Participation of INP BSU in CMS. Past, Present and Future

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Outline

- Past
- Letter of Intent
- Nikolai Shumeiko, Michel Della Negra, Peter Jenni
- Contribution to the CMS Experiment
- Today
- Future
- Outlook

The Past

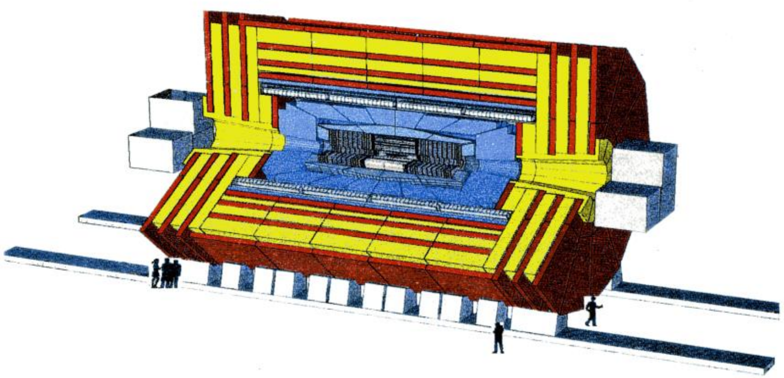
At the very beginning – Letter of Intent

CERN/LHCC 92-3
LHCC/I 1
1 October 1992

LABORATOIRE EUROPÉEN POUR LA PHYSIQUE DES PARTICULES
CERN EUROPEAN LABORATORY FOR PARTICLE PHYSICS

CMS

The Compact Muon Solenoid



Letter of Intent

Members of the CMS Collaboration

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Jyväskylä University, Jyväskylä, FINLAND
J. Hattula, R. Julin, V. Ruuskanen, J. Äystö

I

Nikolai Shumeiko

1942-2016

Father Founders of CMS and ATLAS

Michel Della Negra

Peter Jenni

Historical Meeting in Minsk, June 1996

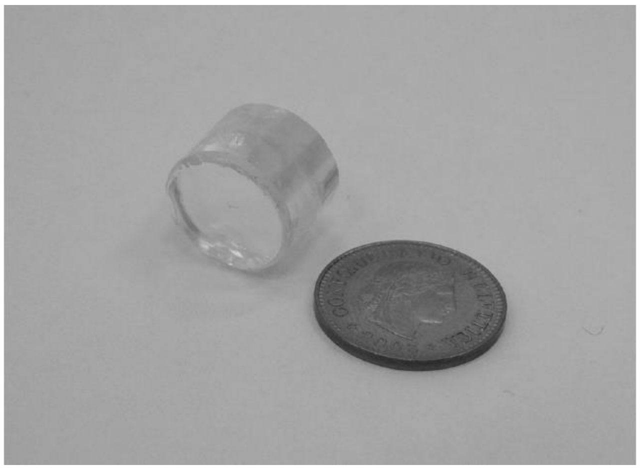
Рабочее совещание Беларусь — ЦЕРН по участию ученых Республики Беларусь в проекте Большого адронного коллайдера. Минск, НЦФЧВЭ БГУ, 1996 г. *Слева направо: 1-й ряд:* П. Йени, М. Делла Негра, А. А. Курилина, Д. Алаби, В. Г. Барышевский, О. Барбалат, В. И. Прокошин. *2-й ряд:* Ю. А.Кульчицкий, Д. Блэкшмидт, И. А. Голутвин, Н. М. Шумейко, Н. Кульберг, А. С. Курилин, О. В. Мисевич, Н. С. Чехлова. *3-й ряд:* С. В. Сушков, А. К. Панфиленко, Ф. Е. Зязюля, П. В. Кучинский, М. В. Коржик. *4-й ряд:* А. Г. Володько, А. Е. Толкачев, Р. В. Стефанович, В. И. Кувшинов, Ю. П. Юреня, В. В. Гилевский, А. В. Солин, А. Ф. Федоров. *5-й ряд:* А. В. Литомин, В. Ю. Каржавин, А. В. Солин.

Contribution to Ecal

LEAD TUNGSTATE CALORIMERY EPOQUE IN HEP INSTRUMENTATION

INVENTION OF PbWO4 SCINTILLATION MATERIAL FOR CALORIMERY

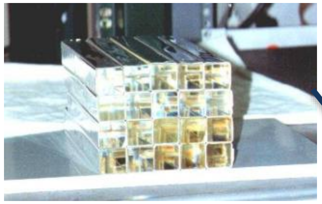
Pioneering article: Barishevsky V.G., Fyodorov A.A., Korzhik M.V., Ka t c h a n o v V.A ., Moroz V.I. et al. // Nuclear Instruments and Methods in Physics Research. A322. 1992. P. 231.



The first PWO crystal grown by ISC (Kharkov) according to INP (Minsk) request

Participants of the First PWO Workshop, Charmonix, Sept.1992, From left to right: M.Korjik (INP), L.Nagornaya (ISC), M.Issi (KEK), J.P.Peigneux (LAPP), M.Kobayashi (KEK)

Jointing of RD18 (Crystal Clear Collaboration) to PWO R&D performed by IHEP (Protvino) and INP (Minsk)



R&D start

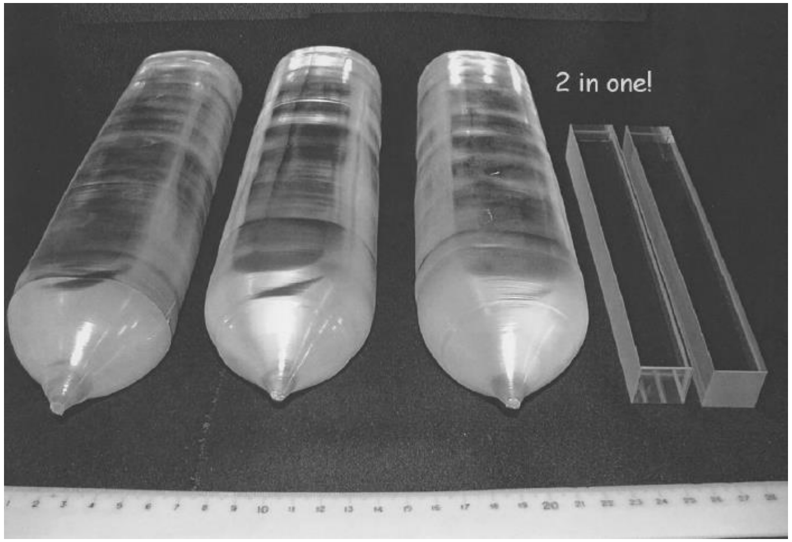
R&D Finish

1994- First joint test at H4 of the 5x5 matrix of 22X0 PWO crystals
1995- P.Lecoq, I.Dafinei, E.Auffray, M.Schneegans, M.V.Korzhik, O.V.Missevitch, VB Pavlenko, AA Fedorov, AN Annenkov, VL Kostylev, VD Ligun Lead Tungstate (PbWO4) scintillators for LHC EM calorimetry, (1995) Nucl Instr Meth Phys Res 365:291-298
2002- Annenkov A, Korzhik M, Lecoq P (2002) Lead tungstate scintillation material. Nucl Instr Meth Phys Res A490:30–50

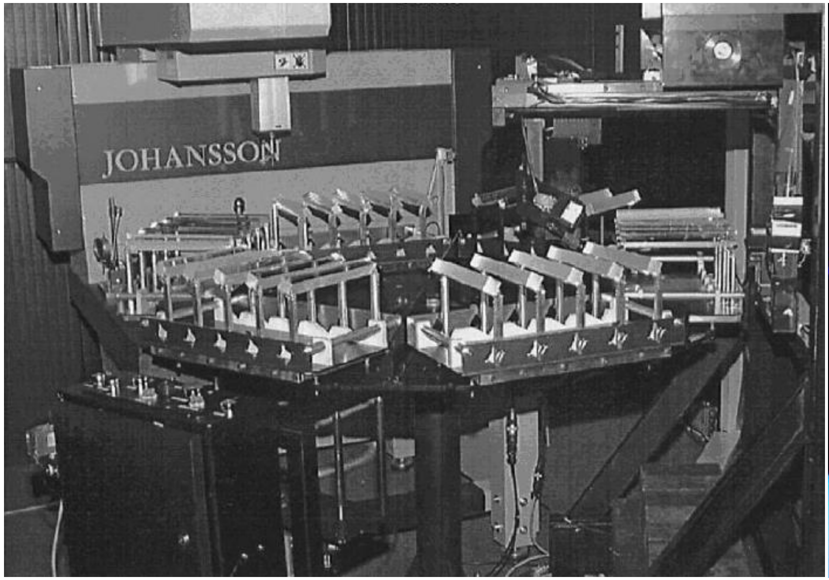
The CMS ALICE experiments at LHC made these Electromagnetic calorimeters on a base of $PbWO_4$ because of its high density, fast luminescence and reasonable light yield and radiation resistance. CMS ECAL , the world largest crystalline calorimeter, have a total volume of 11m^3 and a weight of 90 tons.

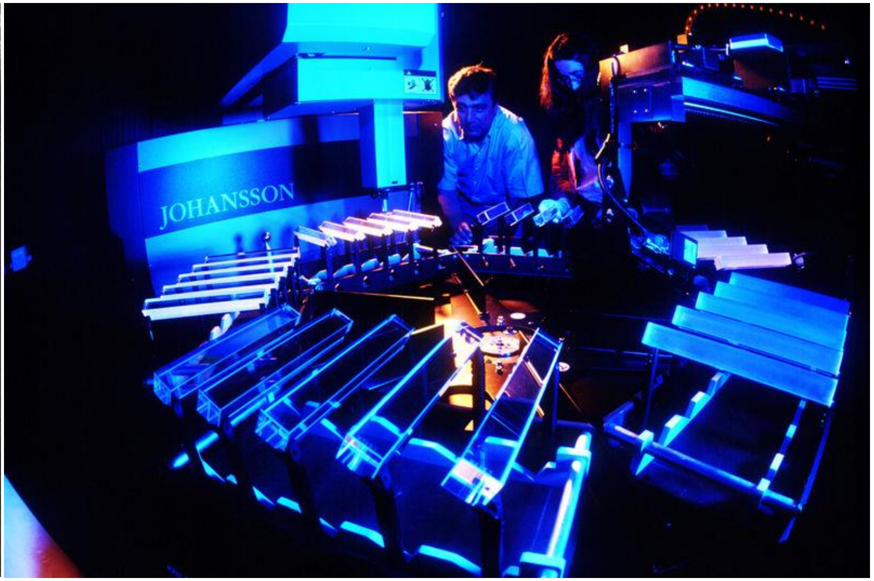
INP BSU experts were a driving force to improve scintillation properties of PbWO4 and made available crystal mass production.

Some PWO crystals produced at BTCP within the largest ISTC (Moscow, Russia) 1718P Project



Mass production of PWO crystals for CMS ECAL (2000-2008)





ACCOS at BTCP ACCOS at CERN

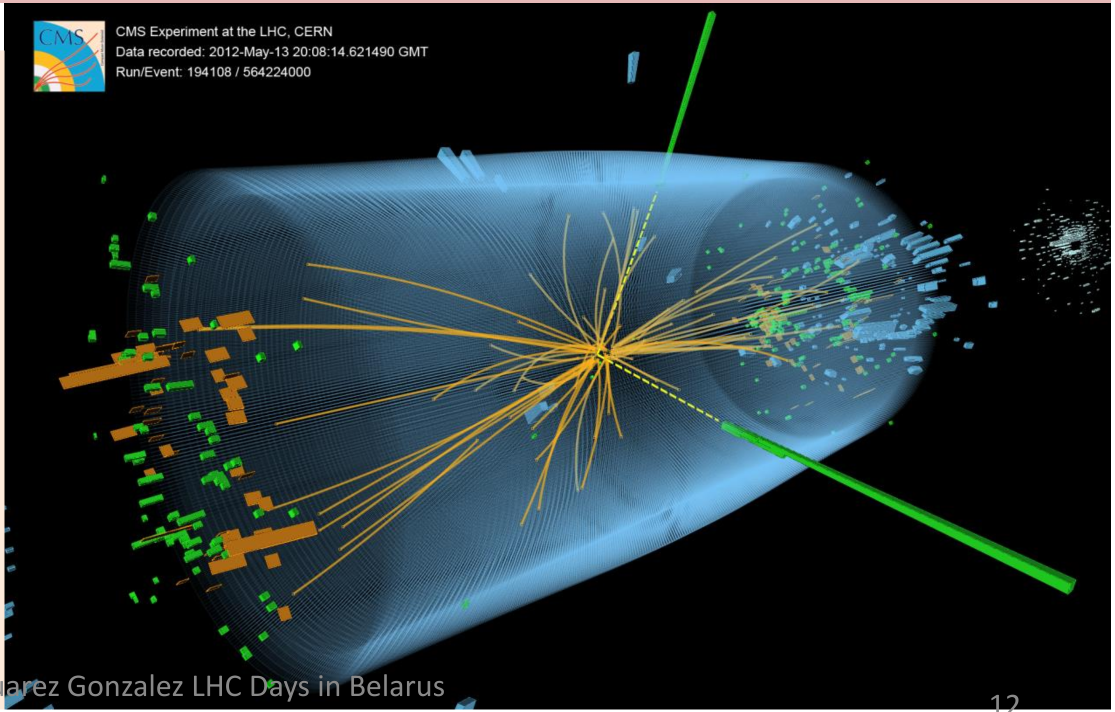
INP designed and built Automatic Crystal Control Systems with LAPP , CERN and ETH for mass certification of CMS scintillation elements for Barrel and End Caps.

CERN ACCOS is still in use to certify PWO elements for PANDA and several other experiments!

Role of PWO Electromagnetic Calorimeter (ECAL) in the Discovery of the Higgs Boson by the CMS Collaboration at LHC

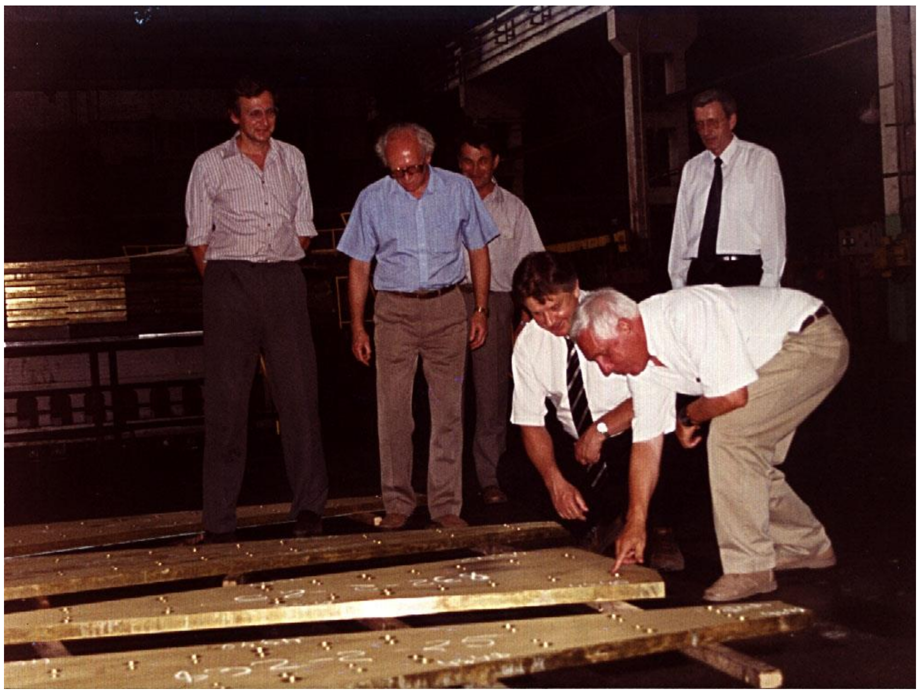
The γγ, ZZ and WW channels are equally sensitive in the search for a Higgs boson around 125 GeV and they all are more sensitive than the bb and ττ channels.
The γγ channel is especially important as it allows the mass of the new particle to be measured with precision. In the γγ channel, the mass is determined from the energies and directions of two high-energy photons measured by the CMS crystal electromagnetic calorimeter.

An event recorded with the CMS detector in 2012 at a proton-proton center of mass energy of 8 TeV.
The event shows the characteristics expected from the decay of the SM Higgs boson into a pair of photons (dashed yellow lines and green towers). The event could also be due to the known standard model background processes (courtesy of CMS Collaboration)



Contribution to Hcal

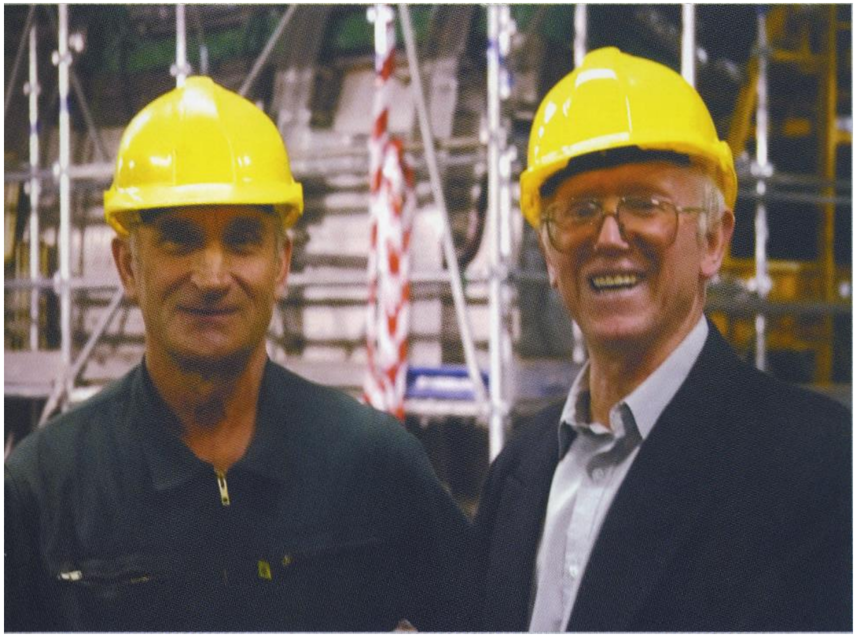
Commissiong of Latium plates for the forward-hadron calorimeter of the CMS experiment at MZOR factory, Minsk by CERN and JINR teams. 2000.



Commissioning of the Latium absorber of the forward-hadron calorimeter of the CMS detector at «MZOR» , Minsk by CERN and JINR teams. 2001

Hcal Installation at P5 CMS

Roman Viktorovich Stefanovich



Engineer of INP BSU playing a fundamental role in the installation of the Hcal and CSC Muon chambers. Now involved in the integration of TOTEM to CMS. 20 years of continue work at CERN point 5.

Installation of hadron-forward calorimeter absorber at point 5 CERN

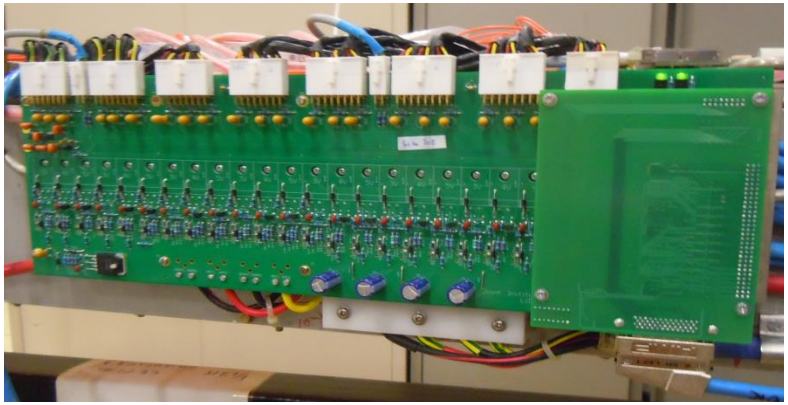
2002, CERN. Installation of CMS end-cap hadron calorimeter absorber

Contribution to CSC Muon System

Electronics for CSC

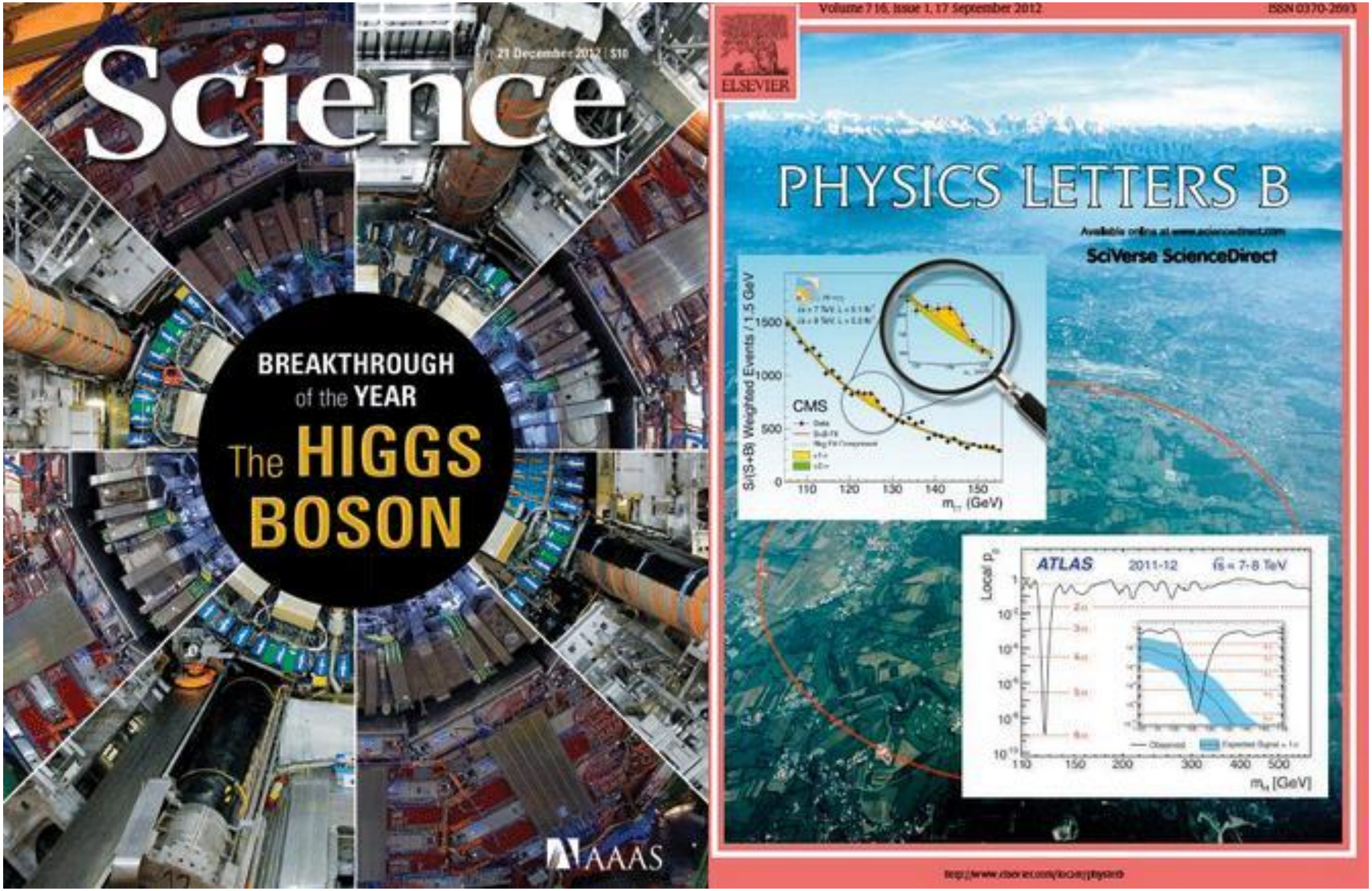
Vladimir Tchekhovski

- Development, manufacture support and testing of application-specific analog and mixed-signal IC for nuclear electronics, radio-electronic and electronic measuring equipment
- Development of electronic components and assemblies for the experimental equipment used in modern particle physics experiments
- Development and prototyping of specialized control and measurement electronics for testing IC and modern element base.



Electronic module for low voltage power supply system of CMS muon detecror

Higgs boson discovery: 14 co-authors from INP BSU



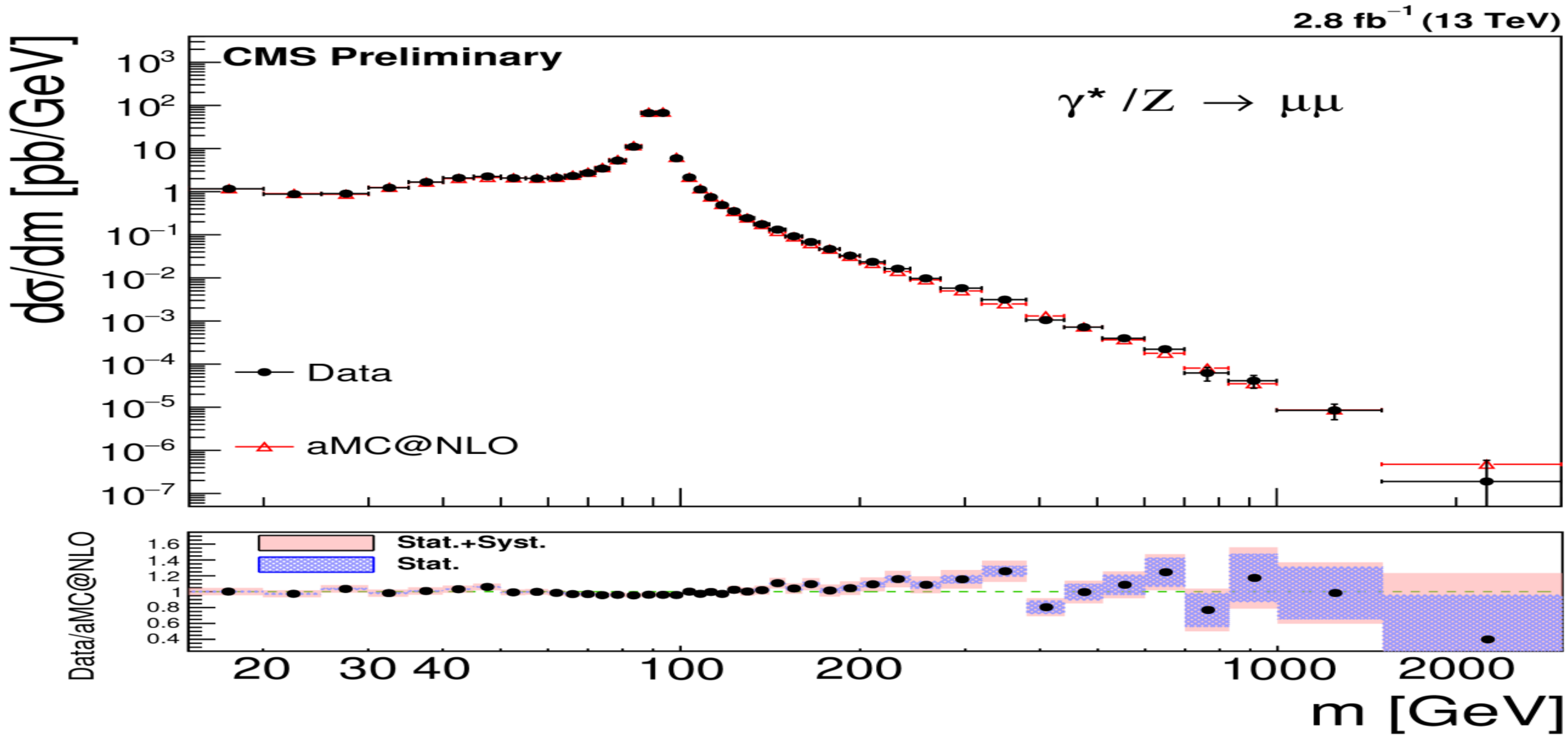
The Higgs boson discovery publications in journals Science and Physics Letters B

The Present

INP BSU Successful participation in CMS

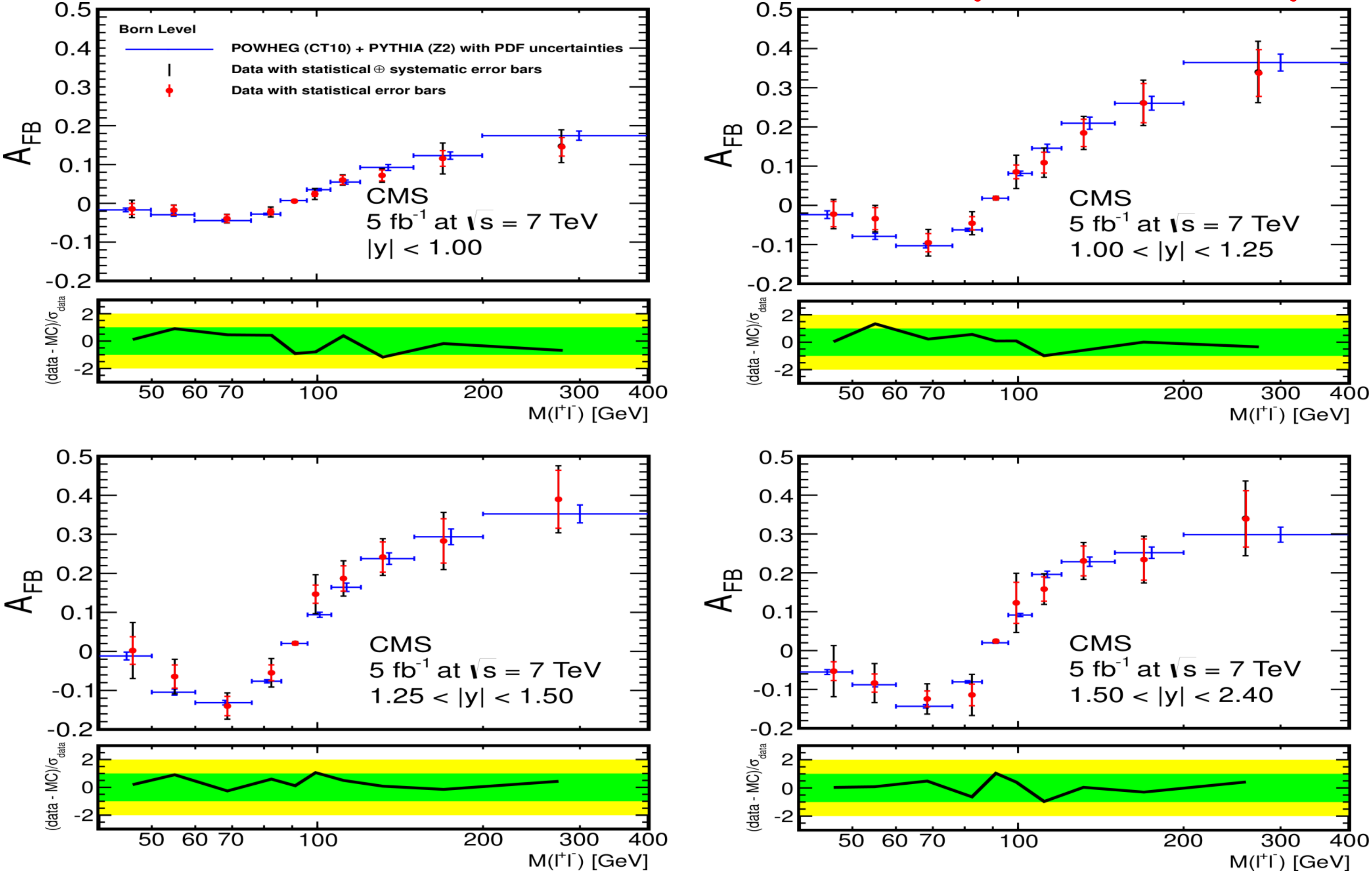
- Author ship of all papers published by CMS Collaboration so far. As today 603 publications send to referee journals.
- Fulfilling our obligations on shifts and pledges (see V. Mossolov talk)
- Participation in various analysis groups – DY, A_FB, Z' (see U. Yevarovskaya talk)
- Participation in the CMS generators' group (MC centralized samples)
- Creation of the MC generator LPPG and integration to the CMS generator system (see Y. Dydyzhka talk)
- Successful operation of the CMS Grid Tier 3 (see V. Yermolchik talk)

Drell-Yan cross section measurement

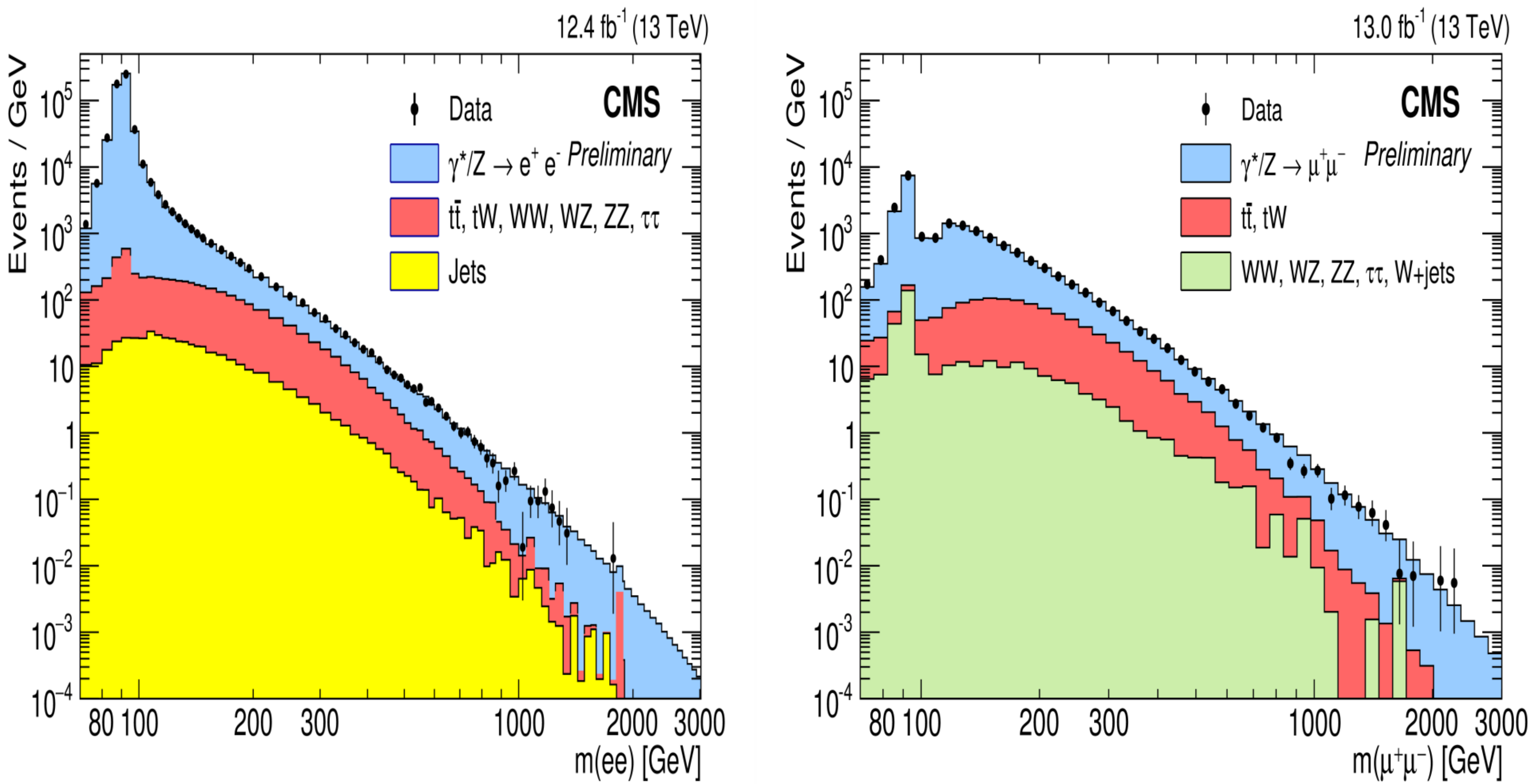


2-3% system. Precision; compared NNLO predictions calculated with FEWZ and NLO predictions calculated with aMC@NLO **[CMS-PAS-SMP-16-009]**

Forward-Backward Asymmetry



Search for Z' in e-e+ and μ-μ+ channels

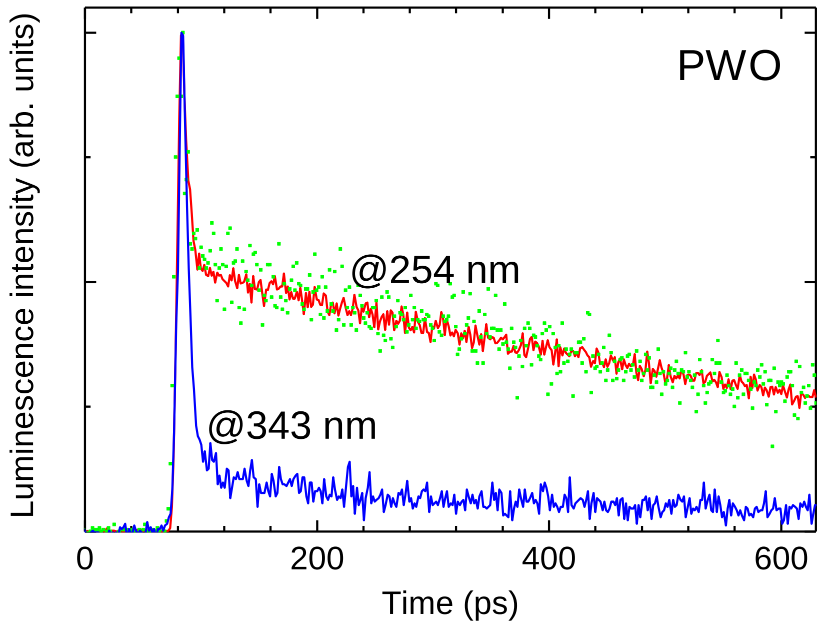


Exclusion limits for: Z'_ssm (3% width)> 4 TeV/c2 (95% CL) and Z'_ψ (0.5% width)> 3.36 TeV/c2 (95% CL) **[CMS-PAS-EXO-16-031]**

The Future

R&D on PWO still continue!

Newly discovered luminescence properties of PWO crystals

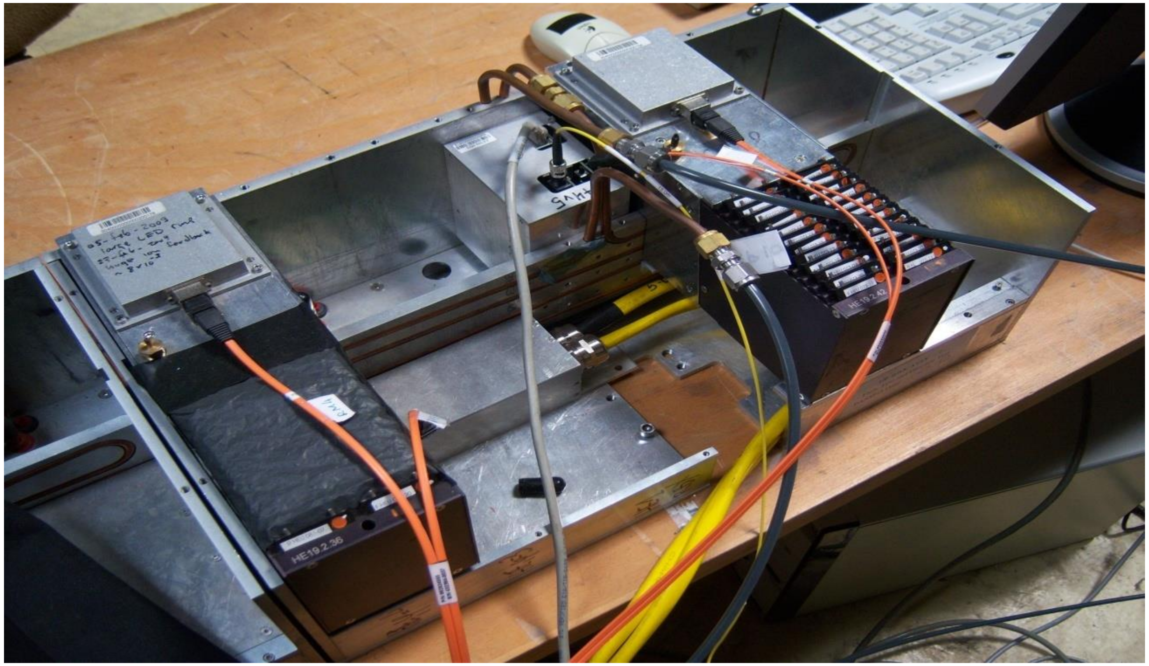


Initial part of $PbWO_4$ photoluminescence kinetics at 343 nm excitation (blue line) and 254 nm excitation with pulse energy of 15 mJ/cm^2 (red) and 1.5 mJ/cm^2 (green)

The results show that the fast rise of luminescence in PWO scintillators is short enough to be exploited for the sub-50-picosecond readout, which is targeted for the future scintillator detectors at High Luminosity LHC and Future Circular Collider.

HE Readout Box and Readout Module Boxes

- Hcal upgrade project phase I
- Big enrolment of Belarus industry in this project



ME CSC electronics upgrade

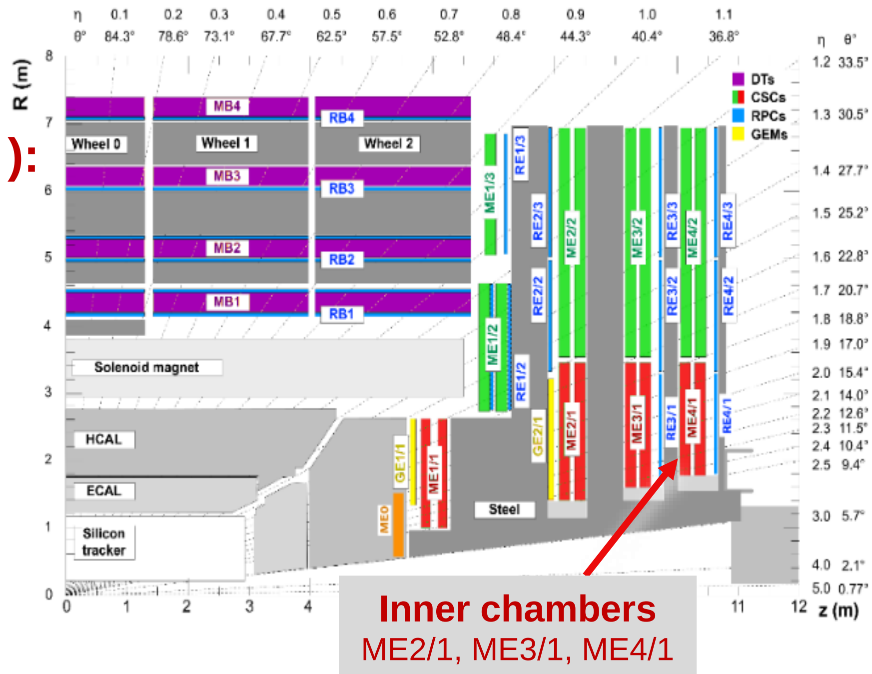
At present L1A rate and L1A latency CFEBs are fine

➢ **At HL-LHC luminosity CFEBs cannot sustain the planned trigger rates and latency**

Proposal to replace electronics on the inner chambers 1.6 < |η| < 2.4 (ME2/1, ME3/1,ME4/1):

- Cathode Front-End Boards (CFEBs) by digital DCFEBs to eliminate dependency on level 1 latency
- Replace DAQ readout electronics (DMB=>ODMB) to accommodate increased bandwidth

✓ Already replaced on ME1/1 in LS1



Perform upgrade in 2 steps:

LS2: On chamber electronics + OTMB (in peripheral crates)
LS3: ODMB (in peripheral crates) + FEDs (in USC) + optical links

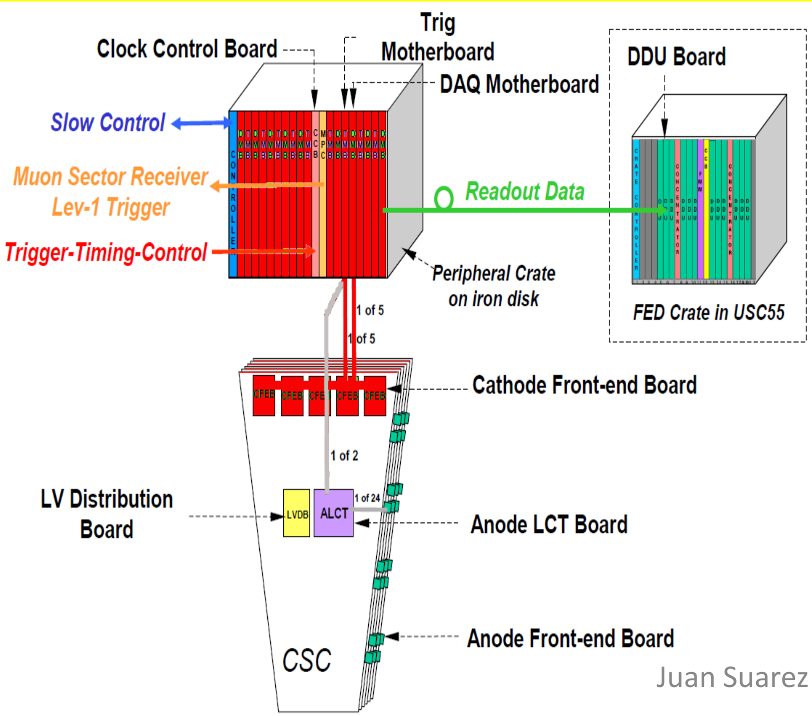
Upgrade of Trigger, DAQ, and FED (Data Bandwidth)

Replacement of CFEBs with DCFEB implies:

Low Voltage Distribution Board (LVDB) -> LVDB5

Trigger MotherBoard (TMB) -> Optical TMB (OTMB)

DAQ MotherBoard (DMB) -> Optical DMB (ODMB)



Increased luminosity at HL-LHC implies:
Increased data bandwidth requirements

Data Rates at $0.75x10^{35}cm^{-2}s^{-1}$

Station	ME1/1	ME2/1	ME3/1	ME4/1
ODMB Rate (DCFEBs)	6.12 Gbps	3.32 Gbps	2.24 Gbps	2.16 Gbps
ODMB Rate (total)	9.96 Gbps	5.41 Gbps	3.66 Gbps	3.52 Gbps

At present DMB -> DDU links are 1.28 Gbp

- ME1/1 ODMBs need to be replaced with high bandwidth version of ODMB (72 needed)
- ME2/1, 3/1, 4/1 DMBs need to be replaced

  with new ODMB2s (108 needed)

ME2/1, 3/1, 4/1 TMBs need to be replaced with OTMBs

No changes needed; simply produce more (108 needed)

ME2/1, 3/1, 4/1 LVDBs need to be replaced with LVDB5s (108 needed)

On chamber power distribution

- ❑ New Low Voltage Distribution Board LVDB 5 will provide 20 output voltage channels:
  - to supply 5 DCFEBs (6V, 5V, 3.3V per each board)
  - to supply ALCT(5.5V, 1.8V, 3.3V)
  - to provide DCFEBs reference voltage power supplies of -5V and +10V
- ❑ New on-chamber electronics requires ~2x more power then the old one

LVDB

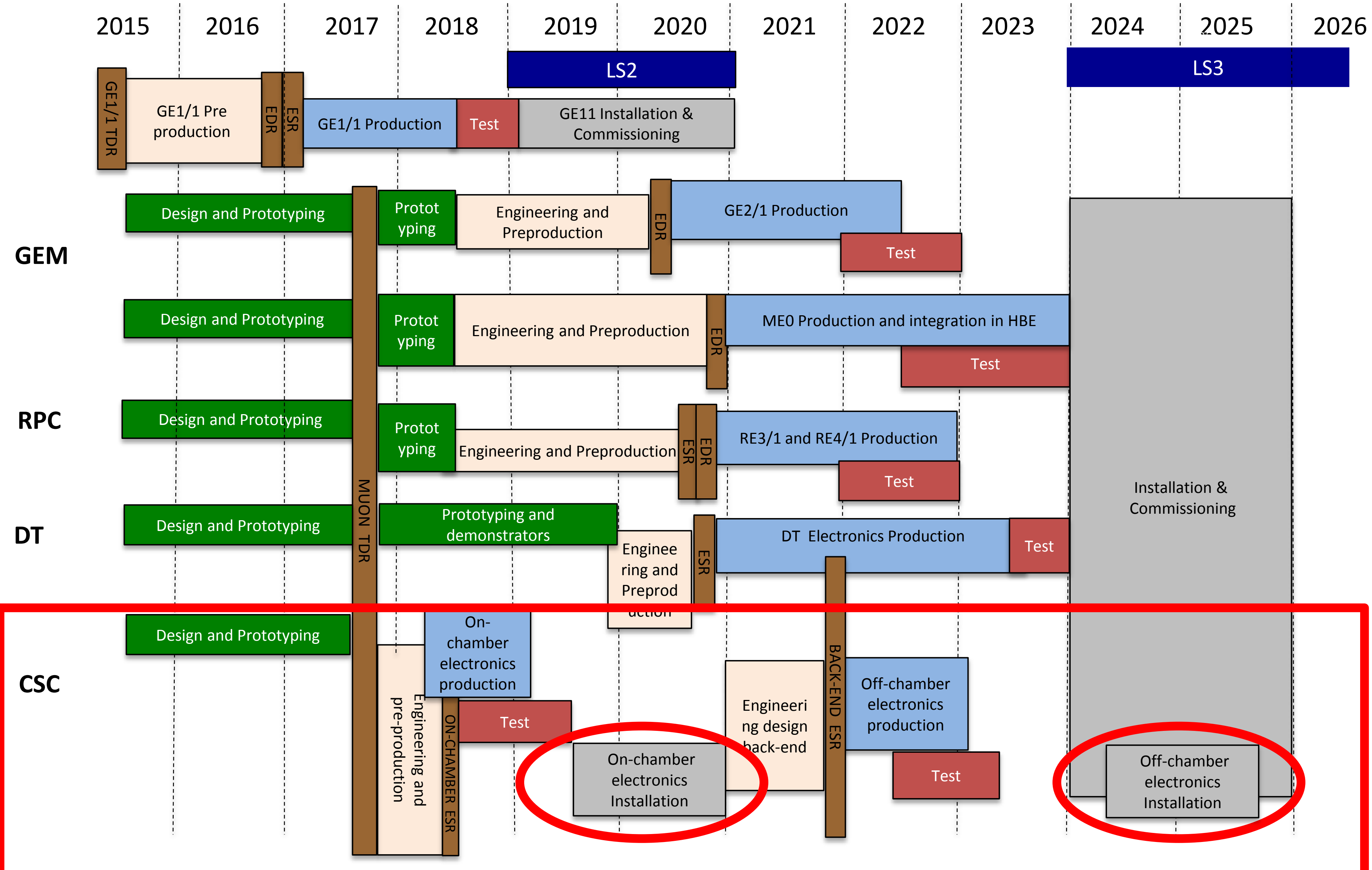
LVMB

LVDB 7

- ❑ JINR and INP, Minsk take responsibility for design and construction of 120 new Low Voltage Distributions Boards (LVDB5) for 108 Muon Endcap inner rings (MEX/1) detectors.

The CSC Upgrade in Muon Project Upgrade

Armando Lanaro UW-Madison



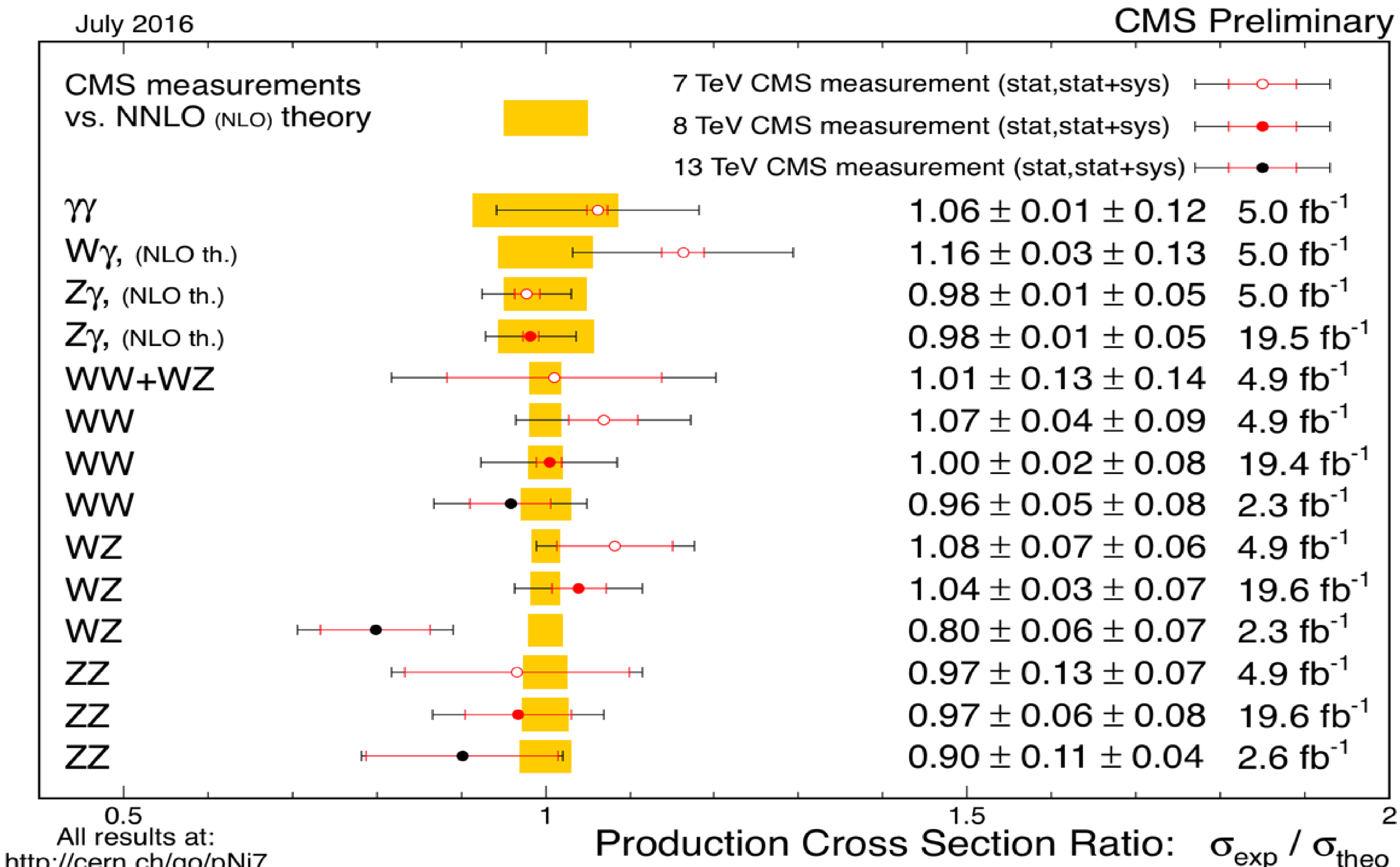
Outlook

- Active and successful participation in a variety of crucial tasks (detector R&D, creation and mounting. Theory, analysis, shifting, pledges and Grid cluster maintenance)
- Hope to continue playing a decisive role in the upgrade of the CMS detector in physics and services

Thank You for your Attention!!!

Backup

Double-boson Cross section



Upcoming ACTIVITIS for Upgrade I

- Install a new pixel detector
  - Four layers in the barrel (BPIX) rather than 3
  - Three disks in each endcap (FPIX) rather than 2
  - Better readout able to run up to $2x10^{34}$ cm^{-2} s^{-1} with almost no inefficiency (from hit loss on readout) or dead time
- Replace the sensors in the Hadron Calorimeter Endcap (HE) with Silicon Photomultipliers (SiPMs)
  - Improved light yield compensates for higher than expected radiation damage
  - More longitudinal segmentation
- Implement multianode feature of PMTS on Forwarh Haron Calorimeter (HF)
  - Reject spurious signals that produce false MET
- Several other improvements/Additions (GE1/1 demonstrator, luminosity monitor replacement)