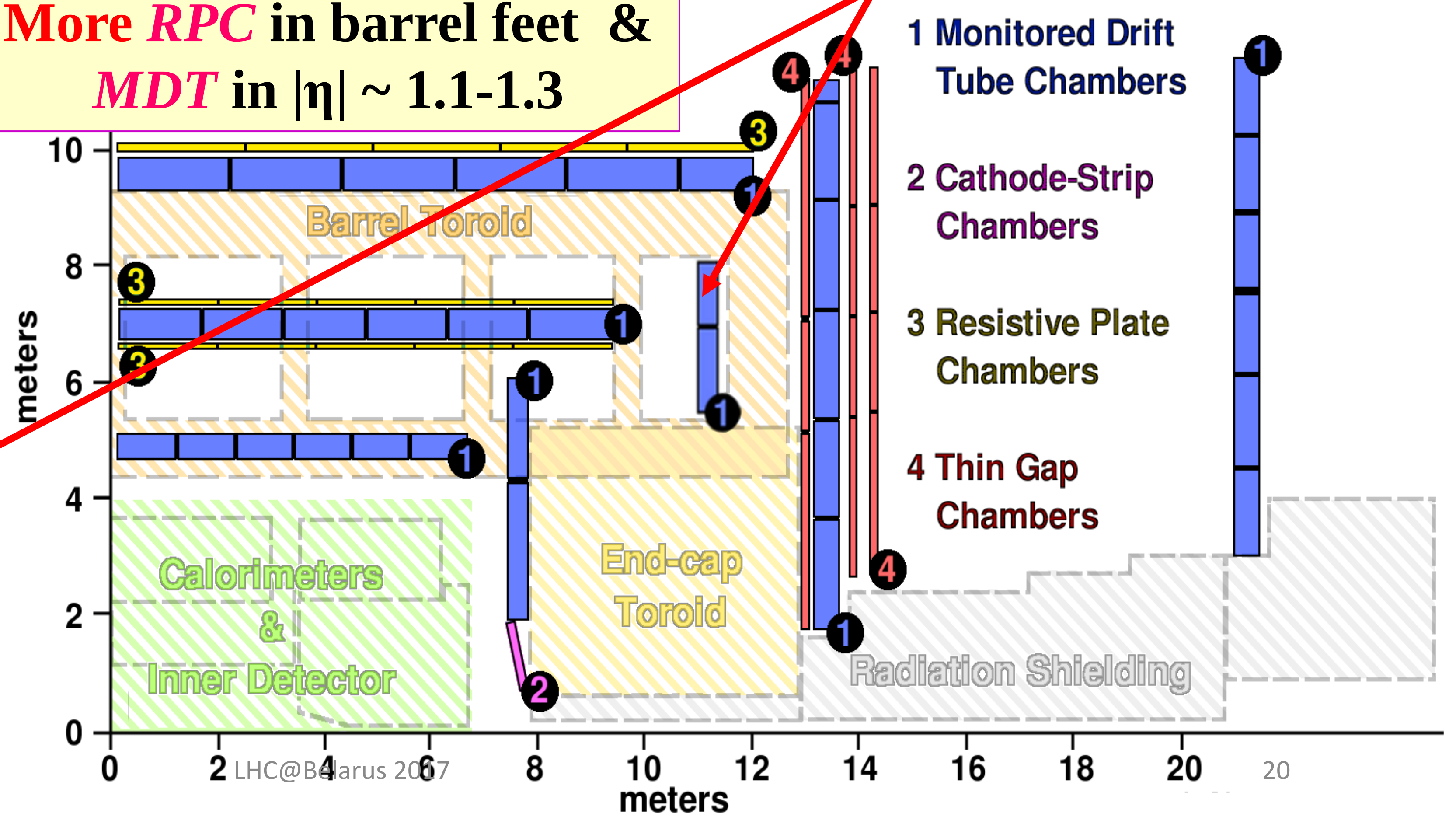
Precise muon chambers: (1) *Monitor Drift Tubes [MDT]:* barrel and end-cap (**in |η| ~1.1-1.3**); **(2)** For **|η| > 2.0** also *Cathode Strip Chambers [CSC]*

Two triggering systems: (3) *Resistive Plate Chambers [RPC]:* **|η|<1.05 (in barrel feet)**; (4) *Thin Gap Chambers [TGC]:* **1.0 < |η| < 2.4**

Improved acceptance from additional chambers in feet and elevator regions

More *RPC* in barrel feet & *MDT* in |η| ~ 1.1-1.3





ATLAS Phase I Upgrades (2019-2020)

Added in Phase 1

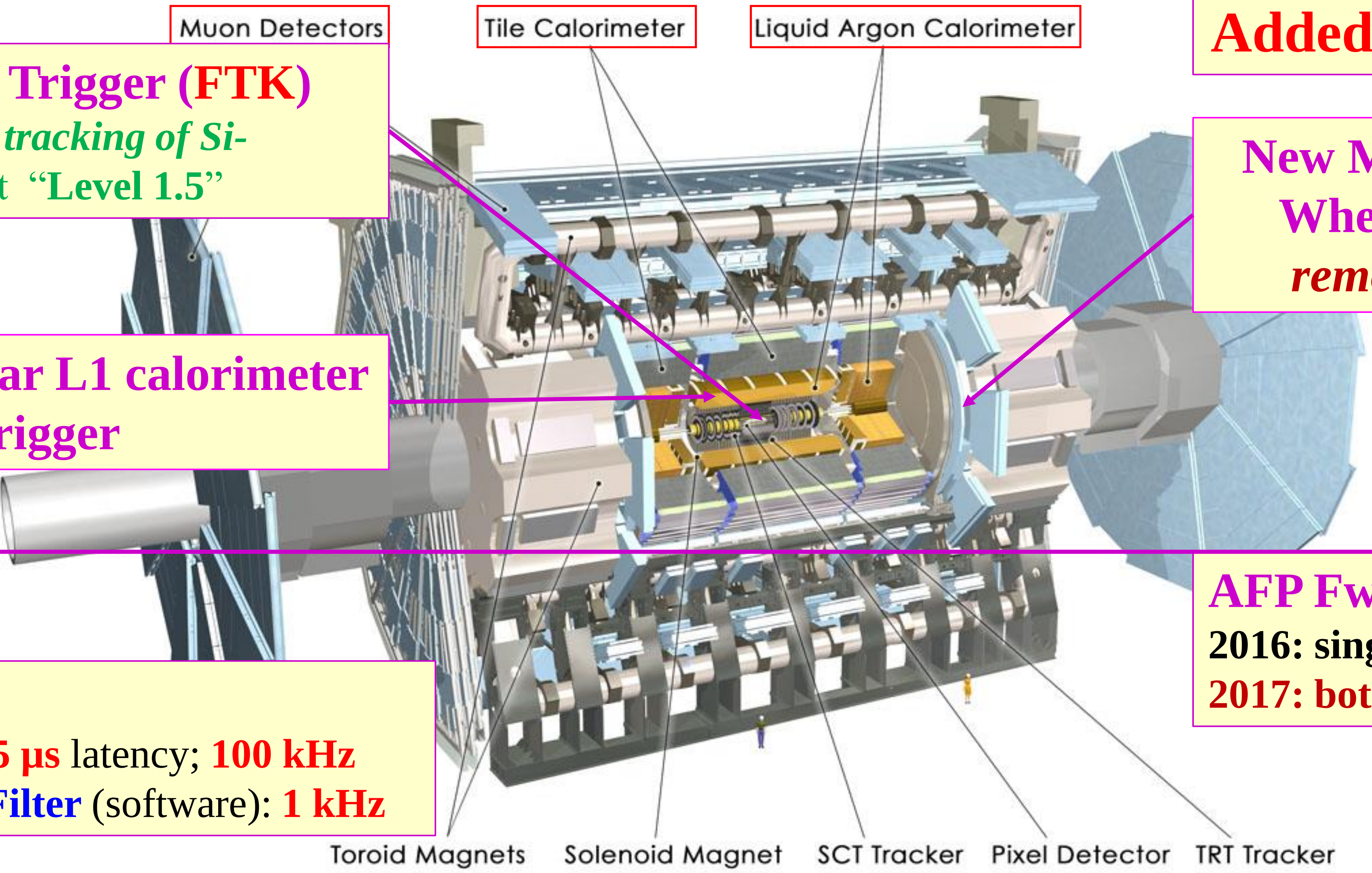
Fast TracKer Trigger (FTK)

Hardware based tracking of Si-tracking layers **at "Level 1.5"**

New Muon Small Wheel (NSW)

remove fakes

High Granular L1 calorimeter trigger



AFP Fwd detector

2016: single arm

2017: both arms

Trigger/DAQ

- **L1 (HW): 2.5 μs** latency; **100 kHz**
- **HLT/Event Filter** (software): **1 kHz**

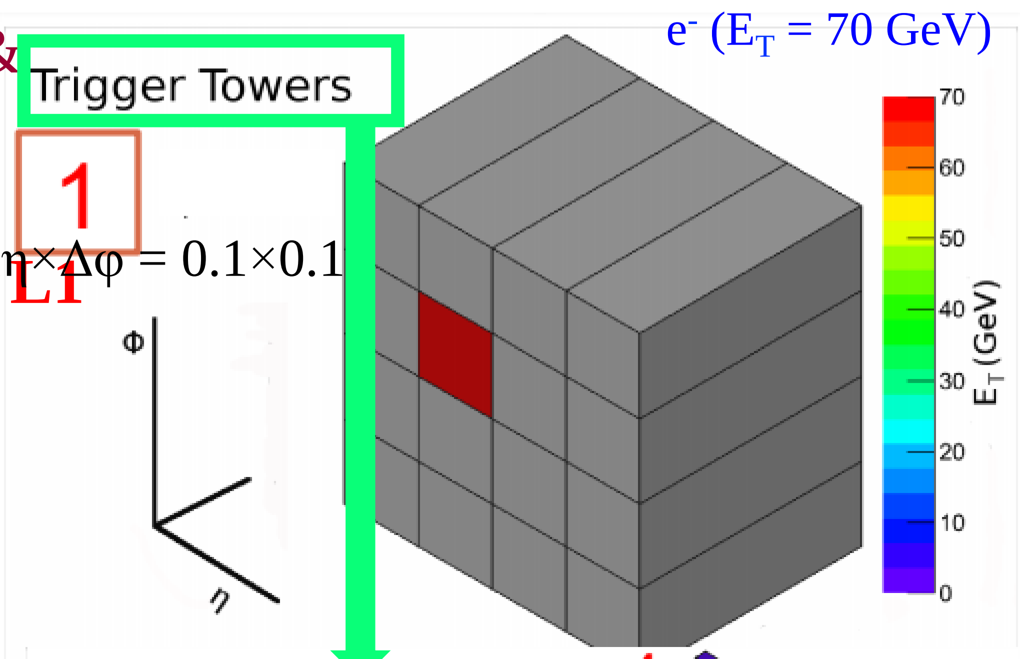
Main target:

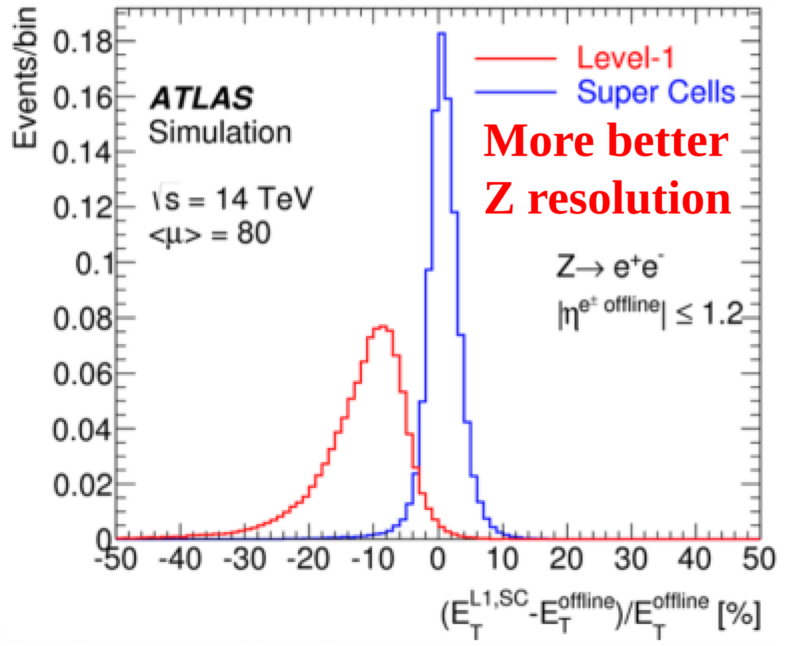
Better trigger capabilities **(efficiency, fake rejection);** ***Maintain same acceptance/p_T thresholds at higher pileup***

CALORIMETER L1 GRANULAR TRIGGER

ATLAS-TDR-022-2013

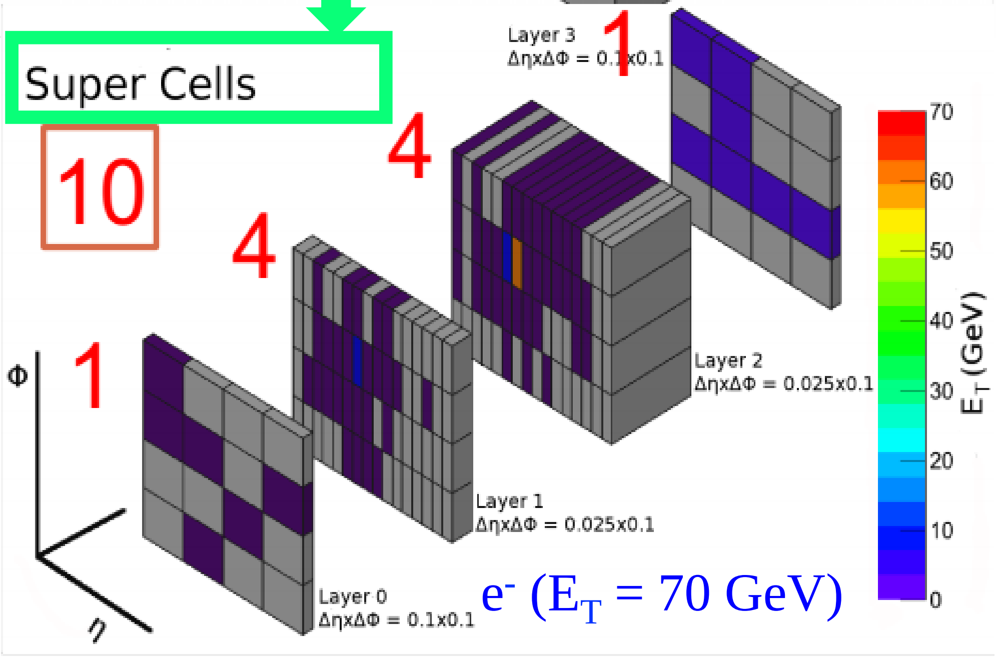
- ✓ **Expect ~270 kHz @ 3x10^{34}cm^{-2}s^{-1}** with current layout & Run1 thresholds (->total **L1** rate of **100 kHz**)
- ✓ **10x more granularity in η/depth (towers->super-cells)**
- ✓ **New readout electronics** feed **40 MHz** digitized data to **L1**
- ✓ Apply offline reconstruction algorithms at **L1**
- ➢ **Better jet rejection, lepton isolation/reconstruction**
- ➢ **Improved** energy resolution
- ➢ **Keep low threshold** for lepton trigger





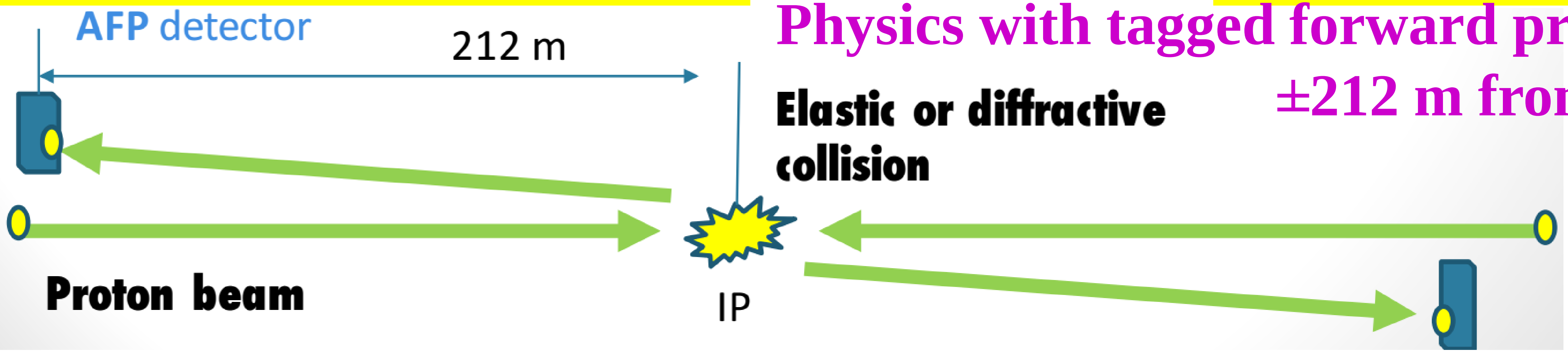
Status/Plans:

- Summer 2014: Installed FE elect. Demonstrator
- 2015: Successful data taking
- On-going: FE and BE prototype and production
- 2019: Installation



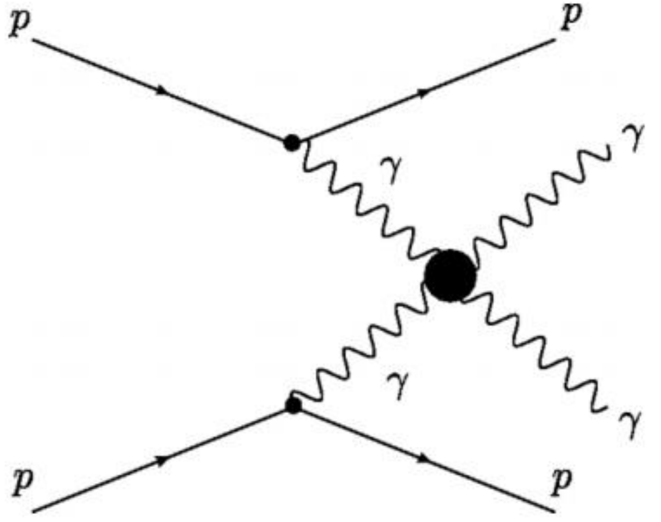
ATLAS FORWARD PHYSICS DETECTOR (AFP)

Physics with tagged forward protons at ±212 m from the IP



- ❑**Primary goal** is to study high rate diffractive physics in special low-μ runs
- ❑Eventually, the detector could work also on high <μ> as an useful tool for searching new physics, but this option is still under investigation

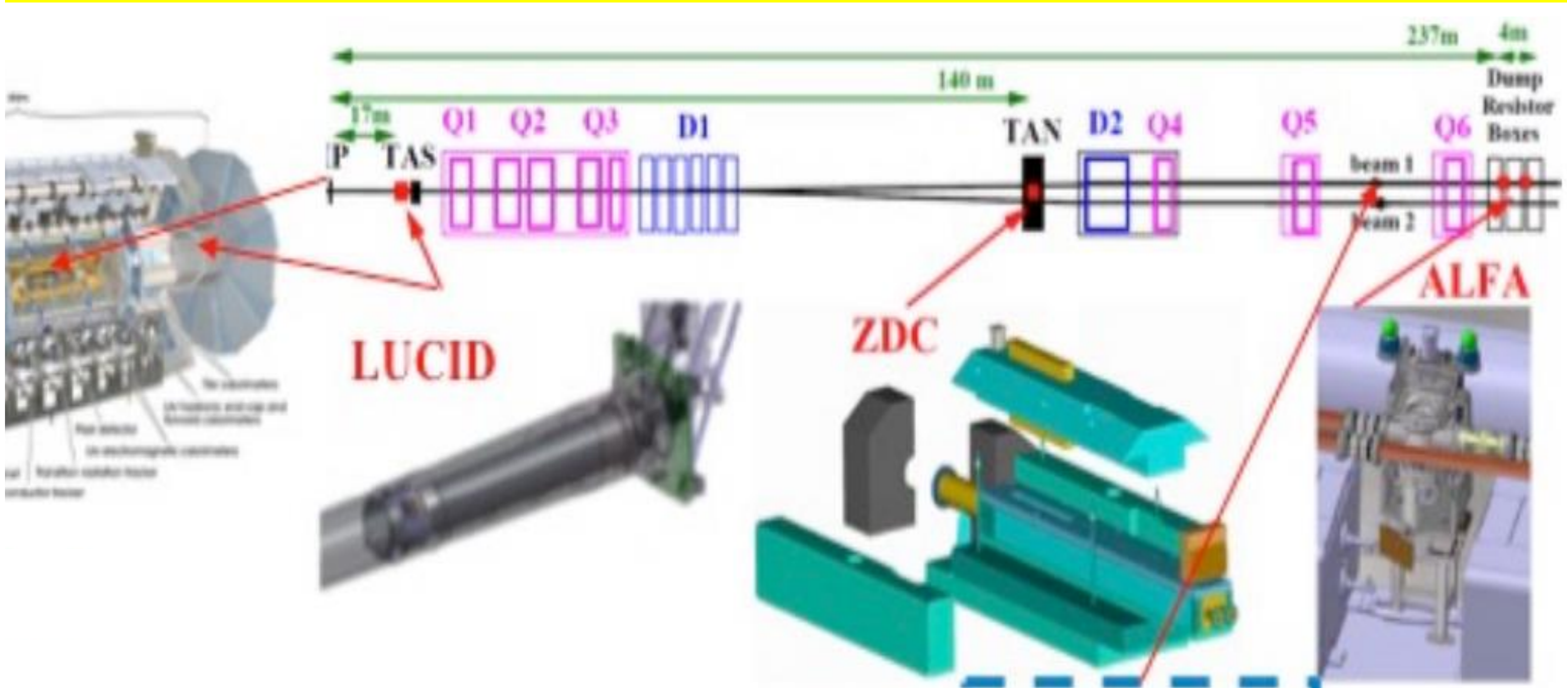
Central exclusive production (CEP)



4-photon couplings are **absent** in the SM

ATLAS FORWARD DETECTORS

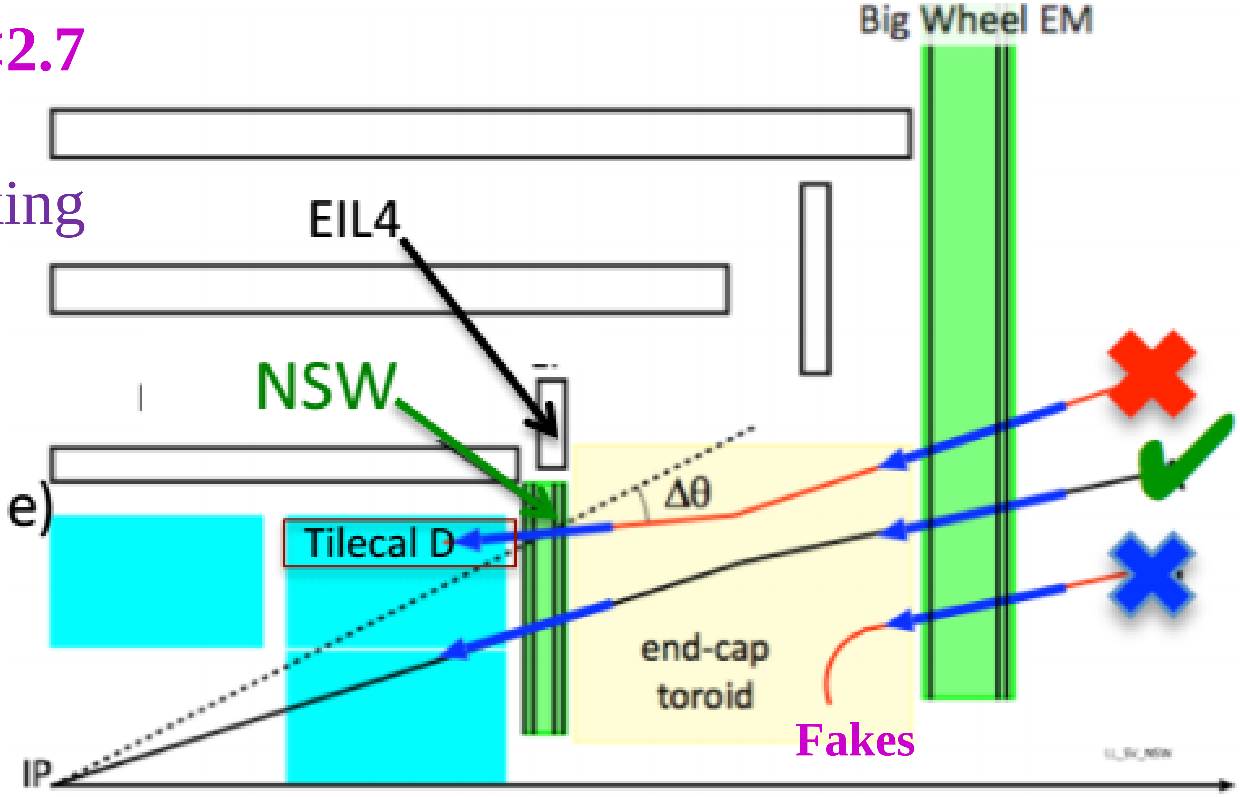
- **ATLAS Forward Physics (AFP)**
  - Infrastructures **installed**
    - Cabling
    - Exterior vacuum chamber between Q5 and Q6 modified
  - **Two stations (one arm) in C6R1 installed** and equipped with tracking system

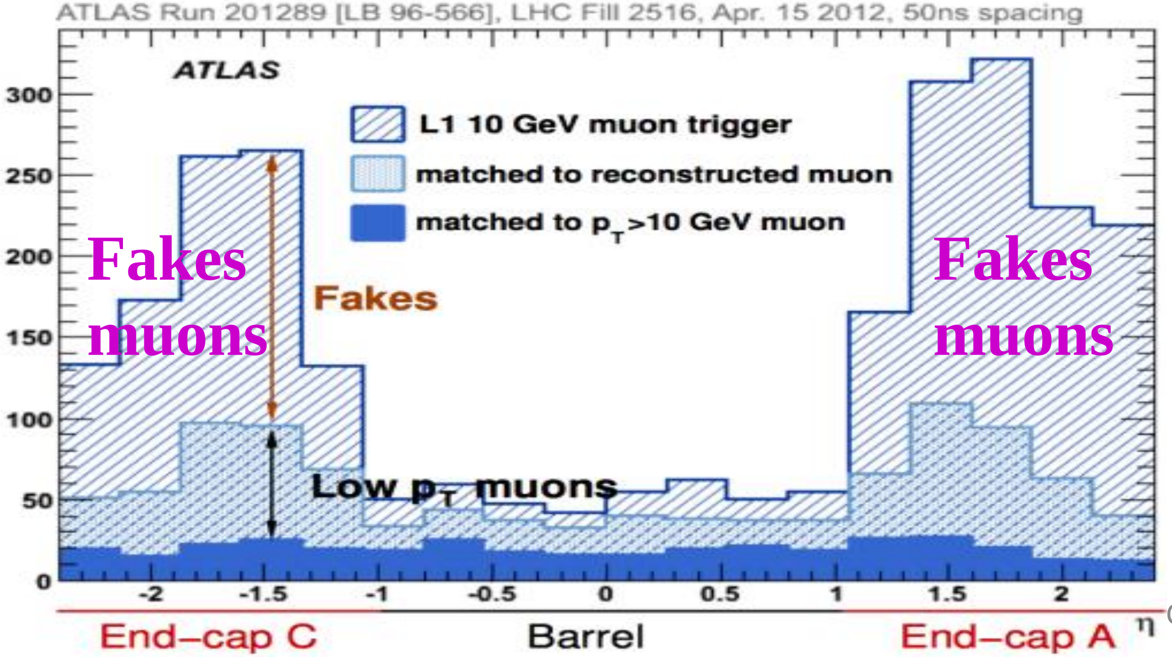


- **ALFA**
  - Maintenance done on fans and vacuum pumps, noisy LVDT changed, DCS and TDAQ upgraded
- **LUCID**
  - 4+4 PMTs substituted with ^{207}**Bi** calibrated ones, TDAQ upgraded
- **ZDC**
  - Detectors placed in the Bdg 180 Buffer Zone for testing and refurbishment

NEW MUON SMALL WHEELS (NSW) ATLAS-TDR-020-2013

- At present **μ L1** dominated by **fakes in 1.3<|η|<2.7**
- **NSW** w/ high-rate capability for **L1**:
  - **sTGC** + **MicroMegas** for trigger/precise tracking (<100μm/plane)
- **L1 μ (p_T>20GeV) ~ 60 kHz**
  - **22 kHz** w/ NSW
  - **17 kHz** w/ NSW + EIL4
  - **13 kHZ** w/ NSW **+ EIL4** + **TileCal D**





Status/Plans:

- Now: Modules 0 construction in various sites
- 2016: Final Design Review and PRR for all sites
- 2017/2018: Production
- 2019: Installation

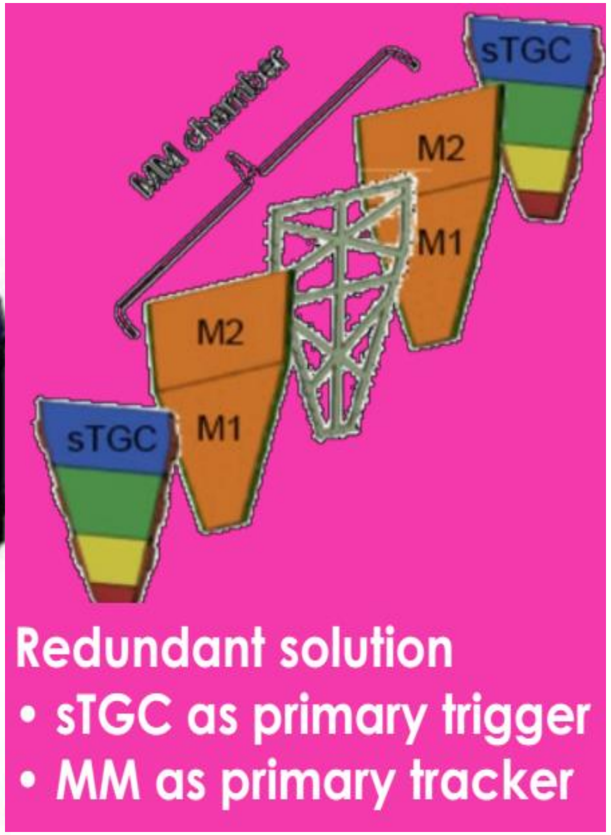
New Small Wheels technology

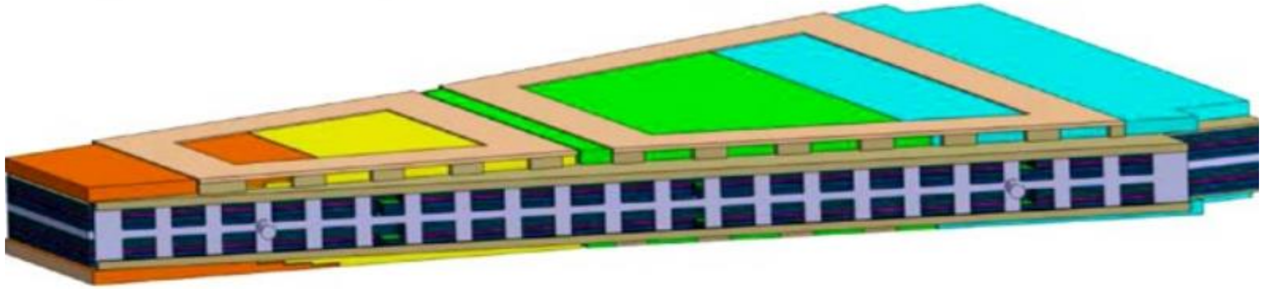
MicroMegas (area of 1200 m^2 distributed on 8 layers)

- Space resolution < 100 μm
- High granularity -> track separation
- High rate capability due to small gas gain

Thin Gap Chambers (sTGC) (area of 1200 m^2 distributed on 8 layers)

- Space resolution < 100 μm
- Bunch ID with **good timing resolution** to suppress fakes
- Track vectors with <1 mrad angular resolution



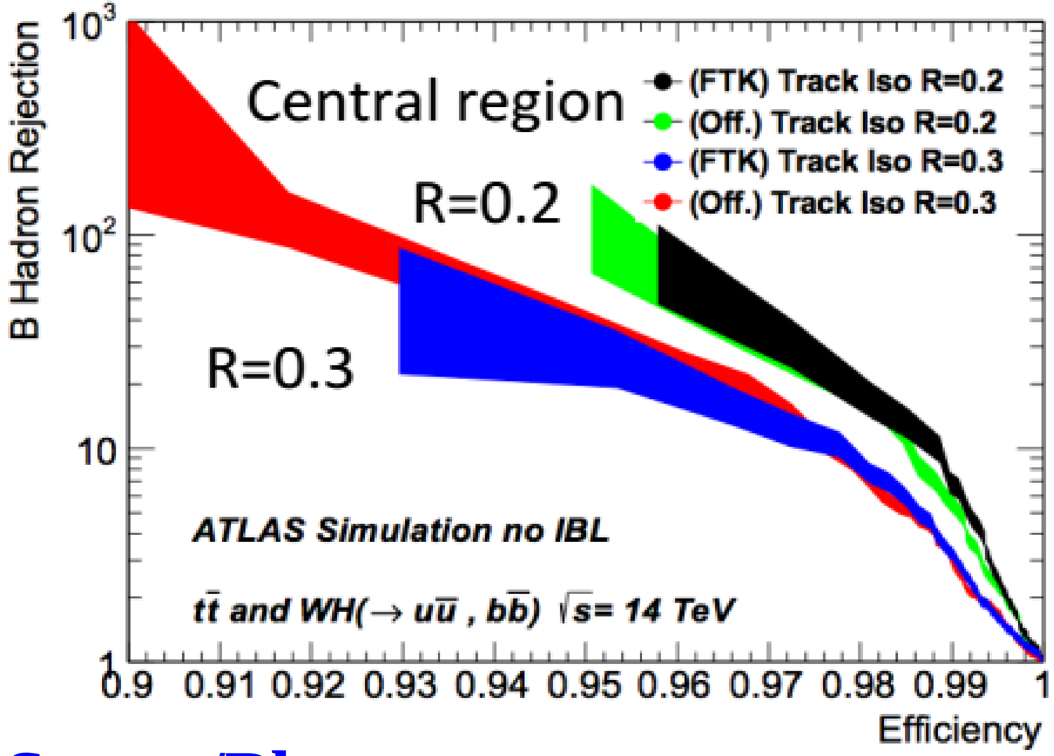


sTGC
MM
sTGC

FAST TRACKER TRIGGER (FTK)

ATLAS-TDR-021-2013

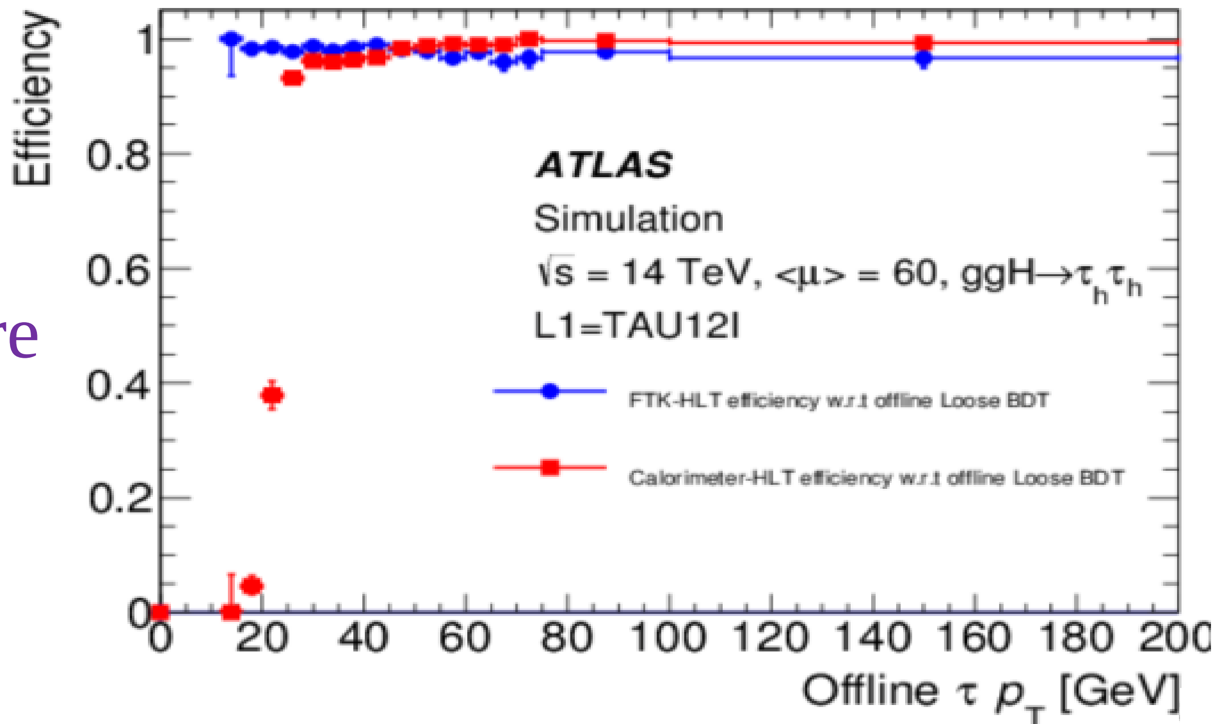
μ rejection from B-decays vs μ efficiency from W



- *Hardware based tracking of Si-tracking layers* at **"Level 1.5"**
- Provides tracking information to **L2** in **~25 μs**
- Two steps: (1) *Pattern recognition*; (2) *Track fitting*

Performance ~ to off-line up to
L= $3 \cdot 10^{34}$ cm^{-2}s^{-1}

τ Trigger efficiency improvement using FTK tracks



Status/Plans:

- Installed hardware/software infrastructure
- July 2016: expect full slice test
- Fall 2016: barrel commissioning
- 2017: full coverage operation

TRIGGER/DAQ PHASE I UPGRADE ATLAS-TDR-023-2013

Trigger/DAQ

L1 (HW): **2.5 μs** latency; **100 kHz**

HLT/Event Filter: **1 kHz**

- Centre-of-mass **8→13 TeV**
  2-2.5x increase in trigger rates
- Peak luminosity **0.8→ 1.7e[34]: ~2x higher** trigger rates

Possible options:

Increase output rate

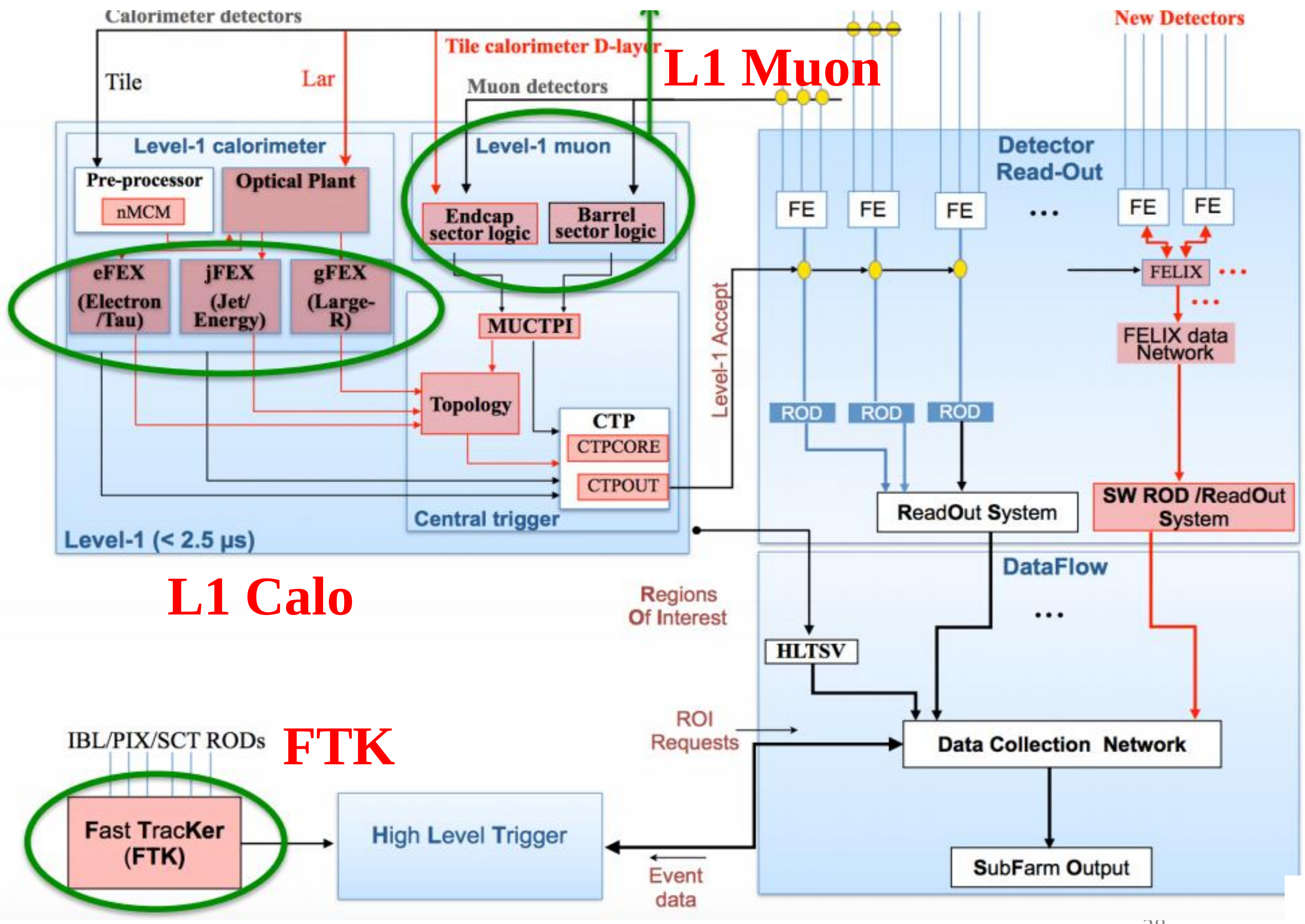
➡ Challenge for offline computing

Increase thresholds

➡ Lose interesting physics

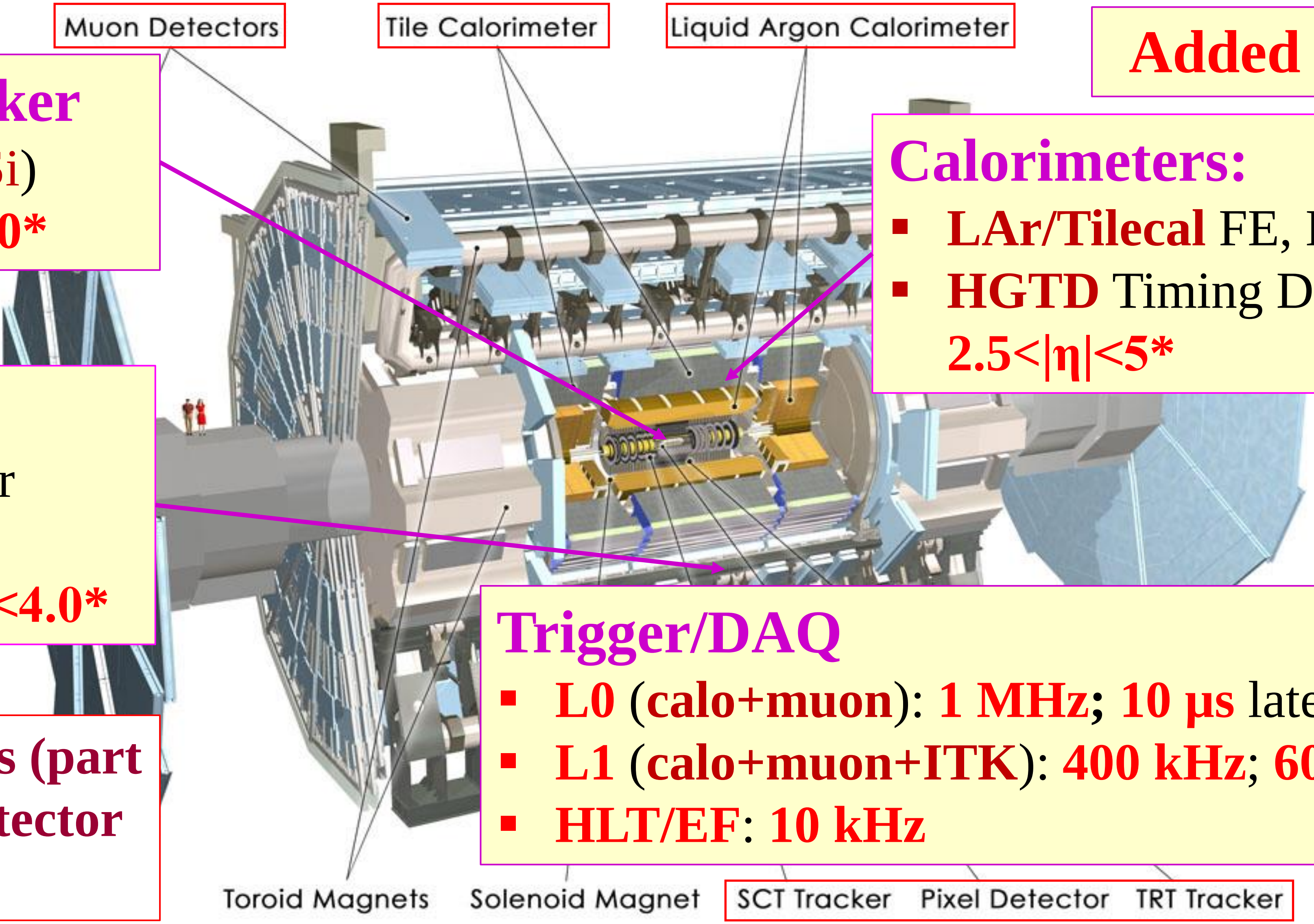
Increase rejection

➡ Better **hardware** and **software**



ATLAS PHASE II UPGRADES FOR HL-LHC (2024-2026)

CERN-LHCC-2012-022; CERN-LHCC-2015-020



Added in Phase 2

ITK- Inner tracker

- Pixels + Strips (Si)
- $|\eta|<2.7 \rightarrow$ **$|\eta|<4.0$***

Calorimeters:

- **LAr/Tilecal** FE, BE electronics
- **HGTD** Timing Detector **$2.5<|\eta|<5$***

Muons:

- Inner Barrel Layer
- Electronics
- Muon tag **$2.7<|\eta|<4.0$***

Trigger/DAQ

- **L0 (calo+muon)**: **1 MHz**; **10 μs** latency
- **L1 (calo+muon+ITK)**: **400 kHz**; **60 μs** latency
- **HLT/EF**: **10 kHz**

*** Large η scenarios (part of the reference detector layout)**

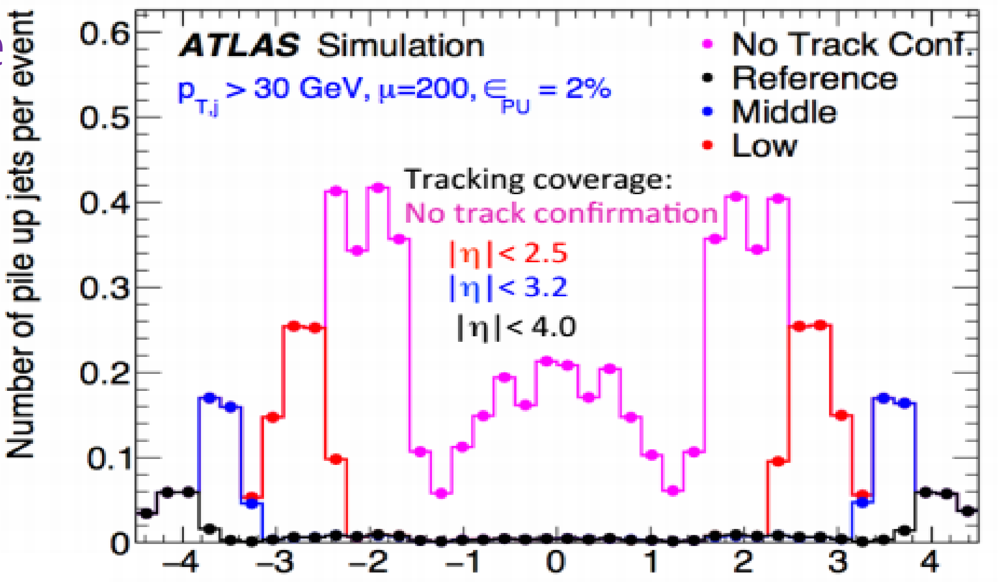
Refs: ATLAS Phase II LoI [CERN-LHCC-2012-022]; IDRs and preparation of design choices →Tech. Design Reports-TDRs (end 2016-end 2017); Impact of different cost scenarios on physics/perf. [scoping doc. CERN-LHCC-2015-020]

INNER TRACKER DETECTOR (ITK) FOR HL-LHC

Goal:

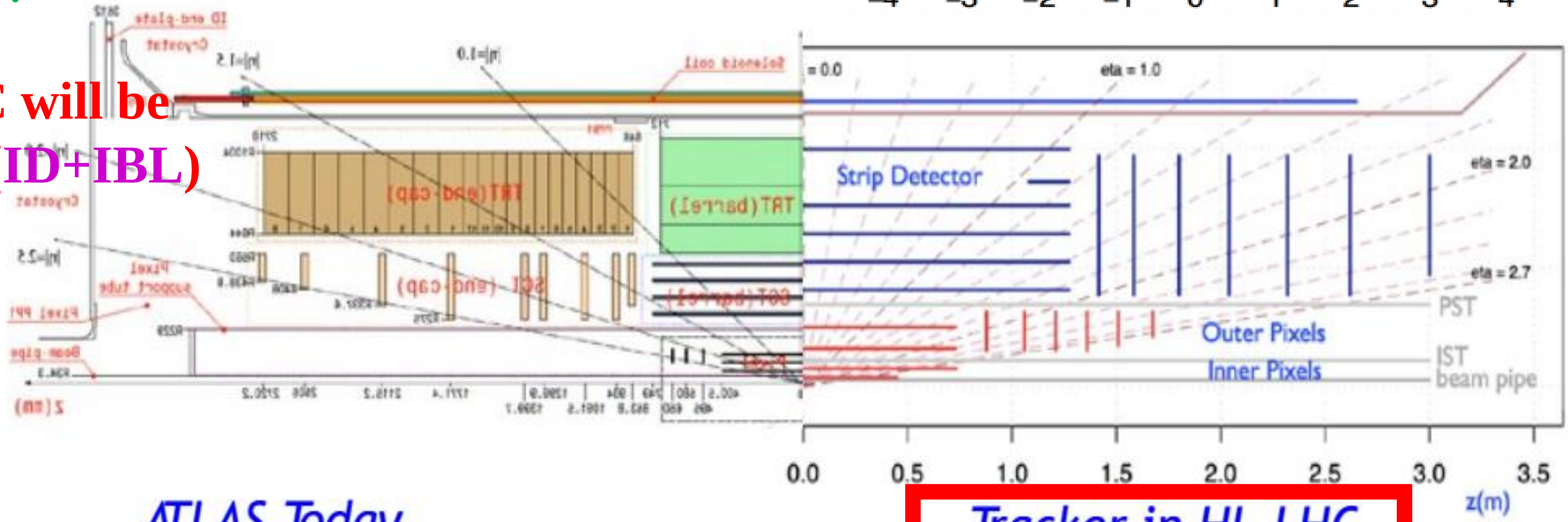
- ❑ **Keep good tracking & vertex perf. + b-tag capabilities**
- ❑ **Pile-up and Radia. levels ($10^{16} n/cm^2$) is a big challenge**
- ❑ **Reference layout** (LoI-VF): ● **4 Pixel Layers** (~9-18 m^2):
  1) Pixel sensors: Planar, 3D, HV/HR CMOS
  2) Hybrid module w/pixel sensors +FE chip + Interconnect
  - ● **2x5 Strip Layers** (~190 m^2): n-in p , HV/HR CMOS
- ❑ **~ 8x more channels** than current ID
- ❑ **~ 2-3x less material** than current ID **($<0.3\ X_0$; $|\eta|<1$)**
- ❑ **Occupancy <1% for <μ>=200**
- ❑ **~14 hits up to |η|=2.5**
- ❑ **ITK perf. in HL-LHC will be same or better than for (ID+IBL)**

Number PU jets vs η (ε PU jets=2%)



Status/Plans:

- **Ongoing:** layout and prototypes optimization
- **TDR:** Q4 2016 (strips) & Q4 2017 (pixels)
- **Construction:** 2018-2023
- **Installation:** **2024-2025**



ATLAS Today

Tracker in HL-LHC

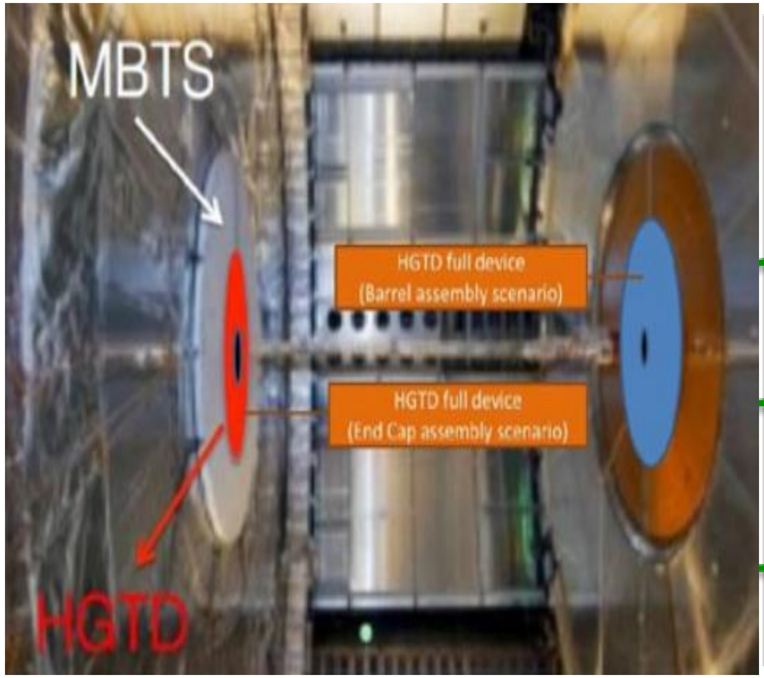
HIGH GRANULAR TIMING DETECTOR (HGTD) FOR 2.5 < |η| < 5

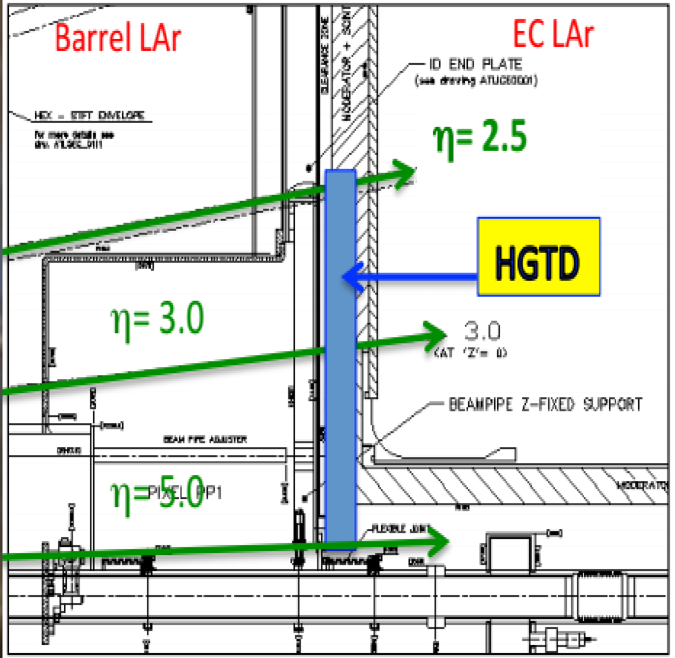
Goal:

- **Pile-up mitigation *in forward***
  - Offline: **Improve e/g and jet/E_T^{miss}**
  - Online: **L0 Trigger time info**
- **Keep lower trigger thresholds**
- **Increase VBF physics acceptance**

Layout:

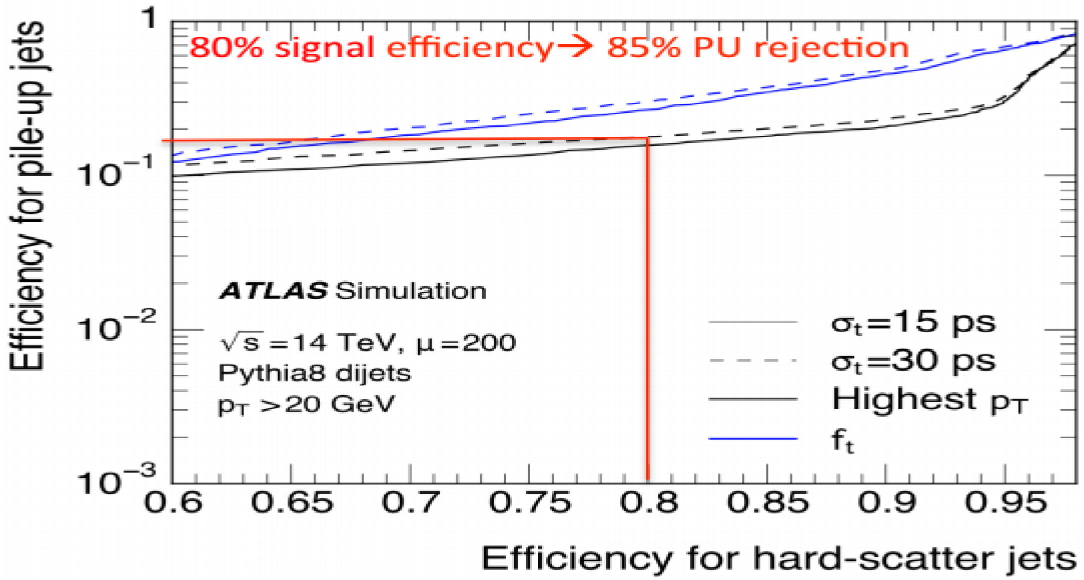
- **4 Si layers** in front of LAr EMEC+FCAL
- **Δt ~30 ps ; < 5x5 mm^2**
- Option: **Pre-shower 3X$_o$ W in 2.5<|η|< 3.2**





Status/Plans:

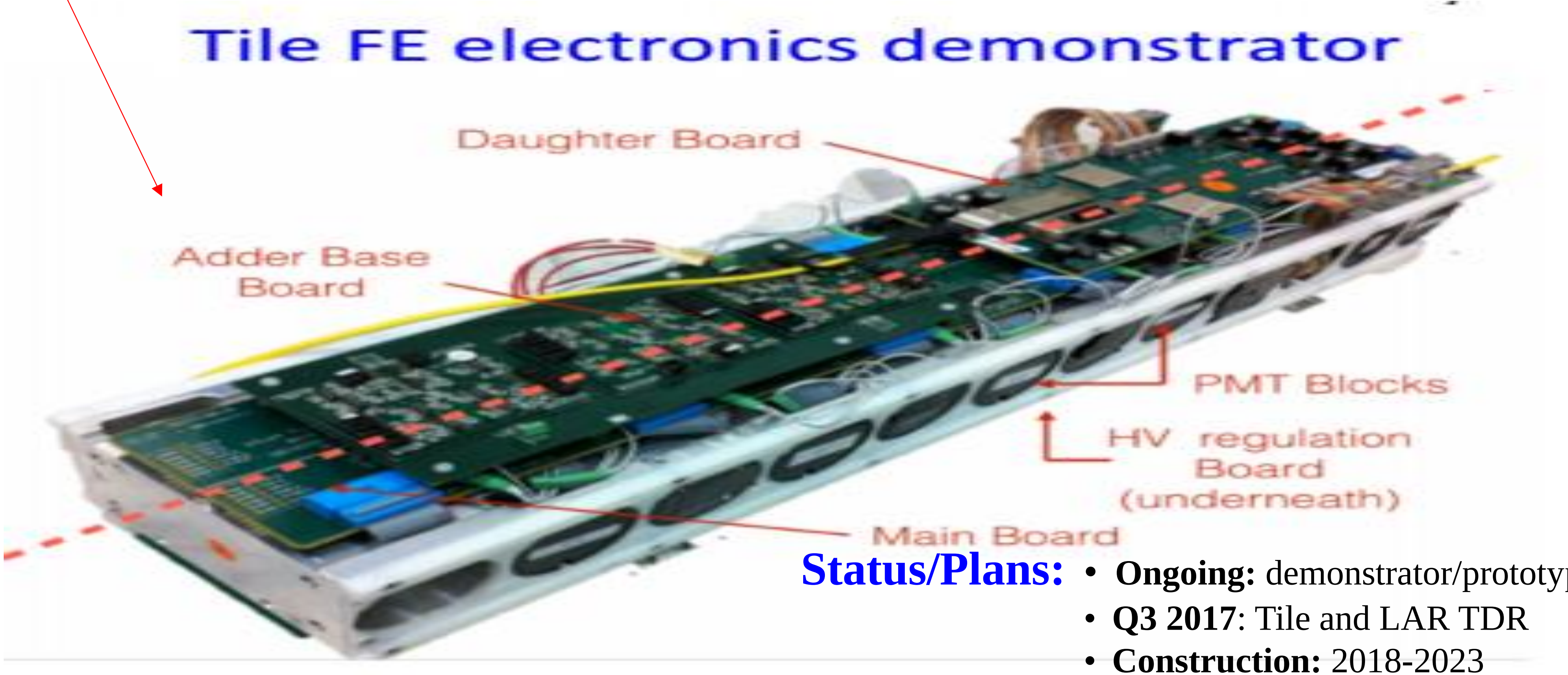
- **Ongoing:**
  - **R&D** in Si sensors (LGAD, pin diode) for speed and radiation hardness needs
  - Study **L0** trigger/perf./physics gains
- **Fall 2016**: Test beams (LGAD, pin diodes)
- **Installation**: **2024-2025**



CALORIMETER (LAR AND TILECAL) AT HL-LHC

➢ **Replace only FE/BE electronics** ***in (Tile/LAr) barrel + End Cup***

- Ageing/Irradiation
- Compatible w/**L0** trigger (rate/latency)
- Send digital data to **L0** trigger (**40 MHz**)



Status/Plans:

- **Ongoing:** demonstrator/prototypes tests (Tile)
- **Q3 2017**: Tile and LAR TDR
- **Construction:** 2018-2023
- **Installation: 2024-2025**

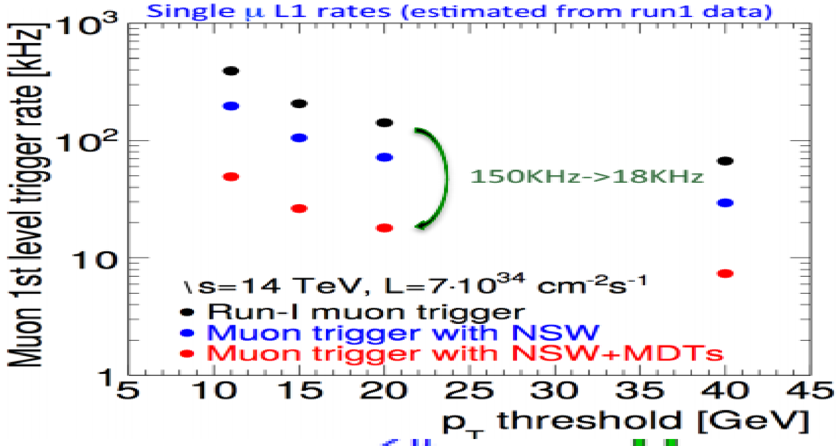
ATLAS MUON SPECTROMETER AT THE HL-LHC

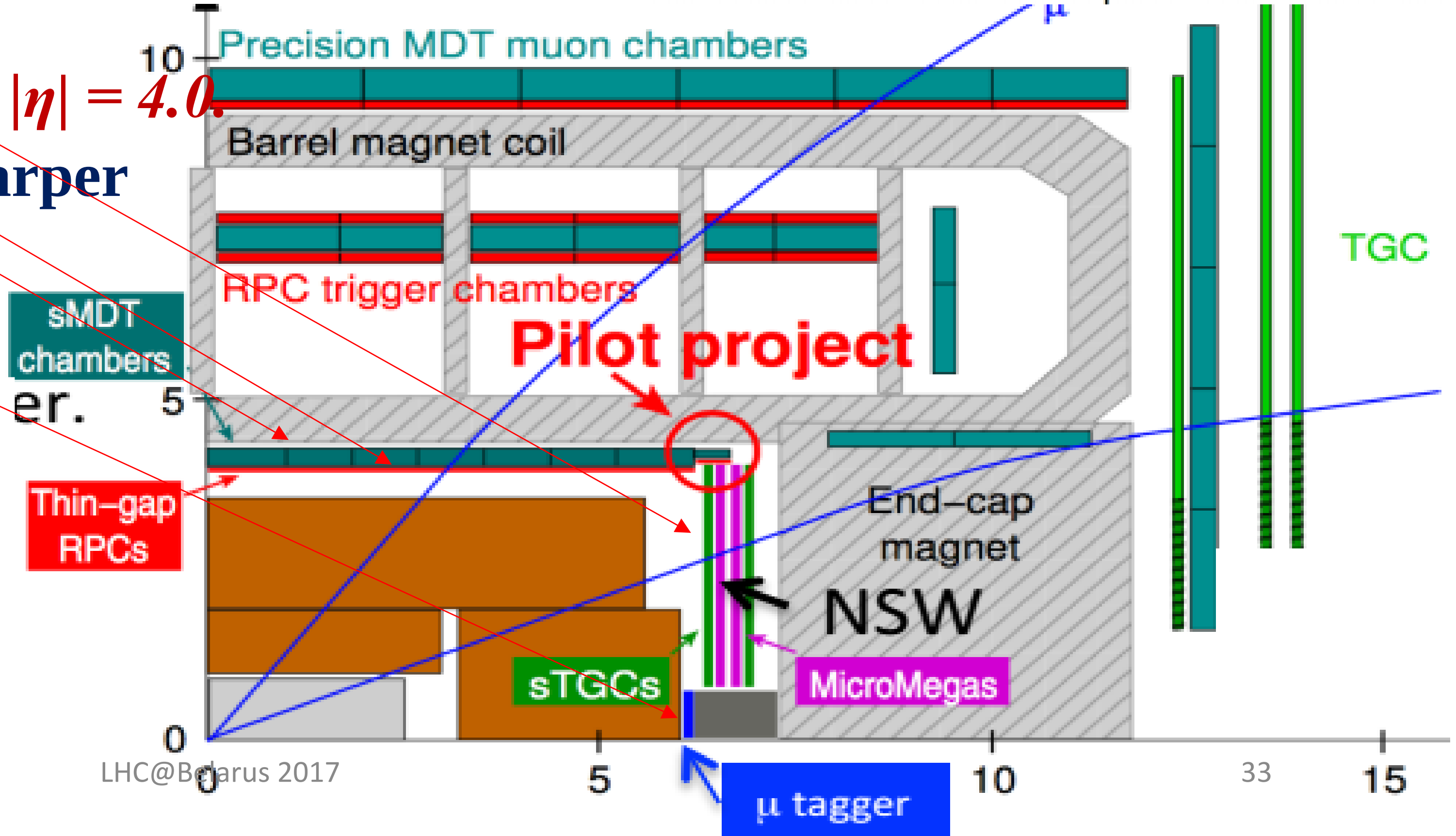
New μ chambers:

- ❑ **NSW** (**sTGCs**+**MM**): ***remove fakes (2019-2020)***
- ❑ **Thin-gap RPCs** in barrel: ***better acceptance and*** σ_{P_T} ***μ trigger***
- ❑ **sMDTs** in barrel: ***to free space for Thin-gap RPCs***
- ❑ **New electronics** in **RPC/TGC** and **MDT** for ***new trigger architecture***

❑*μ tagger*: *to identify muons up to |η| = 4.0*

- ❖ **Better trigger acceptance, ε and sharper thresholds**
- ❖ **L1** ***μ***$_{P_T}$***>20 GeV***: ***150 kHz → 18 kHz*** (w/ **NSW+MDT**)





Status/Plans:

- ❖ **Ongoing**: maturing decisions on electronics and chambers proposals
- ❖ **June 2016**: decide scope of electronics replacement for MDT barrel
- ❖ **Construction**: 2018-2023
- ❖ **Installation**: 2024-2026

TRIGGER/DAQ AT HL-LHC

New design of hardware trigger:

Move part of the High Level Trigger (**HLT**) reconstruction into the early stage of trigger.

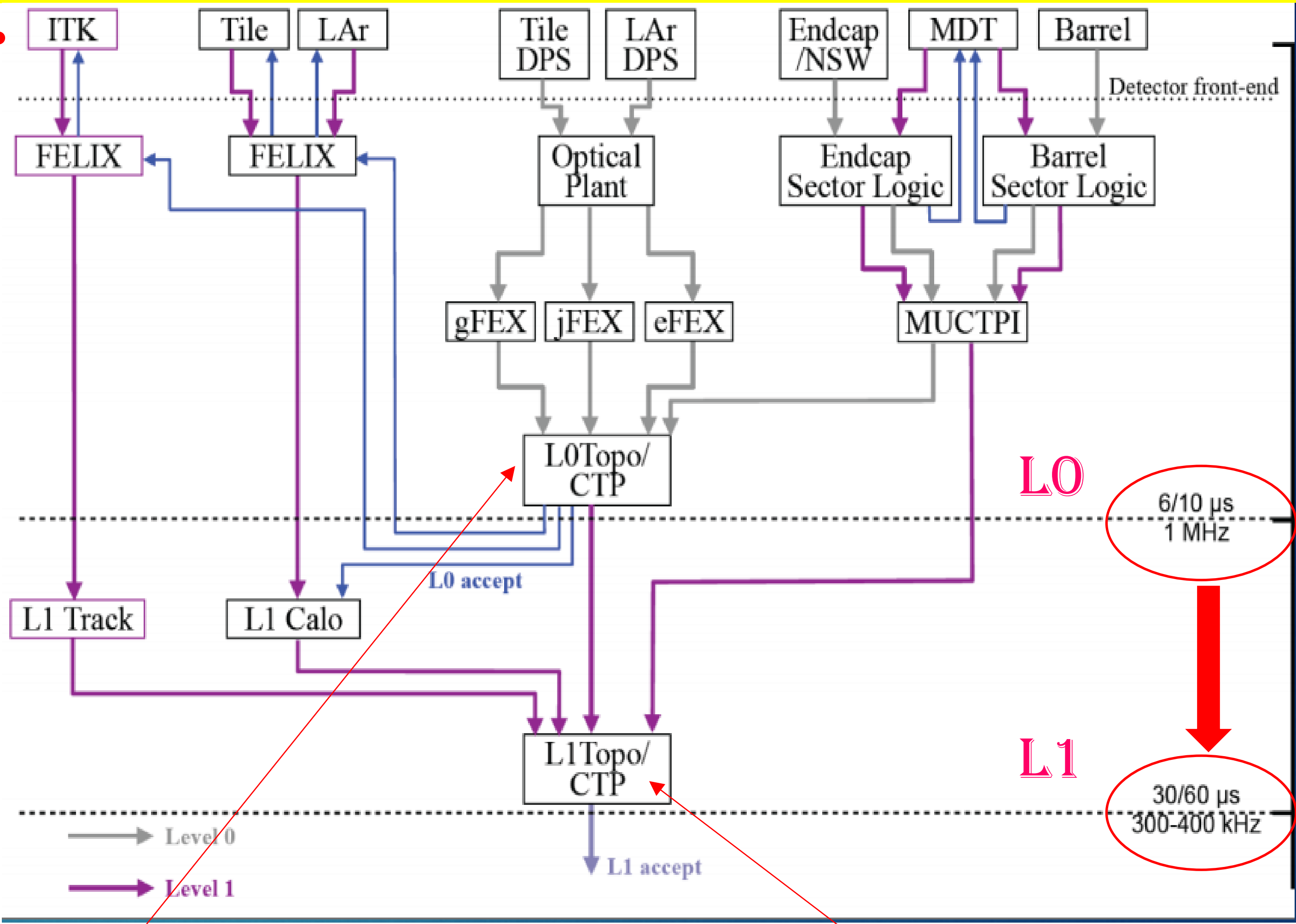
- ***Goal:*** ***keep thresholds on p_T of triggering leptons and L1 trigger rates low***

Triggering sequence

- **L0** trigger (Calo/Muon) *reduces* rate within **~6 μs to 1 MHz** and defines ***Regions of Interests*** (RoIs)
- **L1** track trigger extracts tracking info inside RoIs from readout electronics

Challenge:

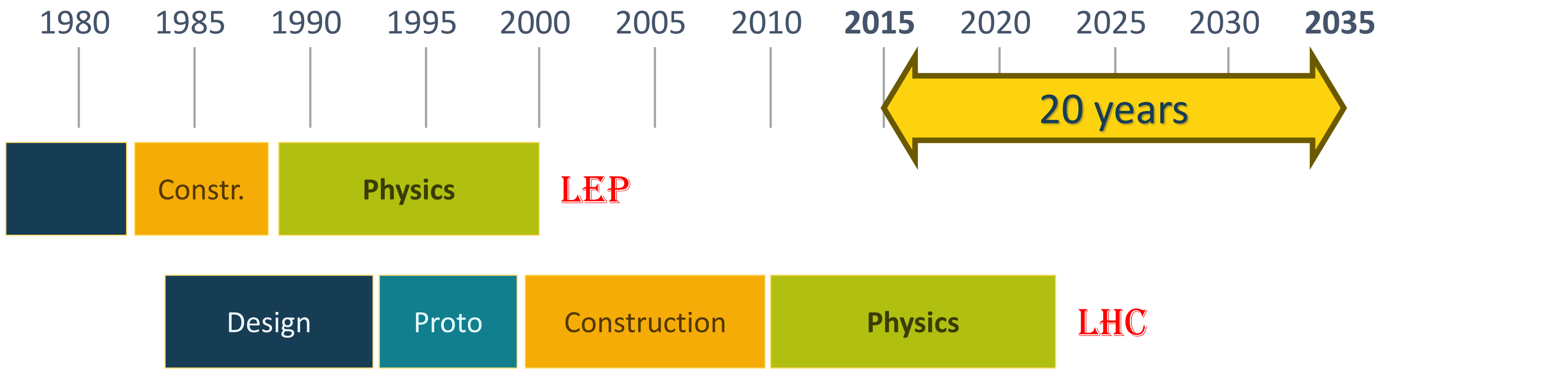
- Finish processing within the latency constraints
- Requires changes to electronics feeding trigger system



LEVEL-0 (L0) Calo+Muon
Latency~**6 μs**, rate~**1 MHz**
Define RoIs for **L1**

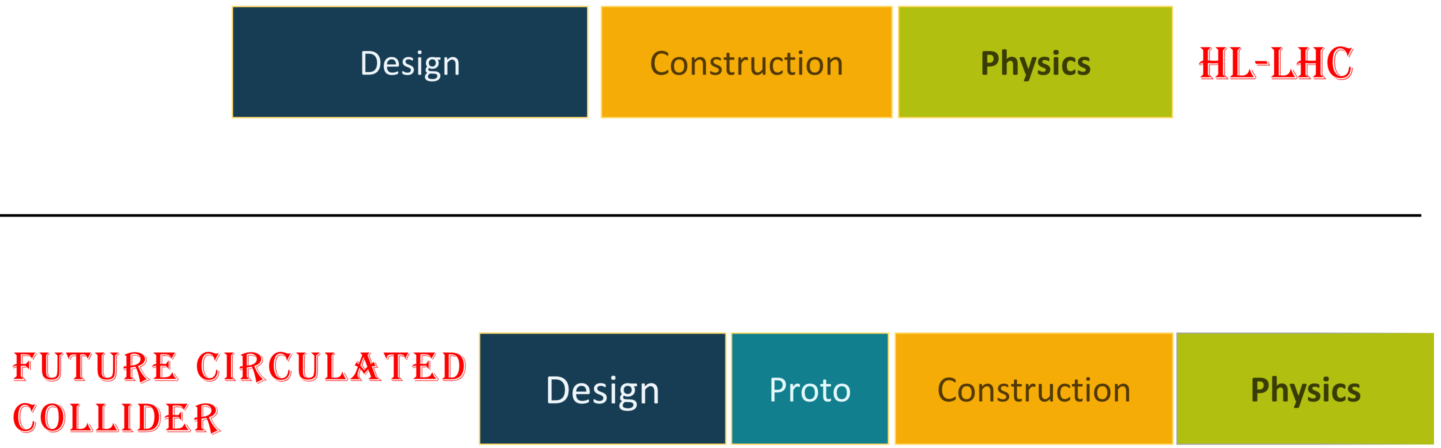
LEVEL-1 (L1) Calo+Muon+ITK
Latency~**30 μs**, rate~**400 kHz**
All data are moved off detector

BONUS: CERN CIRCULAR COLLIDERS + FUTURE CIRCULAR COLLIDER (FCC)



Challenge against time…

- *Detector degradation and ageing* → **inject new technologies**
- *Developer community need to* **transfer knowledge to the next generation**
- *Develop* ***HL-LHC*** *detectors* **not forgetting what will come NEXT**



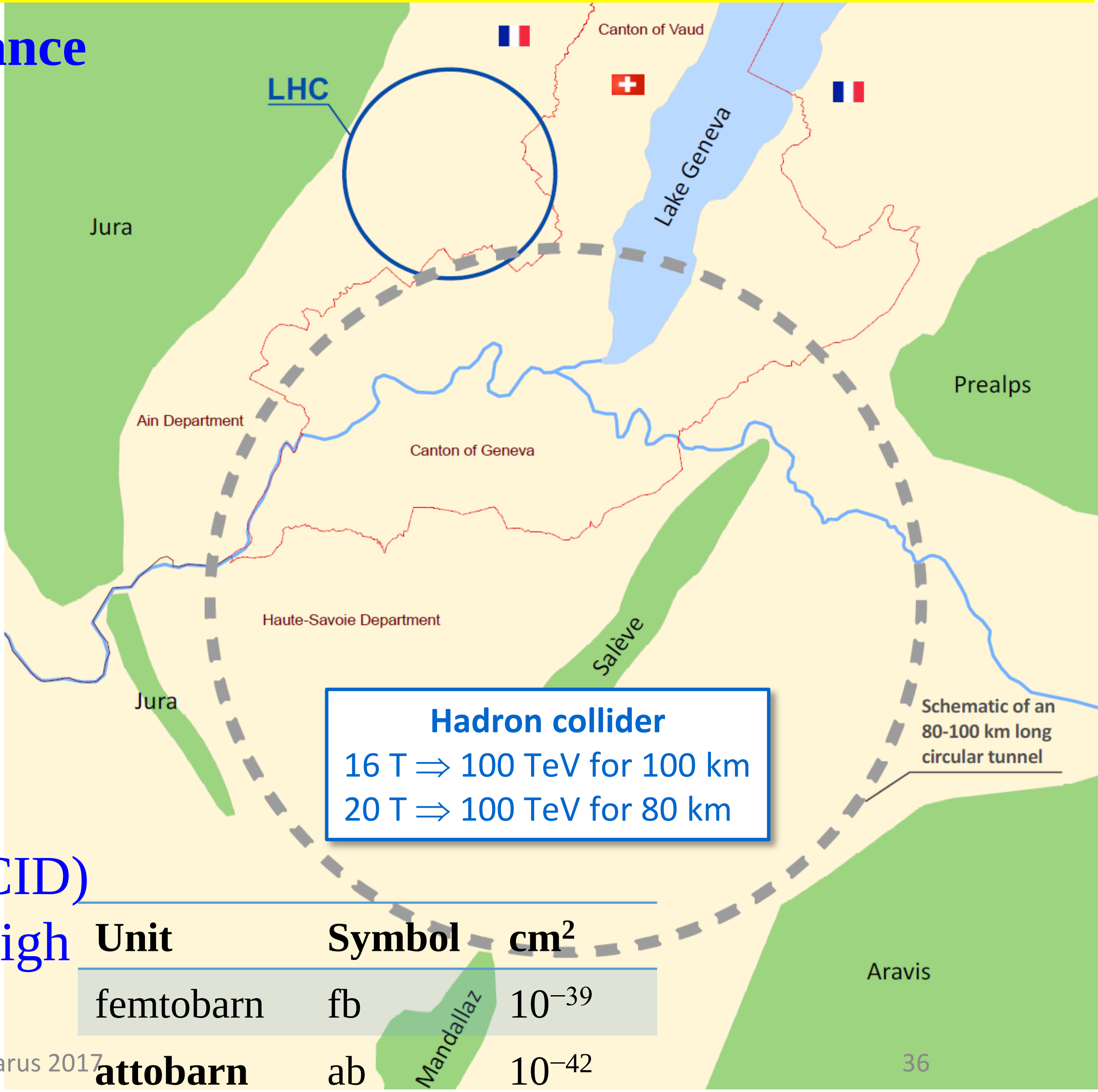
“***Preparation of CERN’s future:*** **design studies for future accelerators: CLIC, FCC (includes HE-LHC)”**

CERN DG Fabiola Gianotti 23/06/2016

BONUS: BASIC INPUT TO FCC INFRASTRUCTURE & OPERATION

Future Circulated Collider (FCC) performance

- Center of mass energy: **100 TeV**
- Peak luminosity ultimate: **≤ $30x10^{34}$**
- Bunch Crossing **<5 ns**
- Integrated luminosity ultimate **~1000 fb^{-1}** (average per year)
- 25 years operation, leading to **~20 ab^{-1}**



Consequence on detectors

- Boosted objects → up to **|η|=6** coverage
- High pileup and fast Bunch-Crossing (BC) → very fast and granular detectors
- Momentum resolution **≈15% at p_T=10 TeV**
- **~1 ns** sharp Bunch-Crossing Identification (BCID)
- Particle flow capability for calorimeters with high granularity **25 $mrad^2$**
- Fine timing against pileup → **< 100 ps**

Unit	Symbol	cm²
femtobarn	fb	10^{-39}
attobarn	ab	10^{-42}

CONCLUSIONS

- THE ATLAS COLLABORATION have developed an ambitious and detailed upgrade program for fulfilling the stringent luminosity conditions of the HL-LHC.
  Maintaining/Improving the current detector performance.
- PHASE 0 is achieved before the start of LHC RUN 2.
- PHASE I projects and almost all in the Full Dress Rehearsal phase. PHASE I upgrade focusing on trigger.
  Maintain low thresholds at up to **2x** design luminosity.
- PHASE II **Letter of Intent** have been approved. PHASE II upgrade to operate ATLAS at up to **7x** design luminosity.

MANY THANKS FOR YOUR ATTENTION!