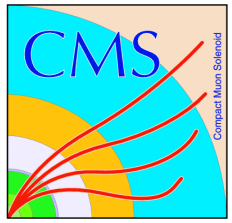


CMS Status Report

Matteo Sani (UCSD)
On behalf of the CMS Collaboration

Outline

- Status of Run I Analysis
- Recent Physics Results
- Detector Commissioning
- Physics Object Readiness

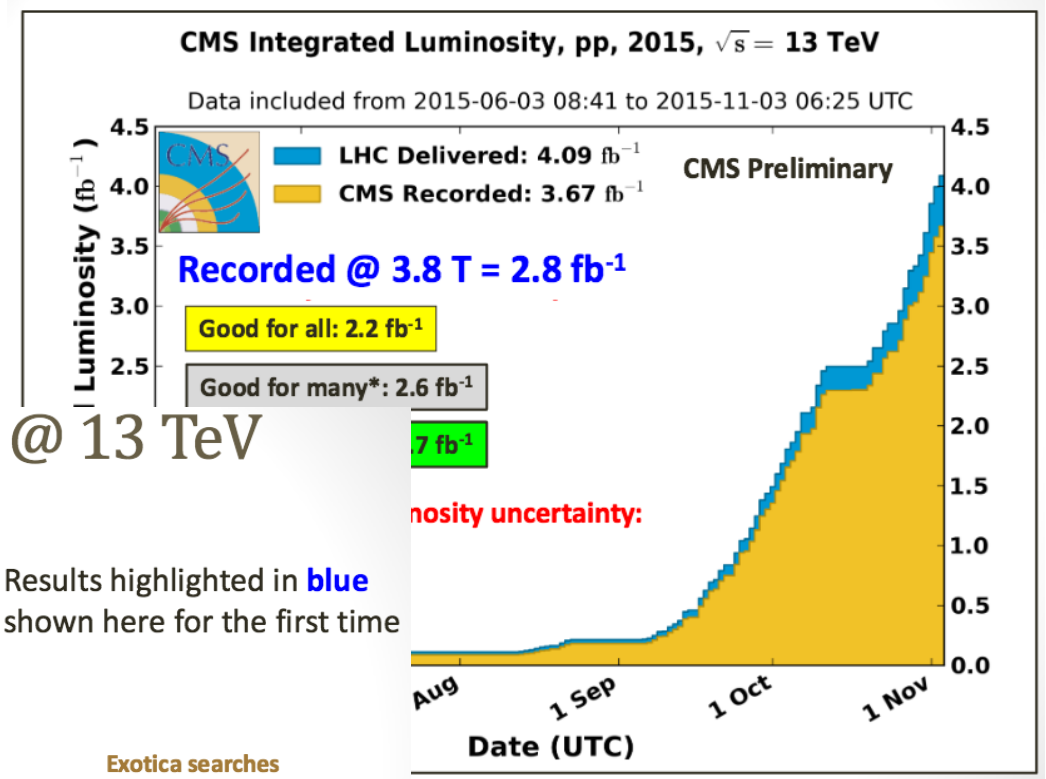
A Successful 2015...

CMS Public Results @ 13 TeV

Standard Model results (15):

BPH-15-004: B production cross section
FSQ-15-001: Pseudorapidity distributions of charged hadrons
FSQ-15-002: Two-particle correlations (the "ridge")
FSQ-15-007: Underlying event
SMP-15-004: Inclusive W/Z cross section
SMP-15-005: ZZ production cross sectior
SMP-15-006: WZ production cross sectio
SMP-15-007: Inclusive jet production
SMP-15-010: Z+jets differential cross sec
TOP-15-003: Inclusive ttbar cross section
TOP-15-004: t-channel single top product
TOP-15-005: Differential tt cross section i
TOP-15-010: Differential tt cross section i
TOP-15-013: ttbar differential cross secti
TOP-15-017: Underlying Event studies in

Results highlighted in **blue**



CMS Public Results @ 13 TeV

New Physics searches (18):

B2G-15-004: Search for W'->tb (semi-leptonic)
B2G-15-006: X53 in SS dilepton and lepton+jets
EXO-15-001: Search for dijet resonances
EXO-15-002: Search for diboson resonances
EXO-15-003: Search for dark matter in monojets
EXO-15-004: Search for diphoton resonances
EXO-15-005: Search for dilepton resonances
EXO-15-006: Search for W' in lepton + MET final state
EXO-15-007: Search for Black Holes
EXO-15-009: Search for new physics in dijets with chi
EXO-15-010: Search for Heavy Stable Charged Particles
SUS-15-002: Search for supersymmetry in multijet+MET
SUS-15-003: Search for new physics in the all-hadronic final state with the MT2
SUS-15-004: Inclusive search for supersymmetry using the razor variables
SUS-15-005: Search for supersymmetry using alpha_T
SUS-15-007: Search for supersymmetry in 1-lepton events using large radius jets
SUS-15-008: Search for SUSY in same-sign dilepton events
SUS-15-011: Search for SUSY in final states with opposite-sign dileptons

Results highlighted in **blue** shown here for the first time

Exotica searches

SUSY searches

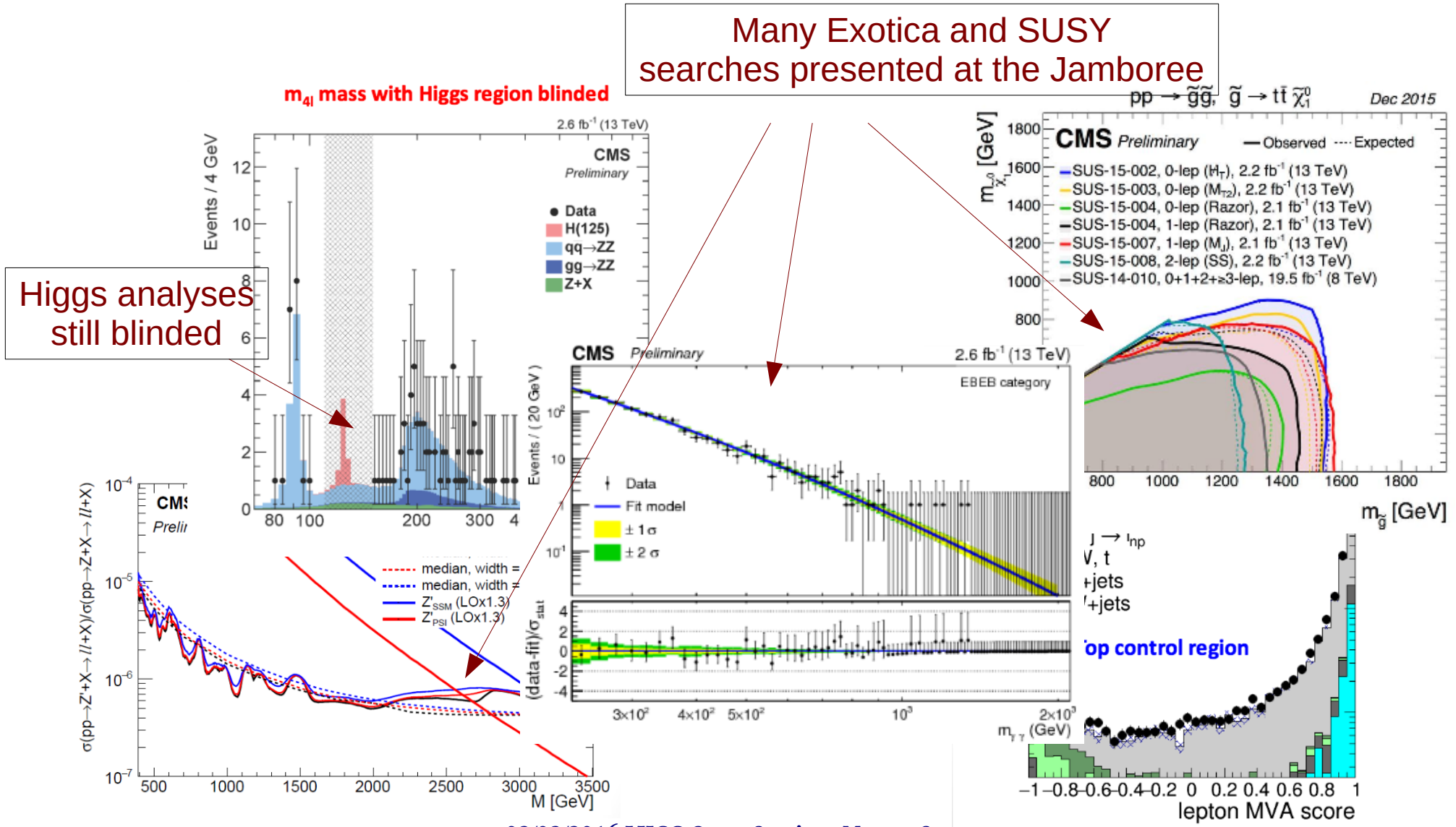
In total 33 new results released on 13 TeV data !

Preparation for Moriond

- Most of the analysis are under scrutiny before publication !

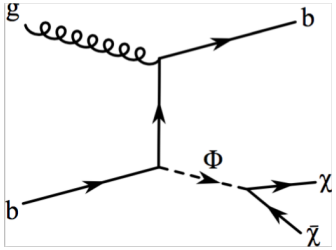
Many Exotica and SUSY searches presented at the Jamboree

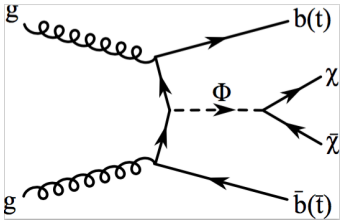
Higgs analyses still blinded

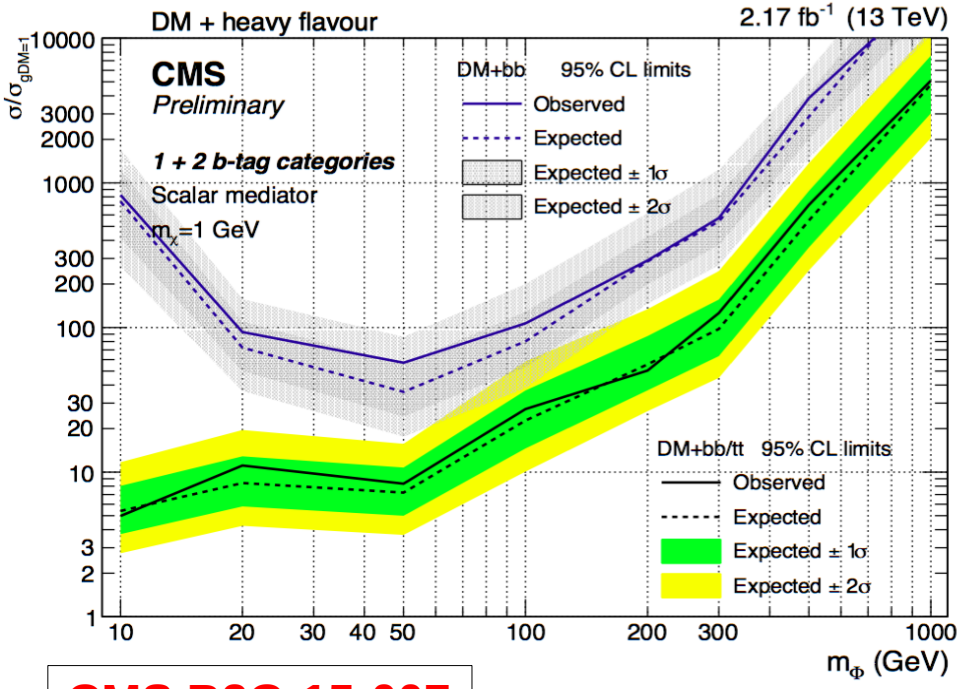


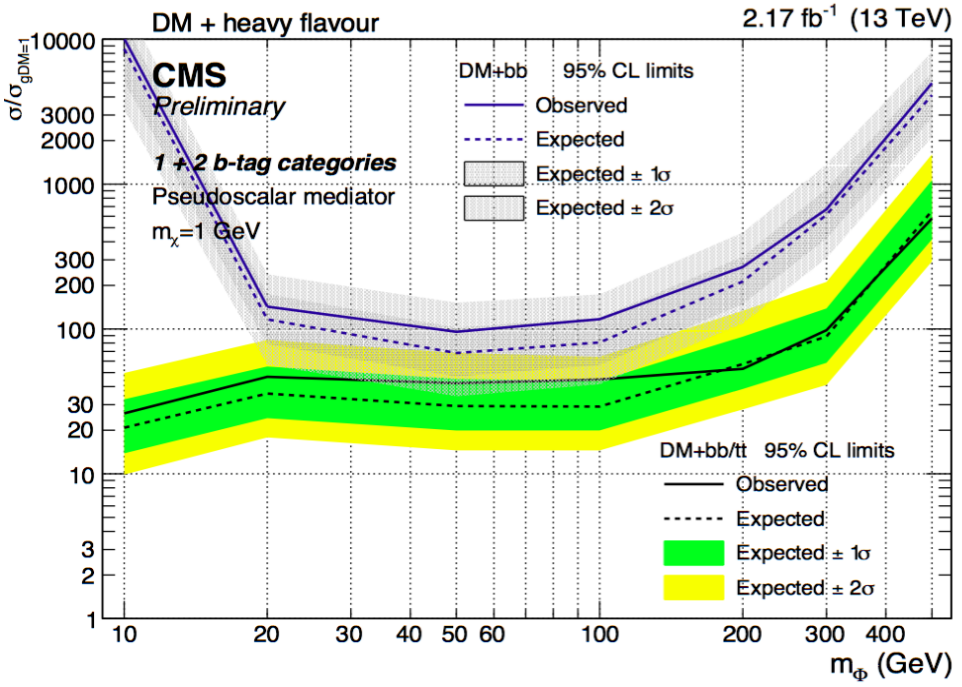
Recent Physics Highligths (Run II)

- Search for Dark Matter (DM) in association with b-jets:
  - First dedicated search at LHC Run-2 at 13 TeV;
  - Also sensitive to DM+tt production;
  - Exclusion limits set as a function of mediator mass (m_Φ) and in the 2D plane (m_Φ; m_χ).







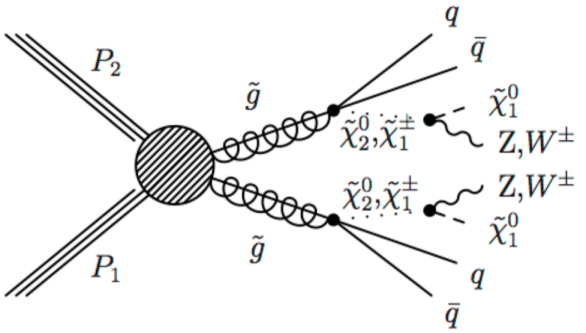


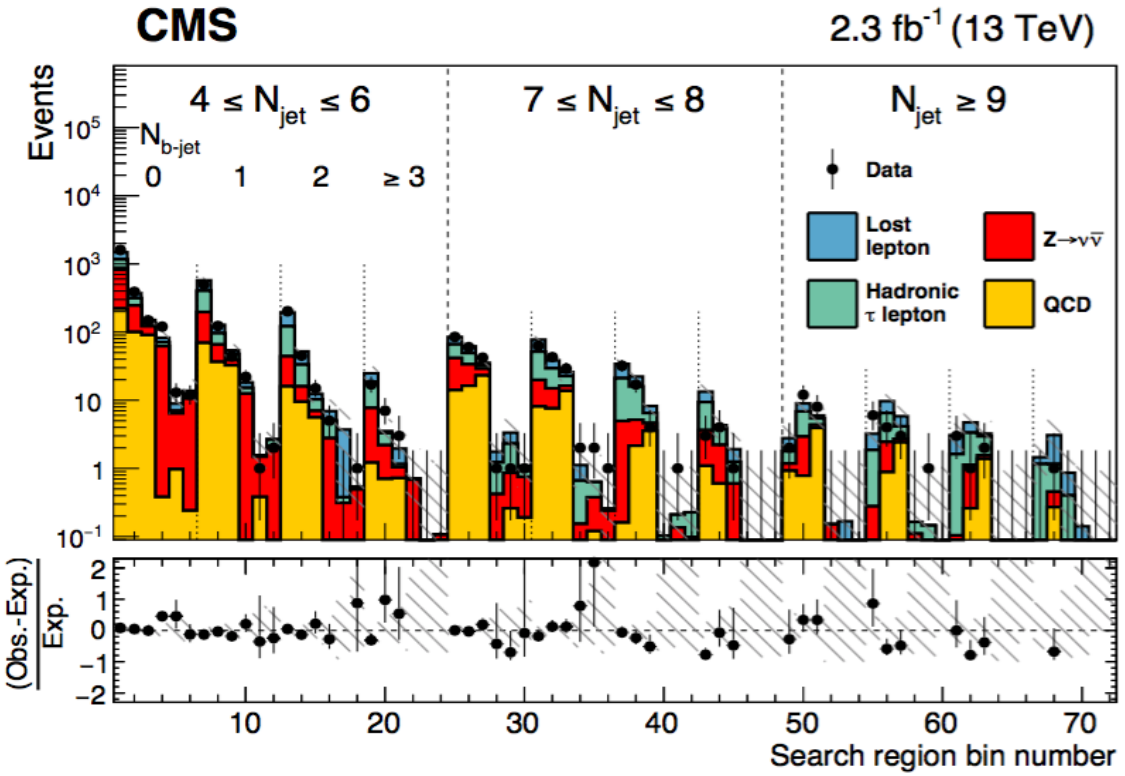
CMS B2G-15-007

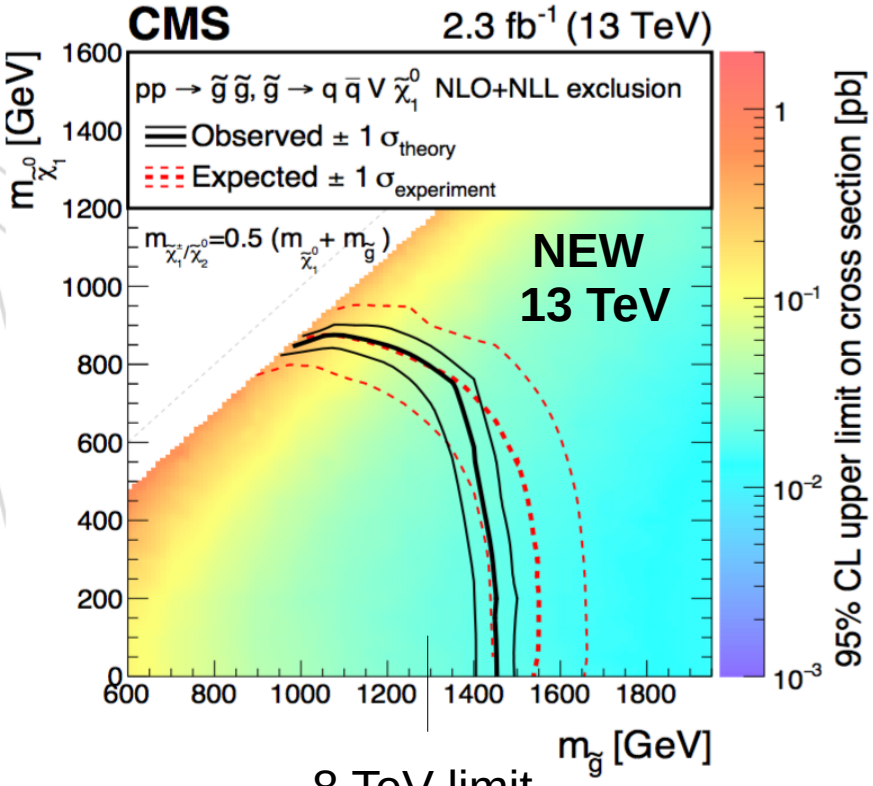
Recent Physics Highlights (Run II)

- Many regions defined by H_T, H_T^{miss}, $N_{jet}(>=4)$, N_b;
- **Published** with final dataset, refined treatments, T5qqqqVV interpretation added.

CMS SUS-15-002
arxiV:1602.06581



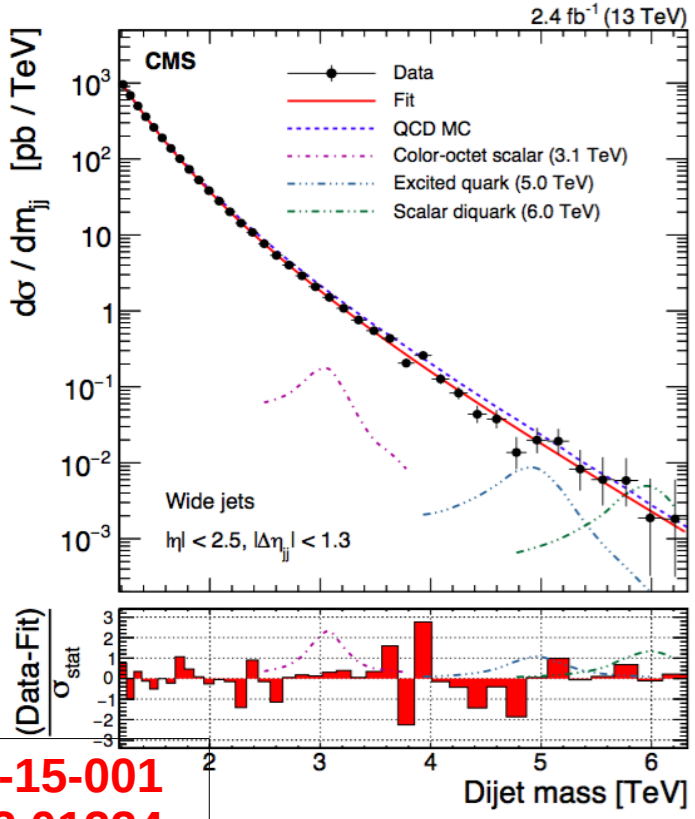


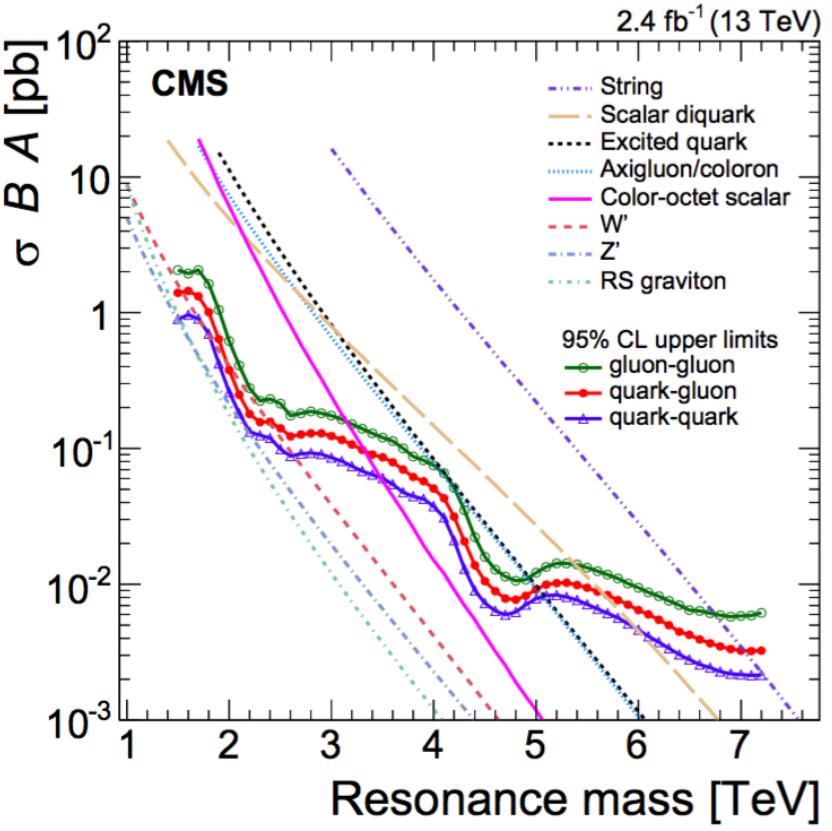


8 TeV limit

Recent Physics Highlights (Run II)

- Model independent search for narrow qq, qg, or gg resonances:
  - In addition various models considered: excited quark, RS Graviton, W'/Z', string resonance;
  - More sensitive than previous for dijet resonances above 2 TeV;
  - **Published** at the end of last year.

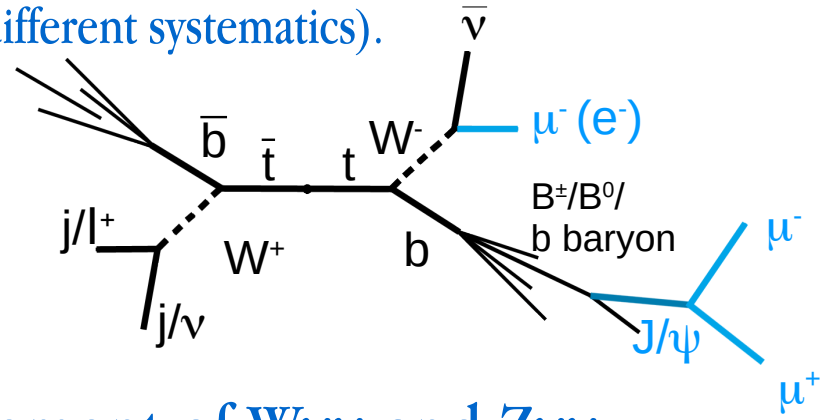




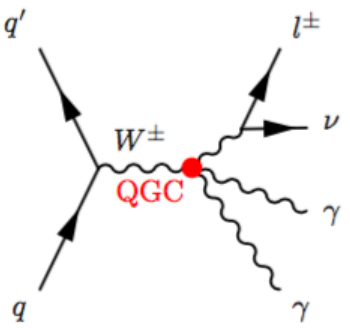
CMS EXO-15-001
arXiv:1512.01224

Recent Physics Highlights (Run I)

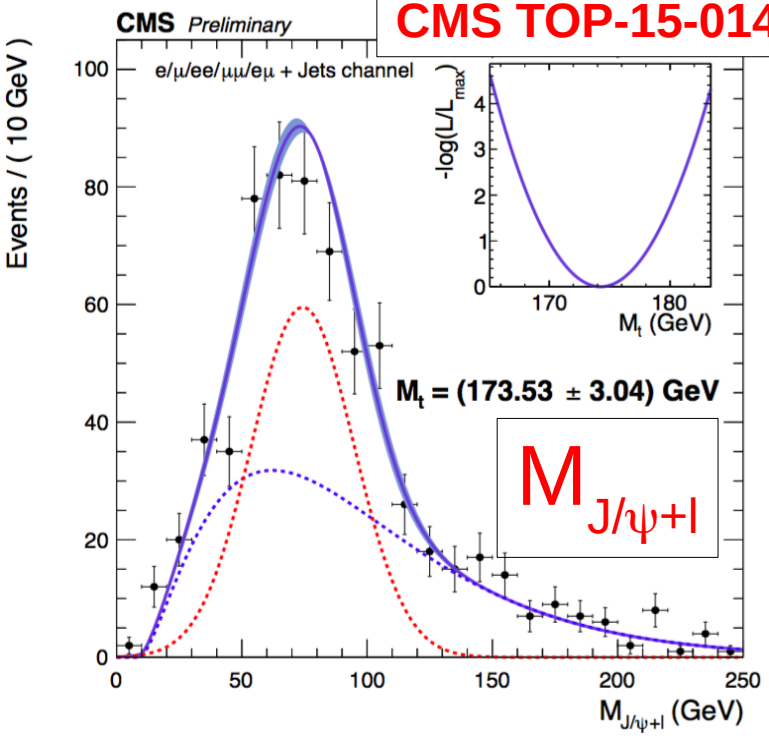
- Top mass measurement in tt events with J/ψ at 8 TeV:
  - Statistics limited. Main systematic from theory (e.g., top pT, b fragmentation). With higher lumi at Run-II: significant a precision improvement, gain in combination with other techniques (very different systematics).



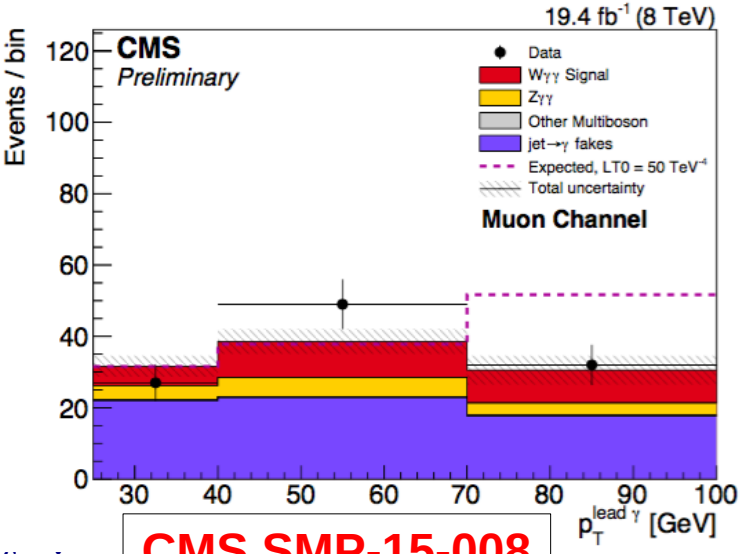
- Measurement of Wγγ and Zγγ cross-section at 8 TeV:
  - Processes sensitive to EW bosons self-interactions via quartic gauge couplings (QGC).



CMS TOP-15-014



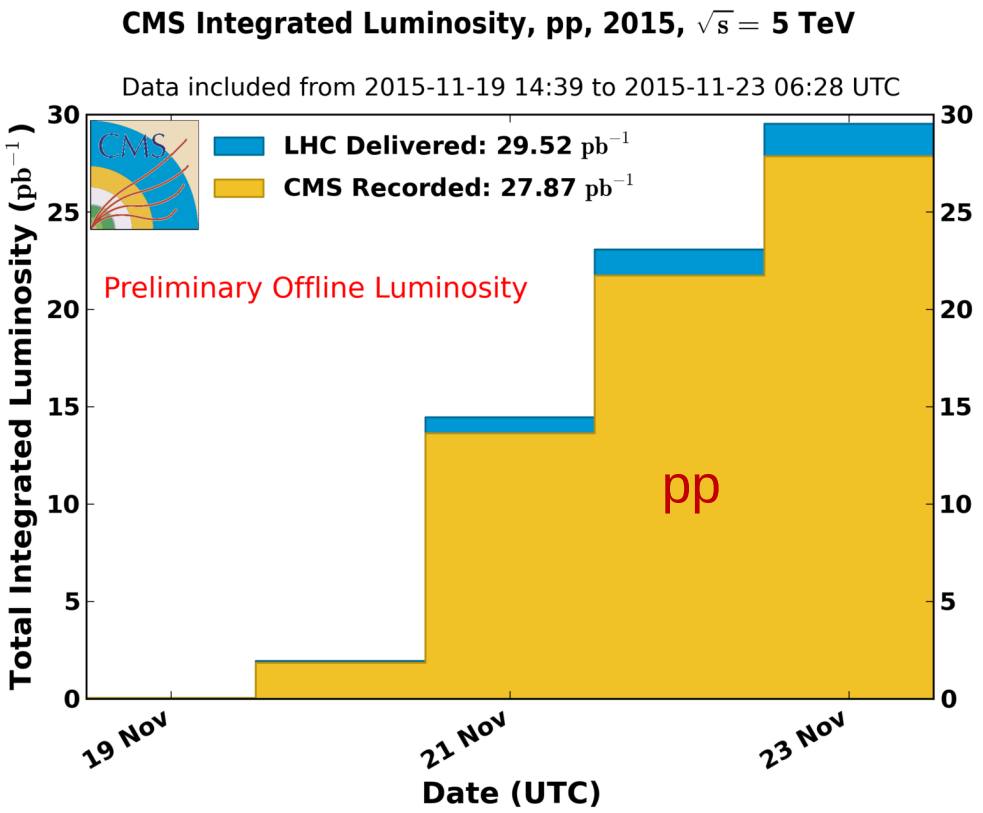
CMS SMP-15-008

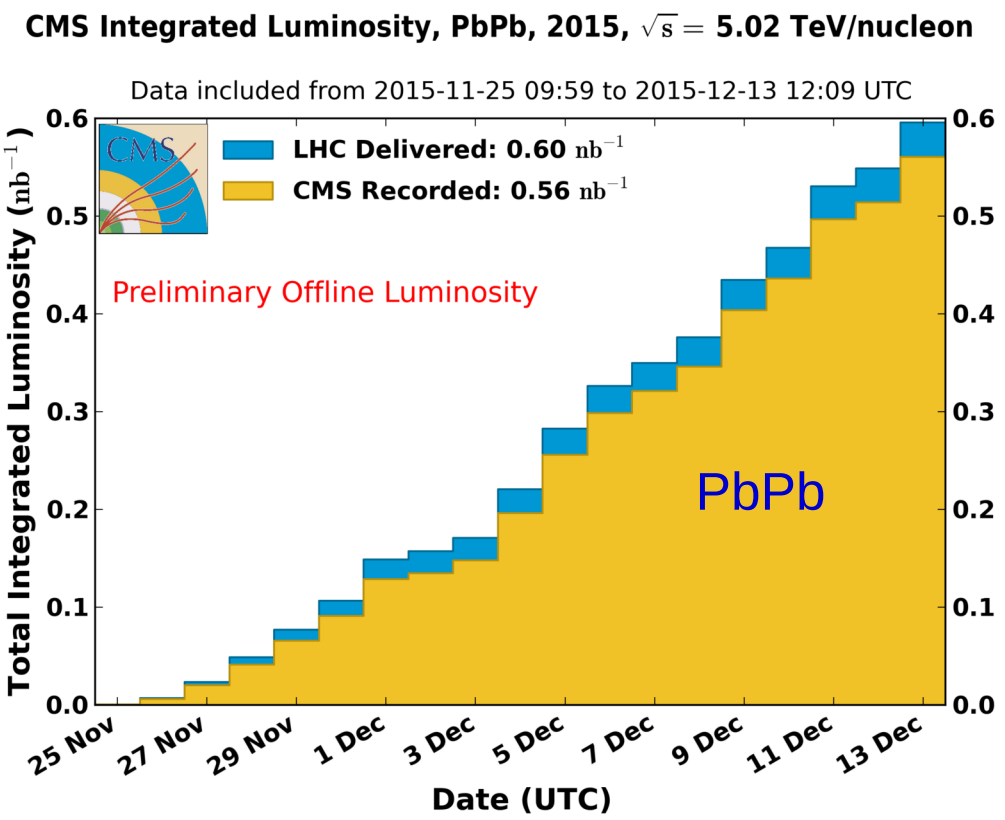


Recent Physics Highlights (Run I)

- A number of other 8 TeV results recently finalized:
  - arXiv:1601.01107: Measurement of quark-antiquark spin correlations and top quark polarization in dileptonic channel.
  - arXiv:1602.09024: Measurements of the t-tbar production cross section in lepton+jets final states in pp collisions at 8 TeV and ratio of 8 to 7 TeV cross sections.
  - CMS-SMP-14-011: Search for electroweak-induced production of Wγ with two jets.
  - CMS-SMP-14-020: Measurement of W production cross-section in association with two b jets.
  - arXiv:1602.04305: Combined search for anomalous pseudoscalar HVV couplings in VH production and H->VV decay.
  - arXiv:1602.03169: Search for direct pair production of scalar top quarks in the single- and dilepton channels in proton-proton collisions at $\sqrt{s} = 8$ TeV.

Heavy Ion





>2 billion pp minbias event recorded for HI heavy flavor program

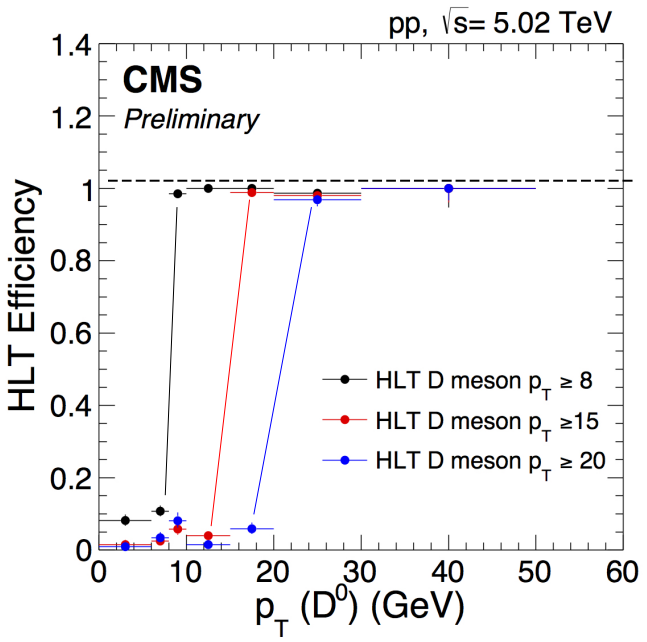
4x more data compared to 2011 *!!*

Very successful data-taking! Collision energy is doubled (2.76 TeV to 5.02 TeV) which increased significantly the cross-section of high p_T probes.

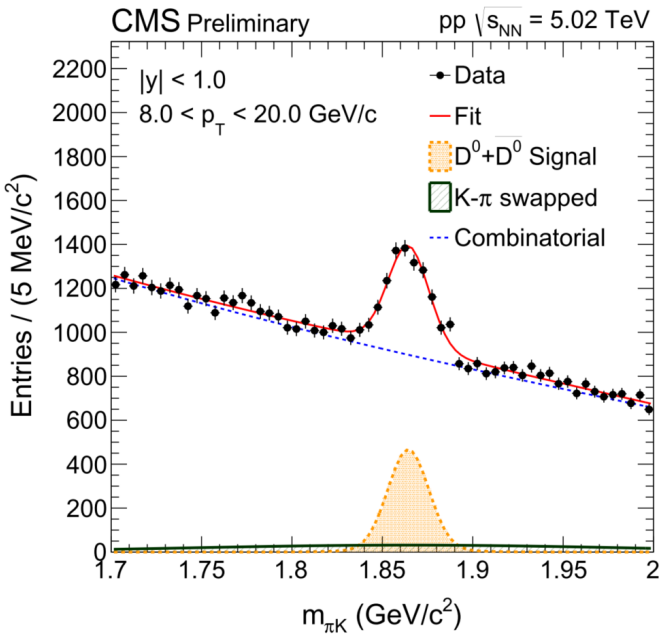
Analysis of the dataset ongoing, first results expected soon !

Improved D Mesons Selection

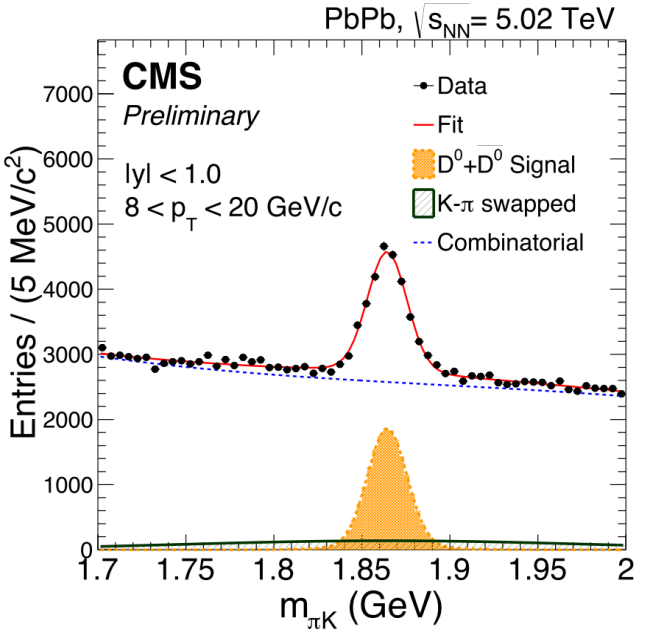
D^0 Trigger



pp

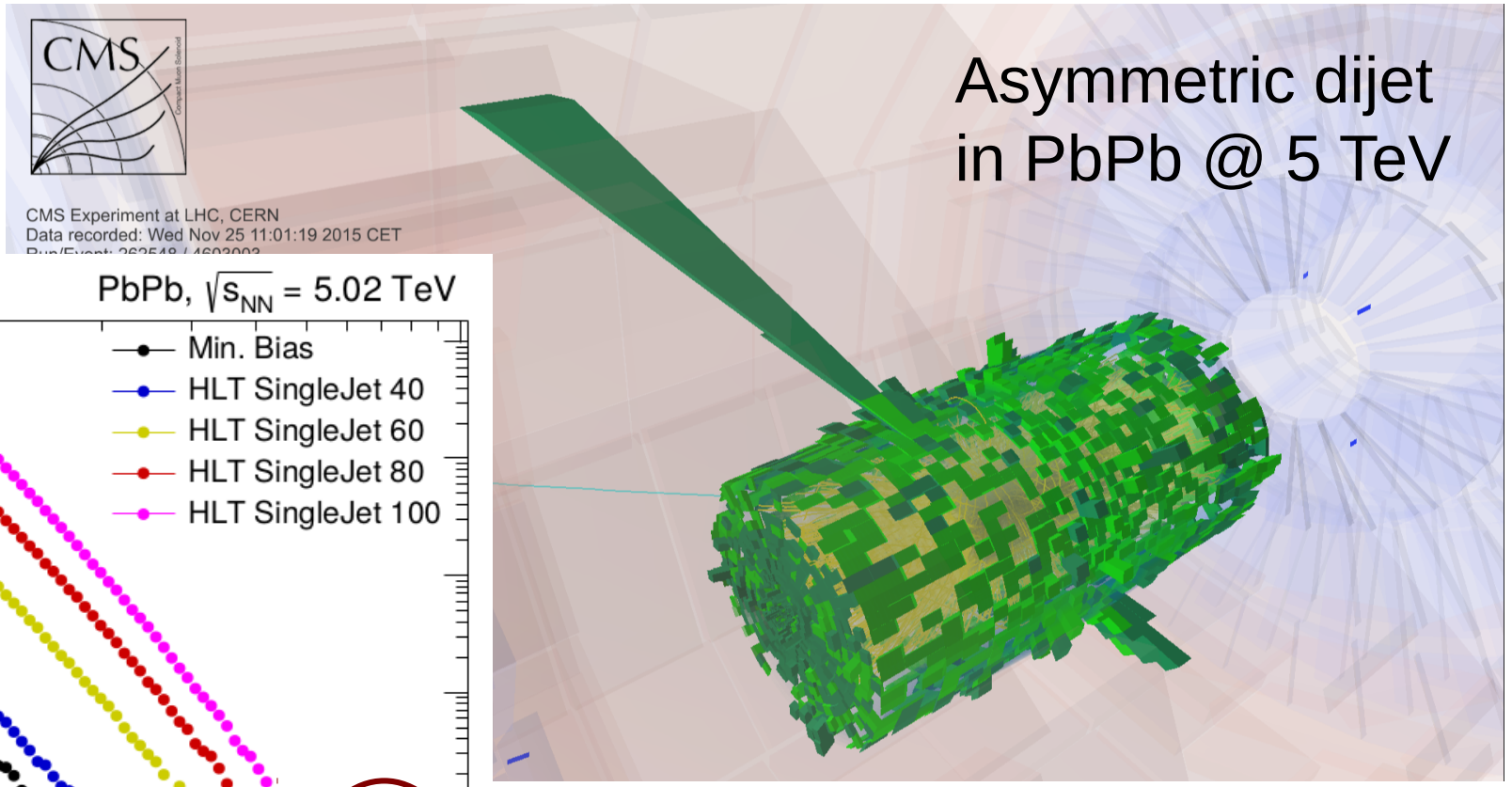


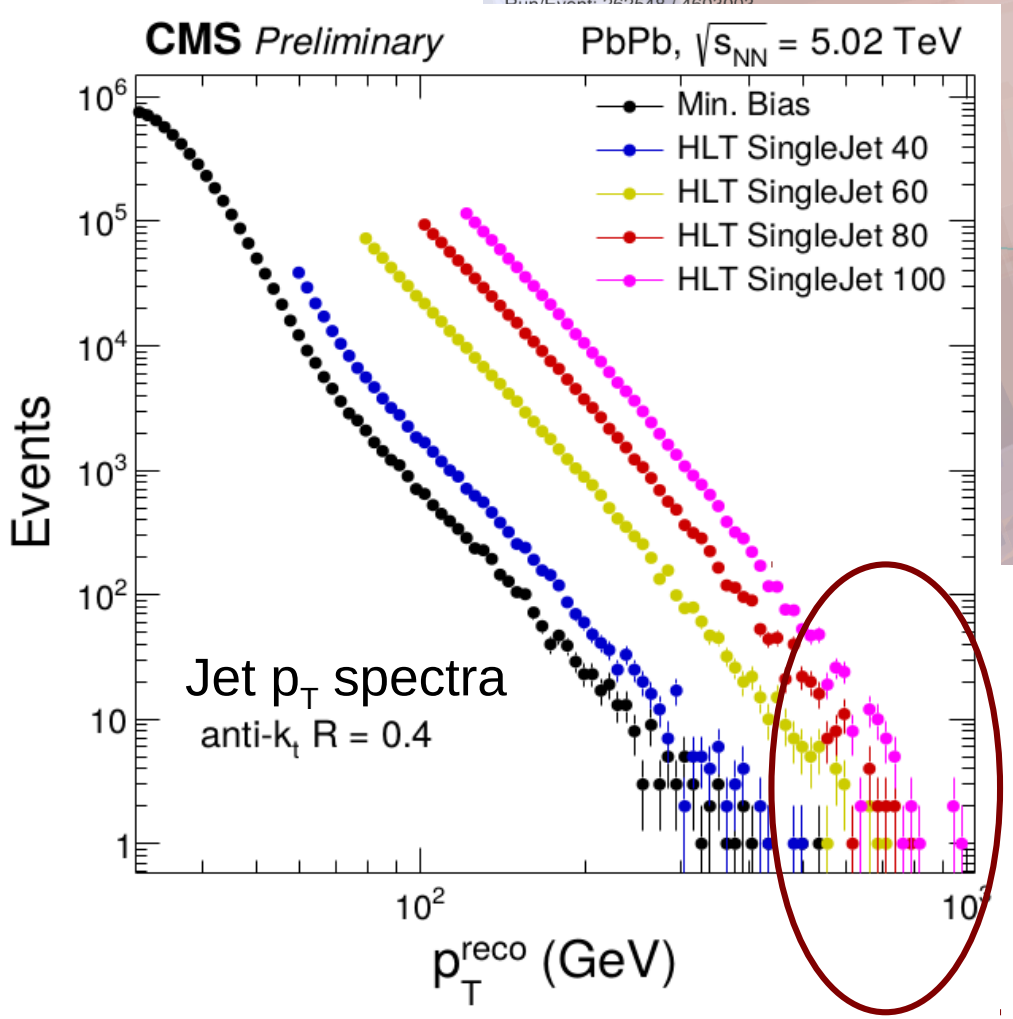
PbPb



- Online D meson reconstruction algorithm and triggers deployed.
- Compared to minimum bias triggers, the high p_T D statistics are increased by a factor of ~800 (~30) in pp (PbPb) collisions.
- Fundamental triggers for the Heavy Ion flavour program in CMS.

γ and Jet Triggers in PbPb

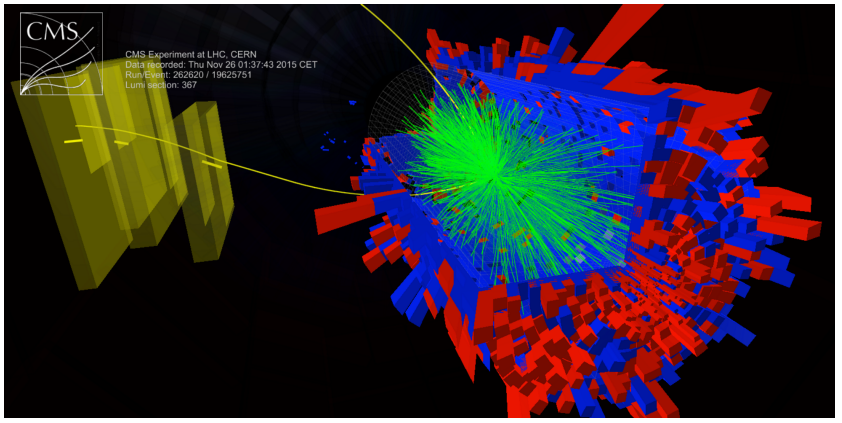




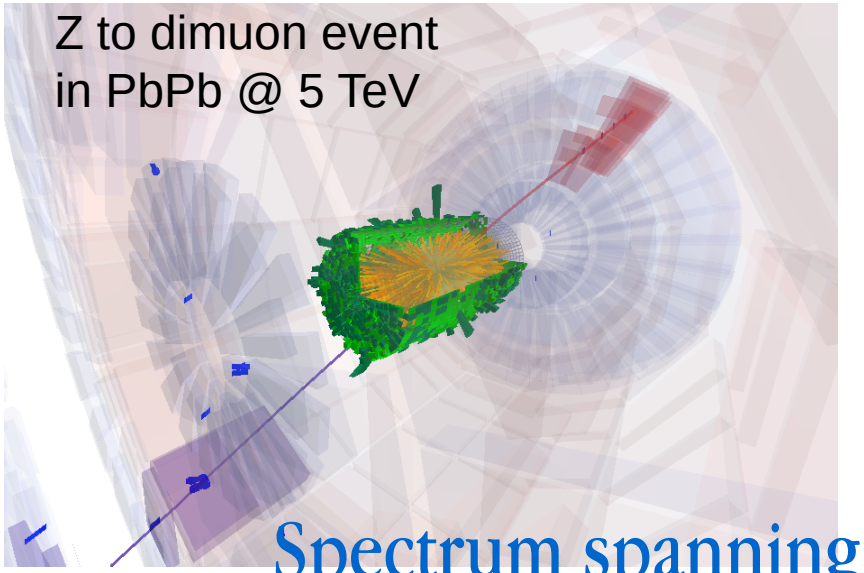
- Excellent performance of photon and jet triggers with stage-1 L1 upgraded system.
- Extended the jet reaches up to 1 TeV.

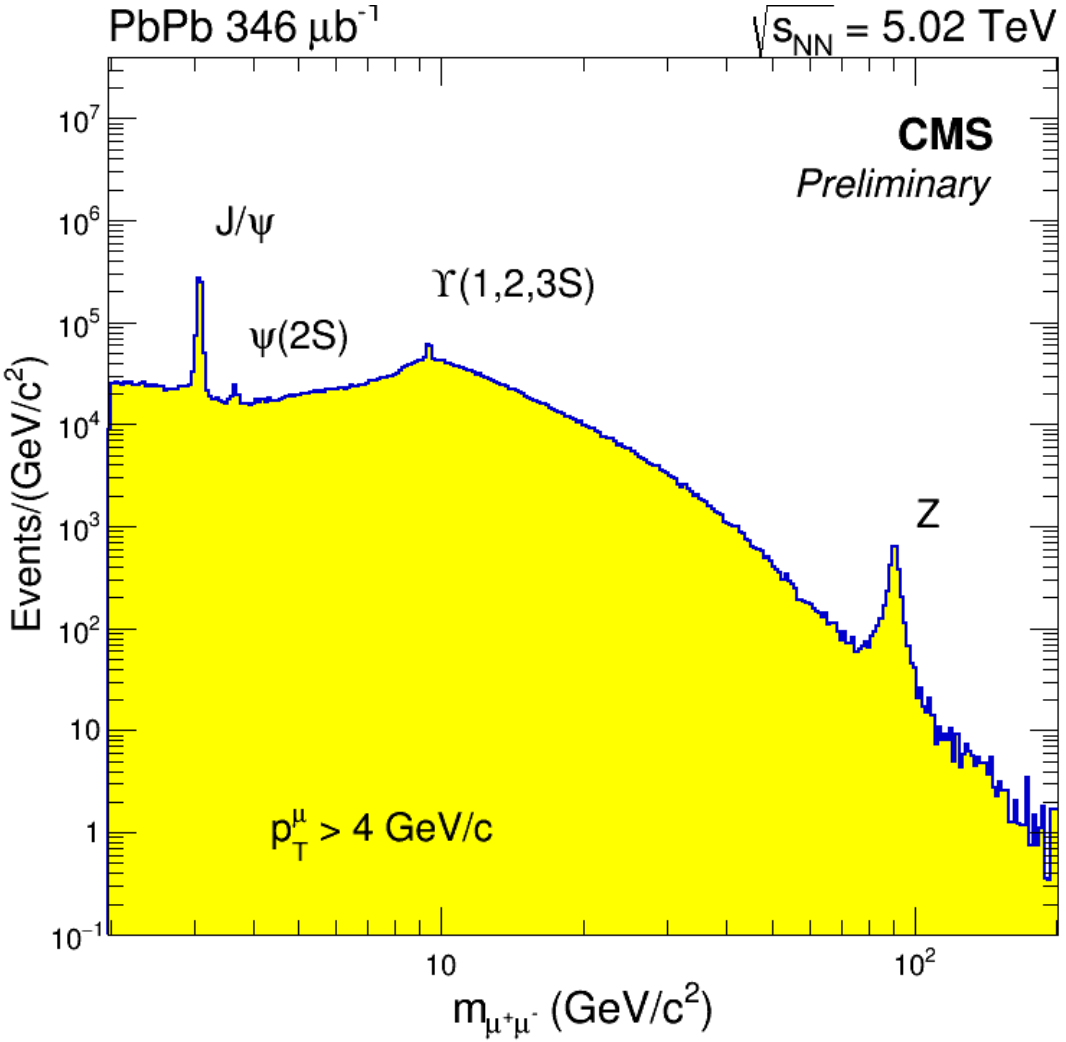
Dimuon Mass Spectrum in PbPb

Upsilon to dimuon event
in PbPb @ 5 TeV



Z to dimuon event
in PbPb @ 5 TeV





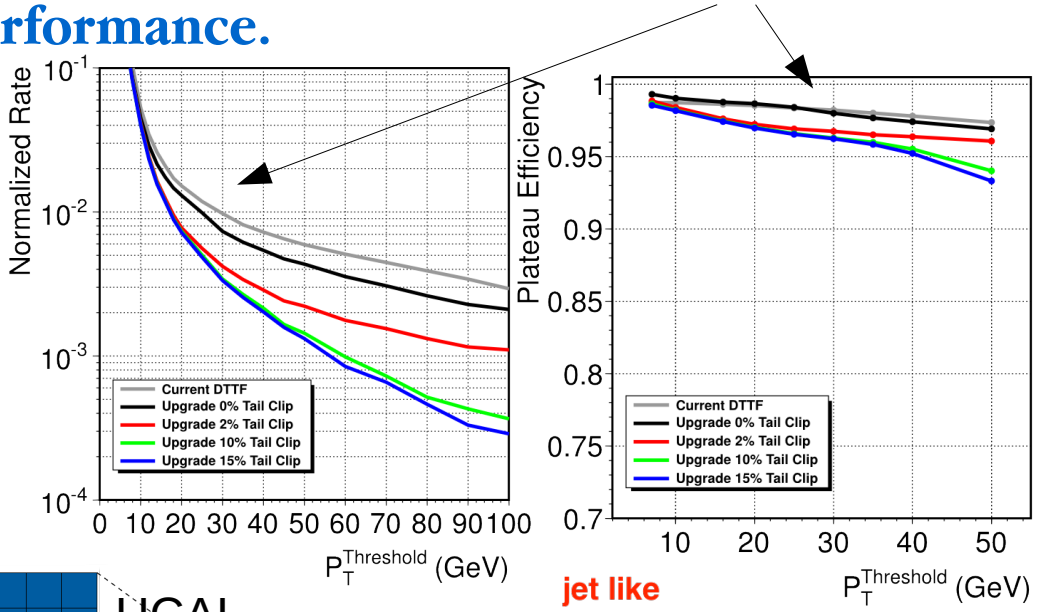
Spectrum spanning several oreder of magnitude:
ready for quarkonia and Z+jet analyses !

Towards 2016 startup: Detector Commissioning

Stage 2 L1 System

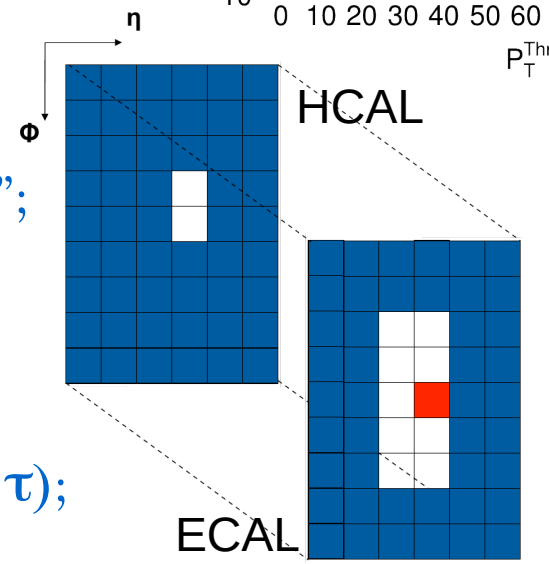
- **Fast readout of the detector with course granularity:**
  - **New hardware in 2016 for better performance.**

Muon Rate reduction x2-3 with similar efficiency

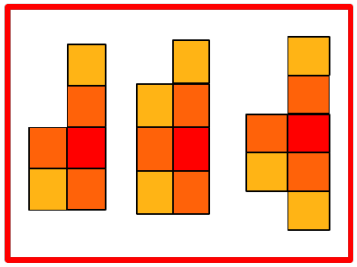


- **μGMT – μTCA Global Muon Trigger**
  - Select 8 leading muon candidates (using DT in barrel, CSC in endcap).

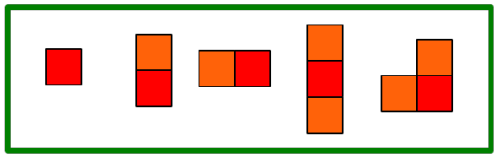
- **L1 Calo Trigger (layer 1):**
  - combines inputs from ECAL (5x5 crystals) and HCAL into "trigger towers";
  - applies position/energy dependent calibrations.
- **L1 Calo Trigger (layer 2):**
  - pattern recognition: (jets, e/γ, τ);
  - computes global quantities: ET / MET, HT / MHT.



jet like



e/g like

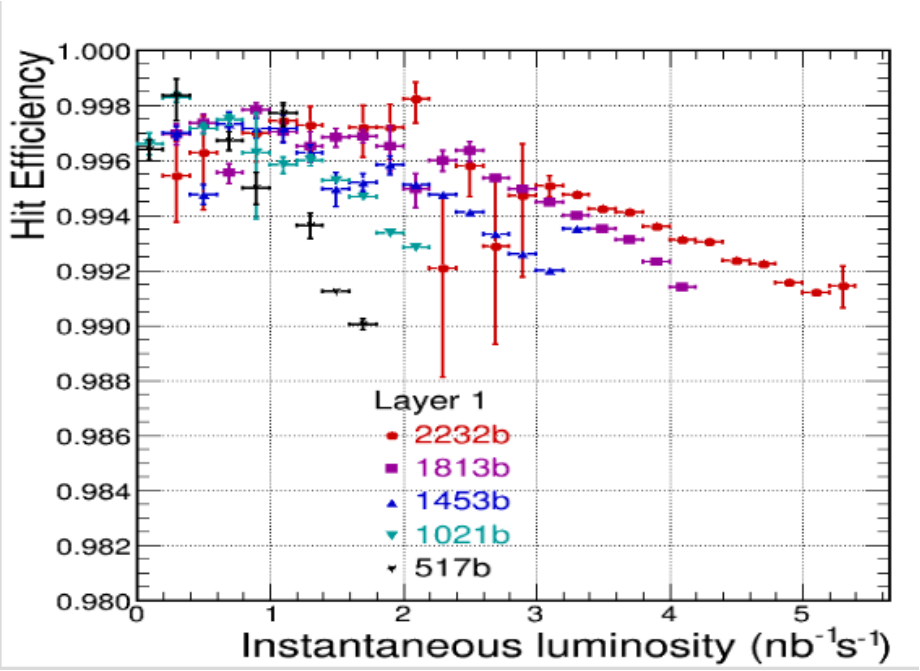


Isolation = $E + H_{6x9} - E_{2x5} - H_{1x2}$

Examples of cluster shapes

Tracker

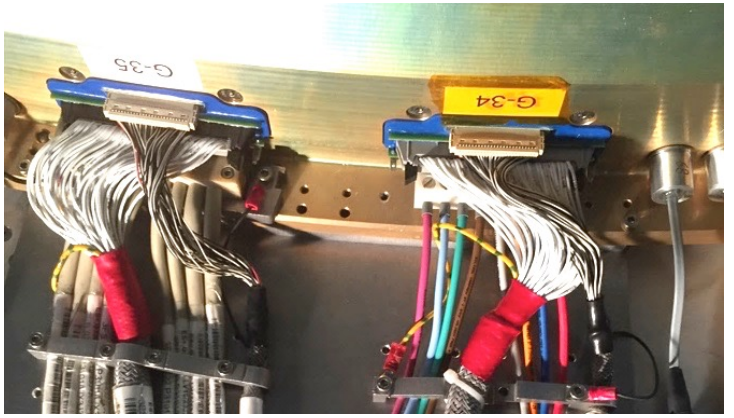
- Tracker in Heavy Ion run: smooth running with excellent data quality:
  - Specially developed readout board firmware allowed 5kHz L1 rate with only 1-2% only dead time.
- Detailed performance studies on-going:
  - Pixel detector resolution and hit efficiency as good as in Run 1
- Preparation for 2016 data-taking:
  - No major intervention on the detector;
  - Re-calibration has been started;
  - No serious performance degradation expected with higher luminosity
    - Pixel detector dynamic inefficiency in the first layer: ~2.5% at $1.2*10^{34}$



ECAL

- **Activities during the Winter shutdown:**
  - Refurbishment of low voltage power supplies:
    - Preventative maintenance of 136 units + spares.
    - **Units now reinstalled and operated.**
    - Completed mid-February.
  - Rework of Preshower (ES) low voltage connectors on detector:
    - Solve problem of unreliable LV connectors (responsible for 3% dead area during 2015)
    - **All ES LV regions are now recovered and ready for Physics**
    - Completed mid-February.
- **ECAL readiness review in early-February: confirmed to be in good shape for 2016 run.**

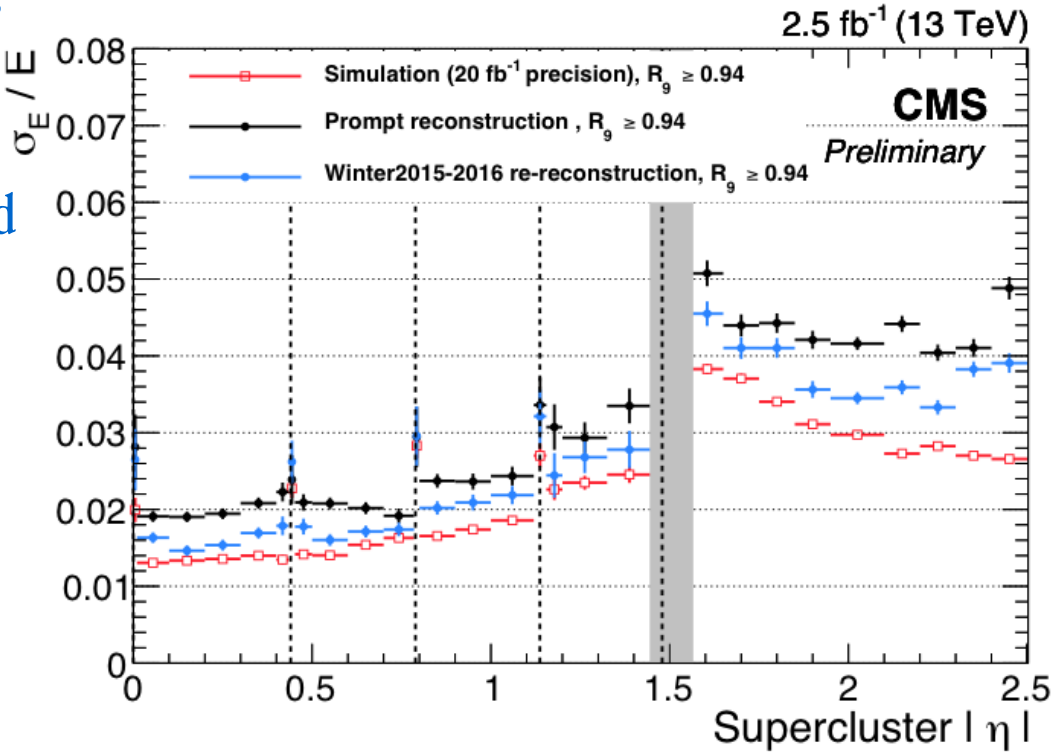
View of opened LV power supply
cooling block to be replaced seen at bottom right



ES Low voltage feedthroughs
Left: before rework; Right: after rework

ECAL Performance

- **Provided updated calibrations for winter conferences:**
  - Improved performance for 3.8 T compared to prompt reconstruction (evaluated using Z→ee events);
  - Also delivered new alignment and calibration for 0T data: improved energy scale and resolution.
- **Now preparing for 2016 run:**
  - New readout thresholds defined to account for higher pileup and noise in 2016;
  - Optimising calibration streams and thresholds to maximise rates of useful calibration events.



Relative electron resolution vs η

Measured using Z→ee events, on 2015 data and MC

Black: resolution achieved in the prompt reconstruction of 2015 data.

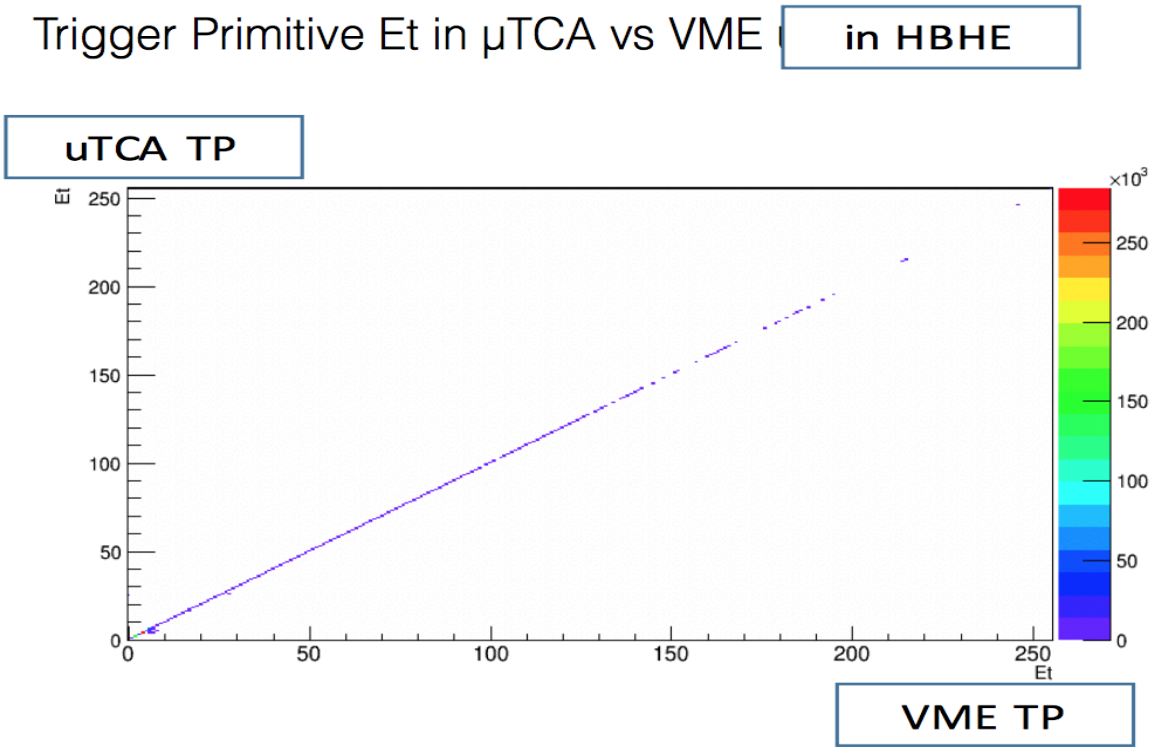
Blue: improved resolution achieved after recalibration

Red: predicted MC resolution, (assuming a larger dataset for calibration of 20fb^{-1})

HCAL Preparation for 2016

- Several maintenance tasks were performed on HCAL during the Year End Technical Stop (YETS).
- HCAL participates in mid-week global run, hardware has been checked out.

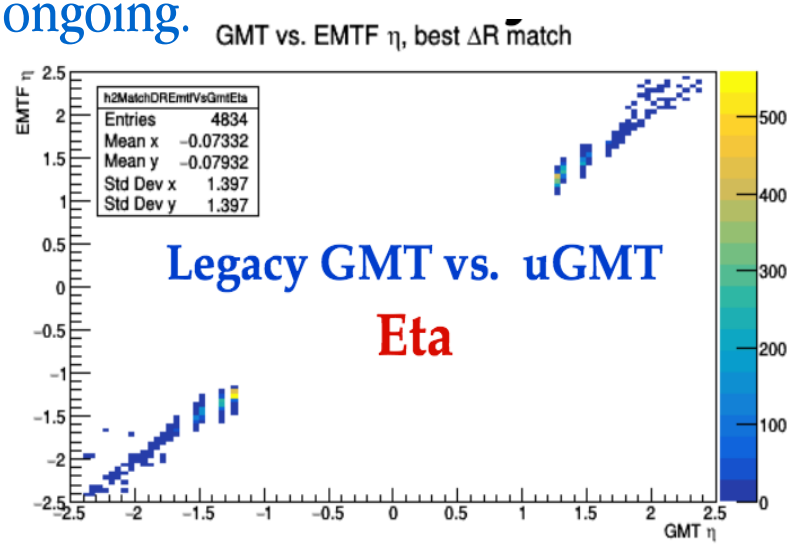
- Commissioning of HCAL trigger primitives generated in uTCA back-end is ongoing:
  - VME: legacy system;
  - uTCA: new stage-2 trigger.

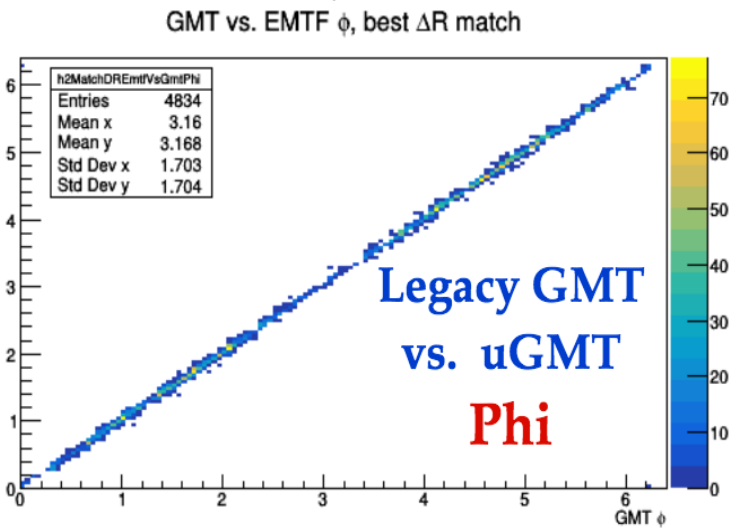


- Laser system to monitor radiation damage in HE scintillators has been re-commissioned.

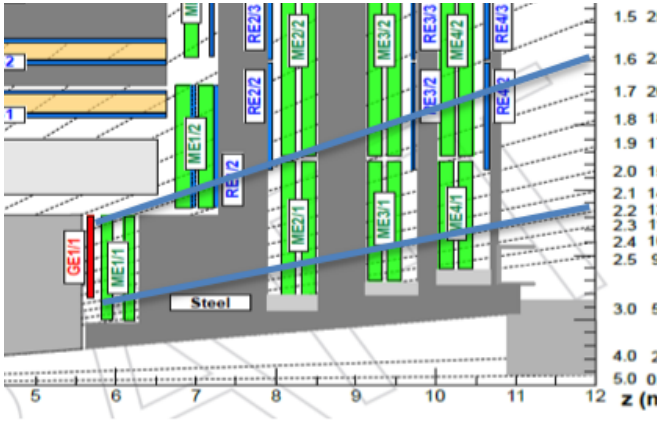
Muon Systems - Progress

- **Muon systems have been powered up in the new year and are working well.**
- L1 muon trigger upgrade requires extensive electronics work
  - Five crates with 60 new TwinMux boards, thousands of optical fibers installed, testing ongoing.



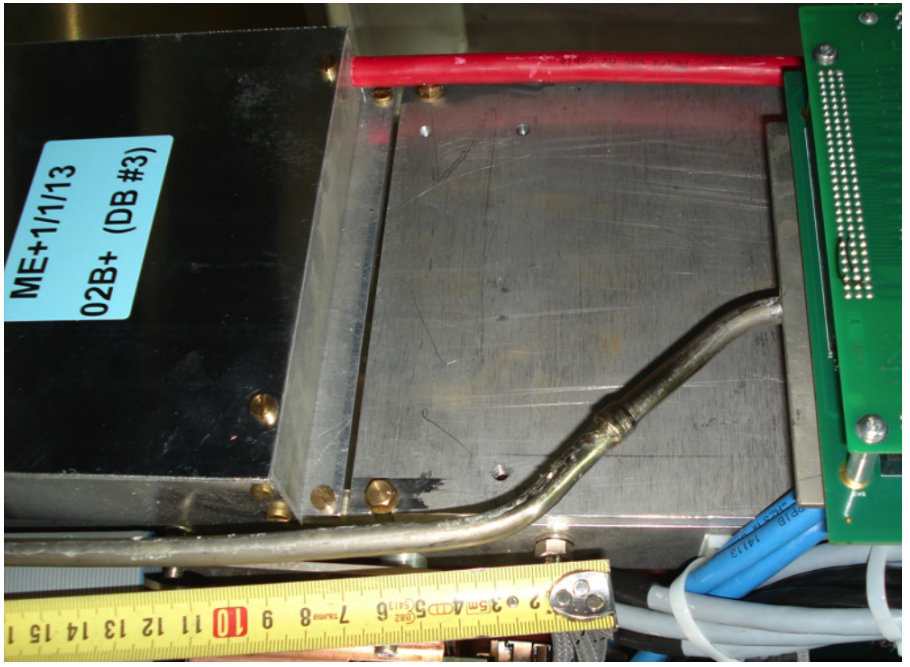


- The GE1/1 project (144 triple-GEM chambers to be installed in LS2) entering in production phase:
  - 8 chambers will be installed during YETS16-17 (2 chambers already assembled).



Intense End of the Run Period

- Mid-December: slow water leak discovered from a CSC chamber on the plus-endcap “nose”.
- Needed to stop Heavy Ion Run with an expected luminosity loss of about 5%.
- Required unplanned opening of the CMS detector endcaps for proper reparations:
  - Leaky brazed fitting was replaced, no significant damage was done overall
  - Leak detection, ability to isolate similar leaks in future have been improved
  - Eventually cooling circuits on ME1/1 chambers need to be replaced.



Magnet/Cryo System Revision

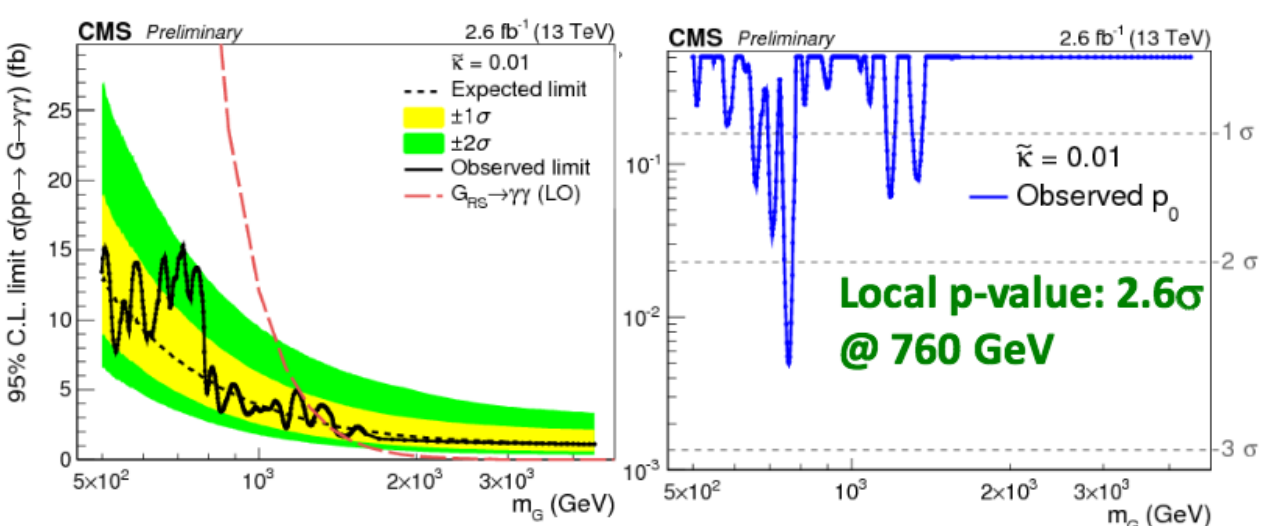
- **Cold box** cleaning with special solvent was successful (extraordinary work by CERN TE and EN departments).
- 370g of compressor oil removed. **All evidence consistent with this being the source of instabilities in 2015.**
- **Oil filters** (surface compressor hall), old oil removal system and coalescers dismounted.
  - All new components delivered (~2 week delay);
  - Reconnection & testing procedure is lengthy and must be done rigorously before connecting to new He transfer line leading underground to the cold box.

Estimate "magnet ready" in week of 25 April

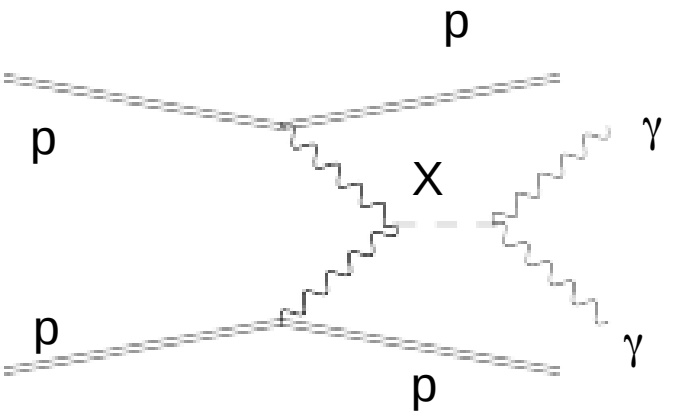
CMS-TOTEM Precision Proton Spectrometer (CT-PPS)

- Results presented at the LHC Jamboree motivated to advance by 1 year the actual 'Physics operations' (foreseen for 2017 in the original CT-PPS TDR).

CMS EXO-15-004



- The CT-PPS aims to explore among other things central exclusive events via gamma-gamma interactions.



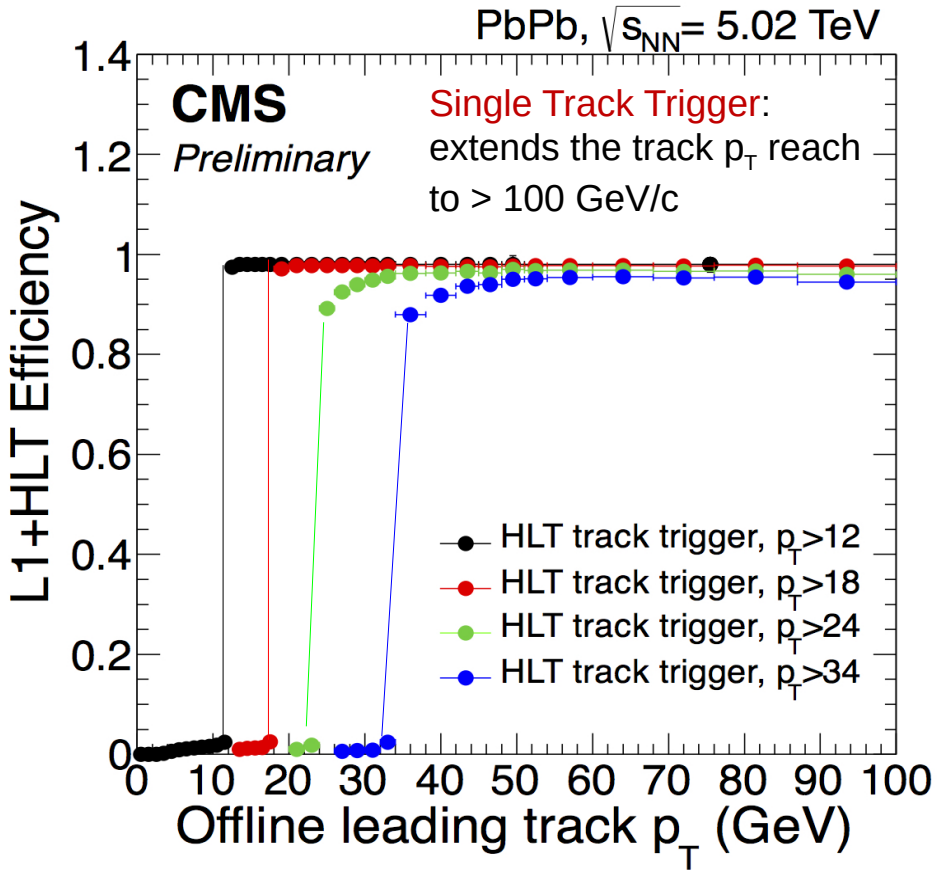
- Aim to integrate forward proton detectors in normal CMS runs at luminosity $\sim 10^{34}$.

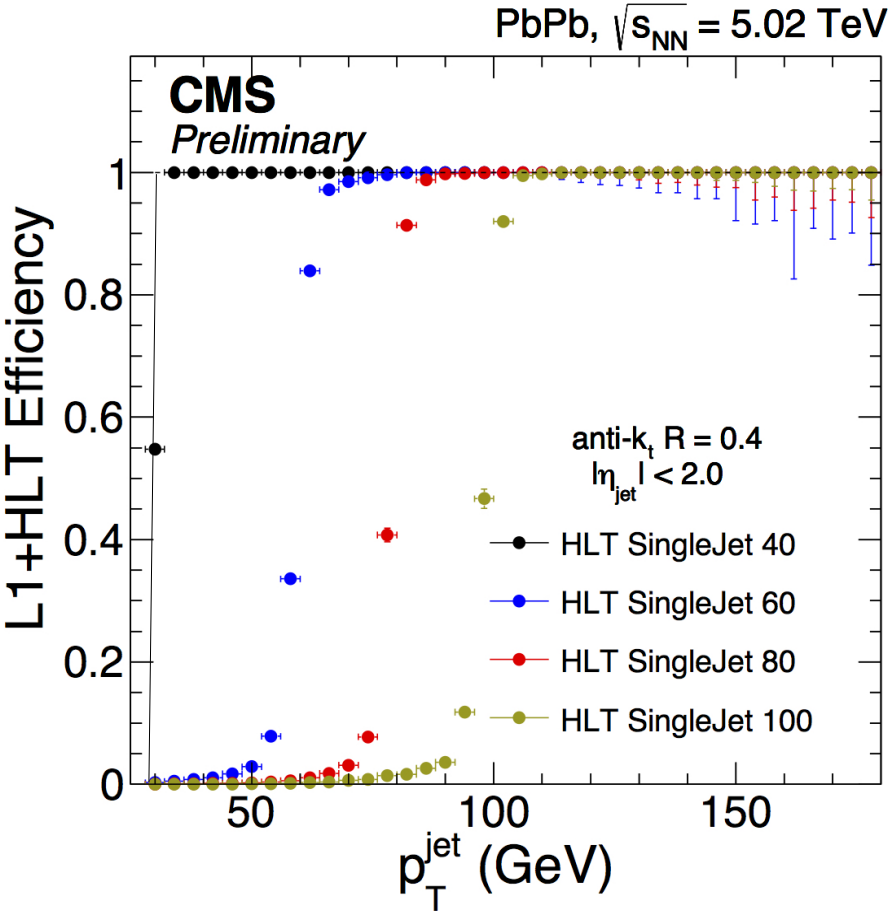
CT-PPS in 2016

- Successful Roman Pot insertion tests performed in 2015.
- Proton tracking detectors
  - use TOTEM silicon strip detectors (lifetime 10-20 fb^{-1});
  - replaced by 3D Pixel Detectors when ready (fall 2016);
  - CT-PPS mass resolution ~1-2%.
- Proton timing detectors
  - use Diamonds adapted from TOTEM developments (50 ps resolution);
  - pursue Fast Silicon and Quartic R&D in parallel.
- DAQ and reconstruction software being integrated in CMS.

Trigger

- Successful operation of the trigger during the 2015 pp and PbPb runs:
  - Some performance highlights from the PbPb run:





Trigger

- Level-1 and HLT menus are being put in place for the 2016 run:
  - Based on the upgraded phase I Stage-2 Level-1 trigger;
  - Will cover different LHC scenarios:
    peak luminosities of 10^{34} -1.3*10^{34} $cm^{-2}s^{-1}$ (Pileup $\sim 25-35$);
  - **Will include many improvements in trigger algorithms to handle the expected increases in rate and pileup ;**
  - **Progress is also being made in finalizing triggers for detector calibration/alignment and special runs .**
- Dedicated menus in preparation for the commissioning period at P5.
- Improvements ongoing for online DQM and Level-1 and HLT rate monitoring.

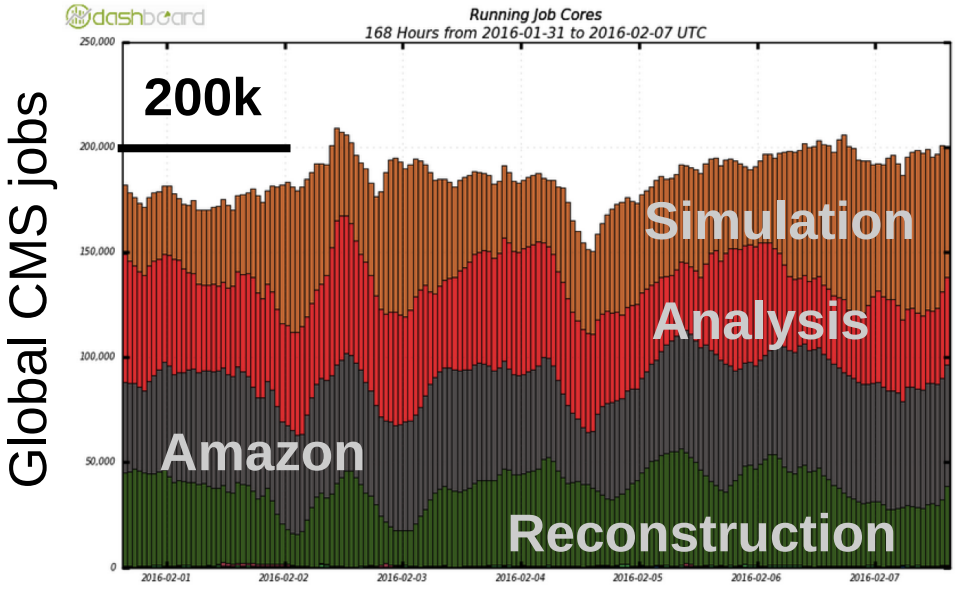
Commissioning Before the Beams

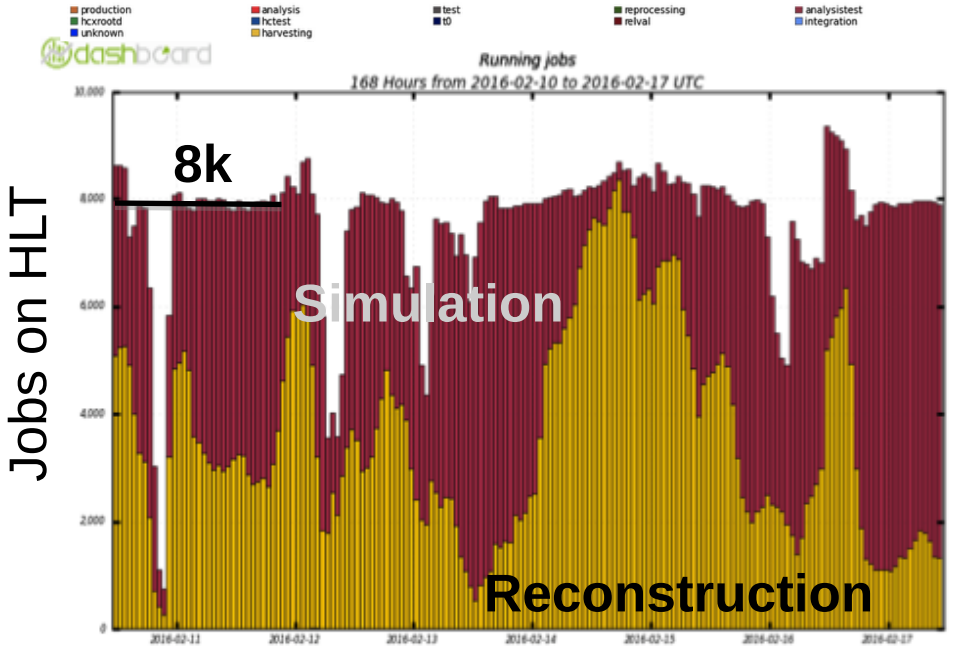
February- March 2016

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

- Series of Mid Week Global Runs (MWGR) for detector commissioning
- MWGR#1: re-establish 2015 conditions/performances.
- MWGR#2: establish global running with upgrade trigger chain;
- MWGR#3, 4: consolidate global running with upgrade trigger and collect cosmics for tracker alignment.

Software/Computing Status



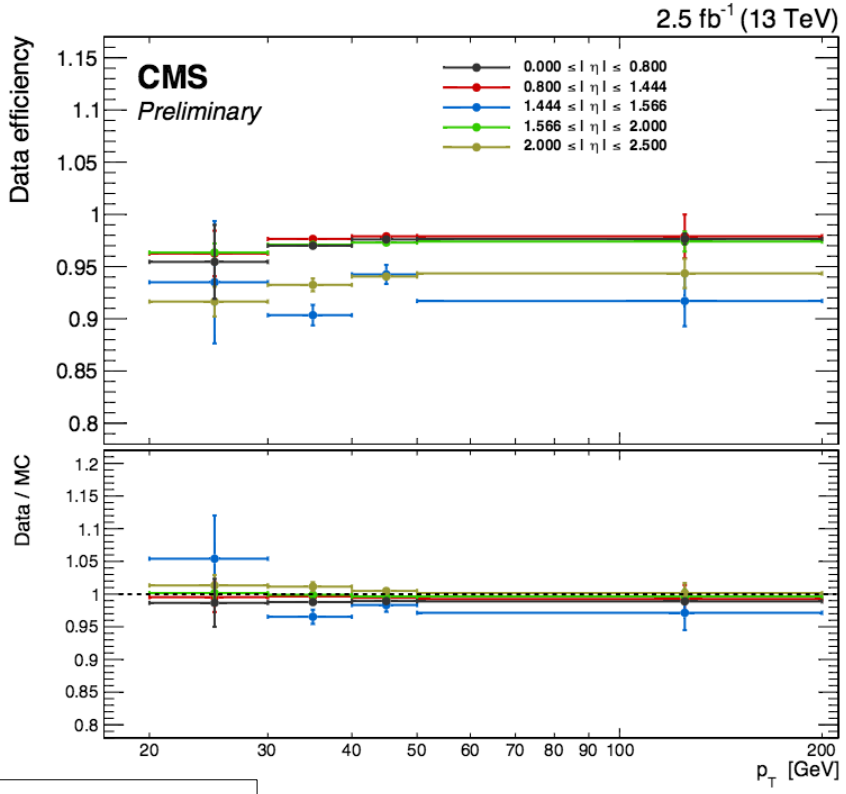


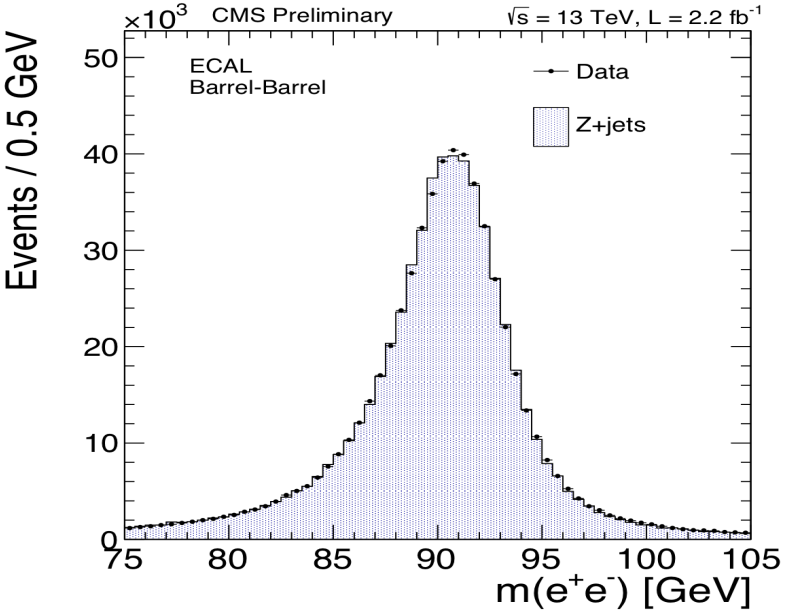
- In 2015 very stable operations across CMS Computing Centers.
- Exploiting new resources:
  - Part of Monte Carlo production done using Amazon "cloud".
- Completed major end-of-year re-reconstruction for 2015 data and MC.
- Global pool reached 200k jobs including commercial cloud and HLT resources:
  - About 5% of the jobs running on our HLT machines.

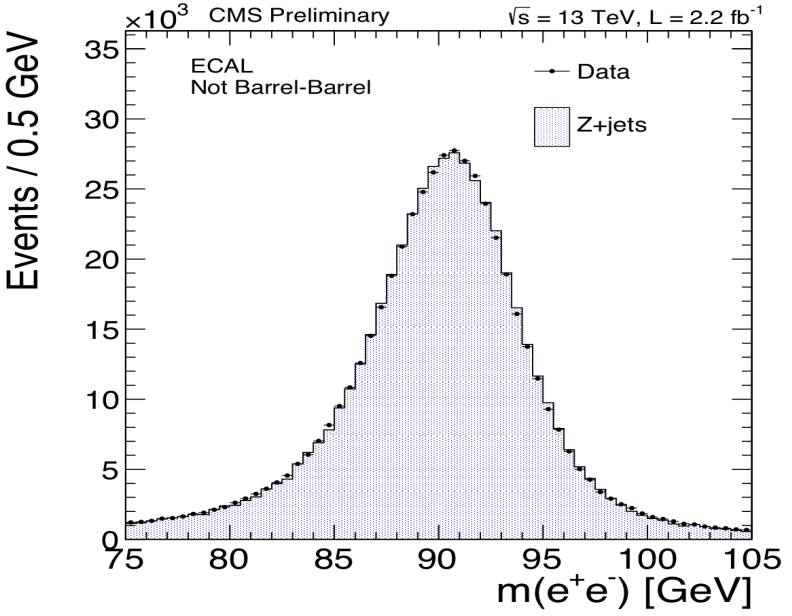
Physics Readiness

Electrons and Photons

- Finalized Reconstruction/ID efficiency measurements.
- New energy scale/smearing corrections.
- In view of 2016 data-taking:
  - Tested possible improvements in energy corrections (i.e. regression) and isolation.



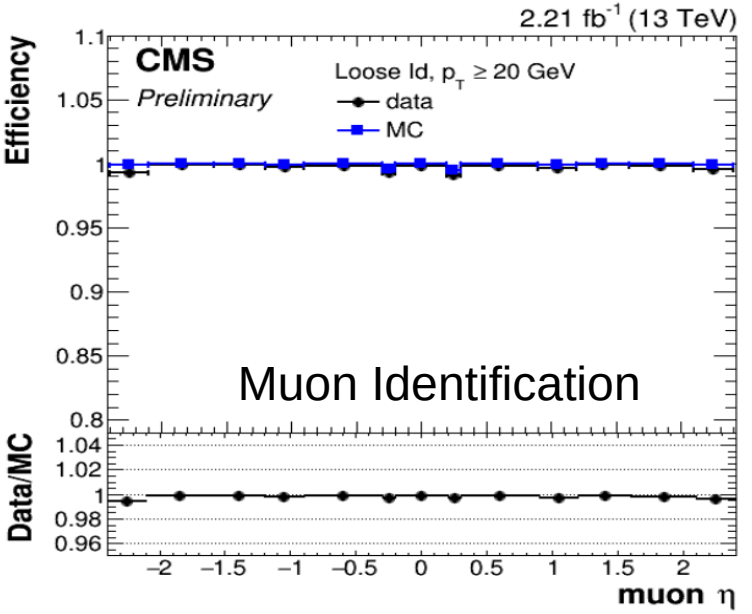


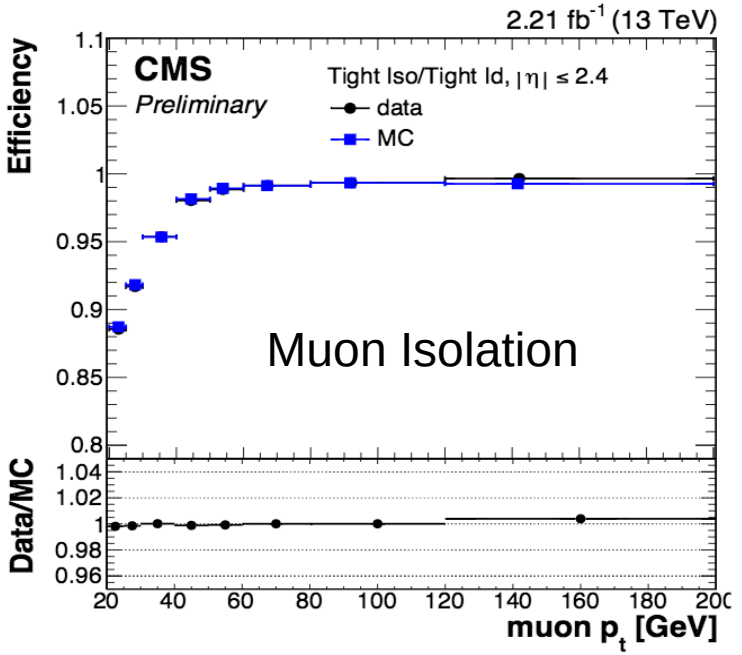


CMS DP-2015-67

Muons

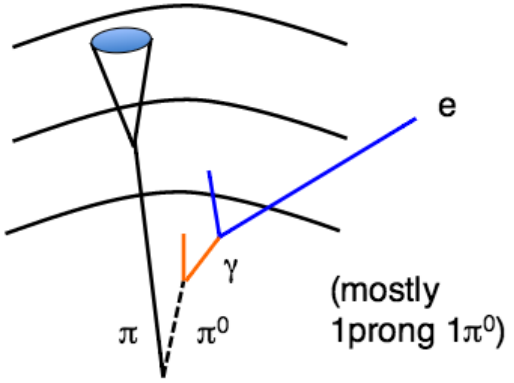
- New alignment conditions deployed in data re-reco improve muon momentum resolution:
  - First version of momentum scale/resolution corrections (serving precision analyses) was produced.
- Reco/ID/Trigger scale-factors computed for Winter conferences.
- Physics impact from deployment of muon alignment position error in reconstruction was studied.
- Activities on the front of checking performance of new techniques for pileup mitigation in isolation.

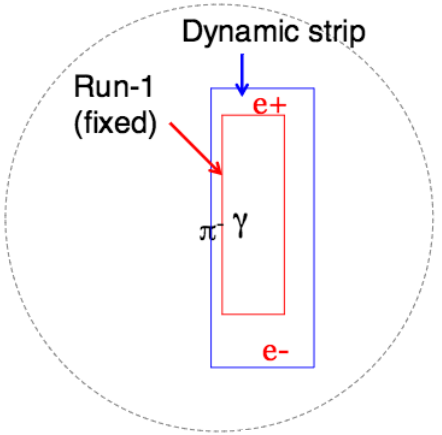


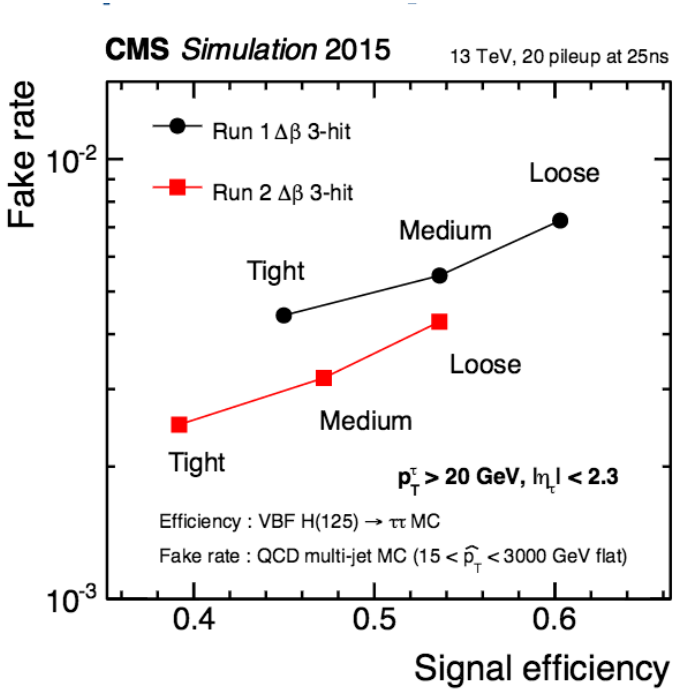


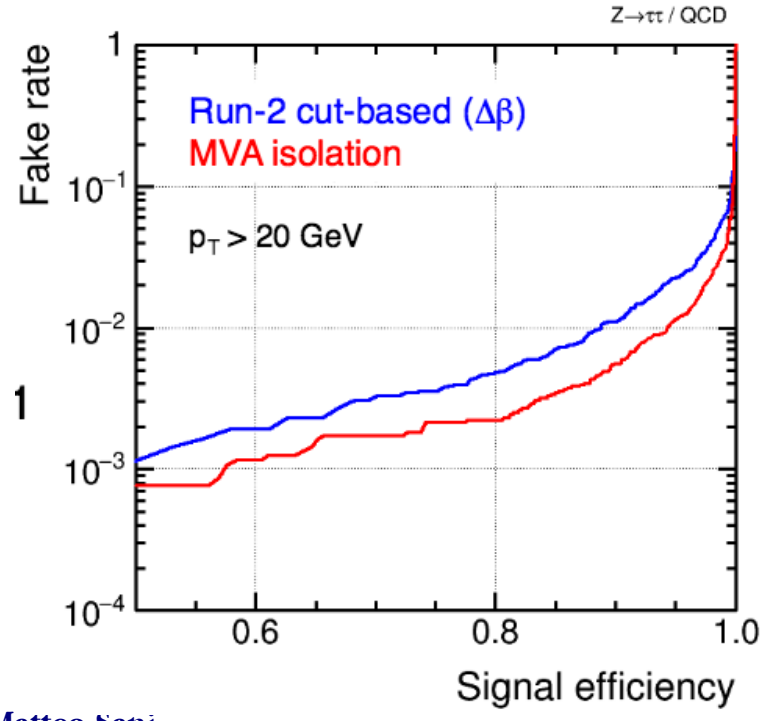
Taus

- Improvements in tau reconstruction/ID.



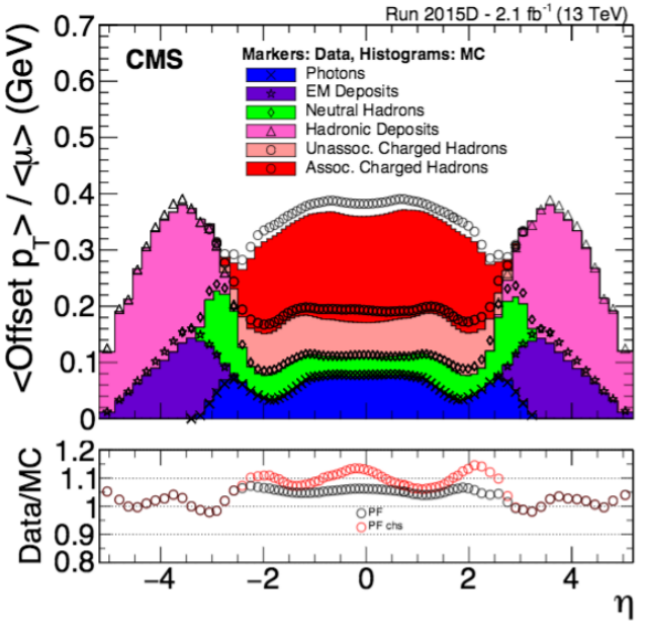


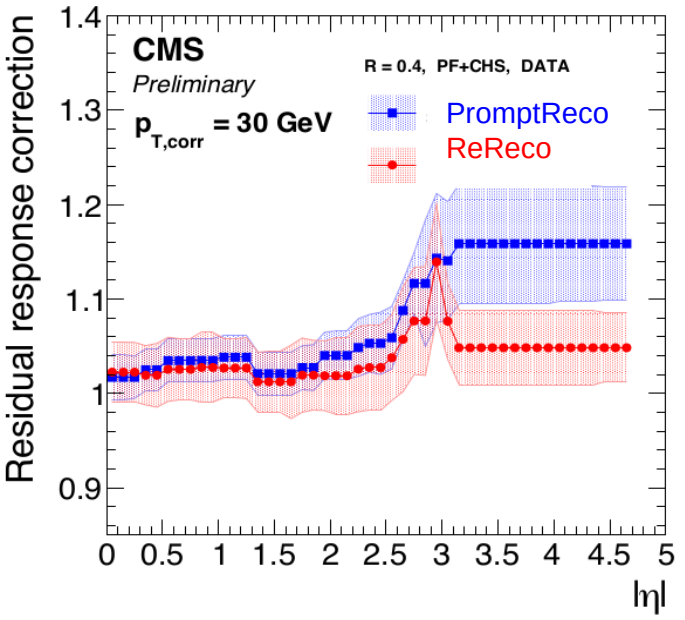




Jets and MET

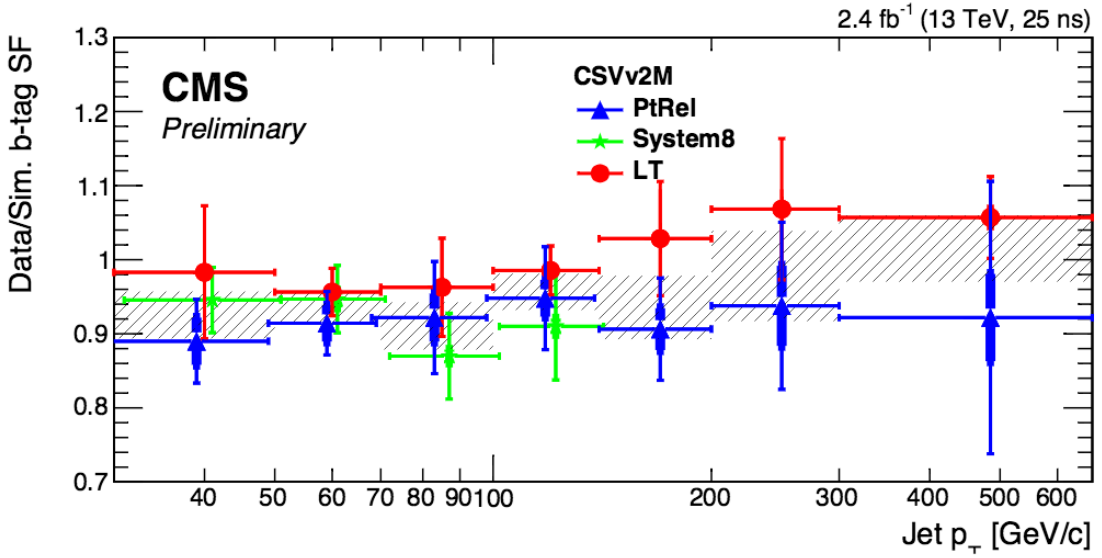
- Intensive work to provide updated jet energy corrections:
  - Stability in jet response vs eta and pT similar to Run I;
  - Data/MC agreement is satisfactory in all components;
  - Strong Improvement in HF with rereco;
  - Residual data/MC correction in Prompt vs Rereco mostly within 5%.
- Missing energy resolution simulated $Z \rightarrow \mu\mu/ee$ events:
  - Excellent agreement between channels.

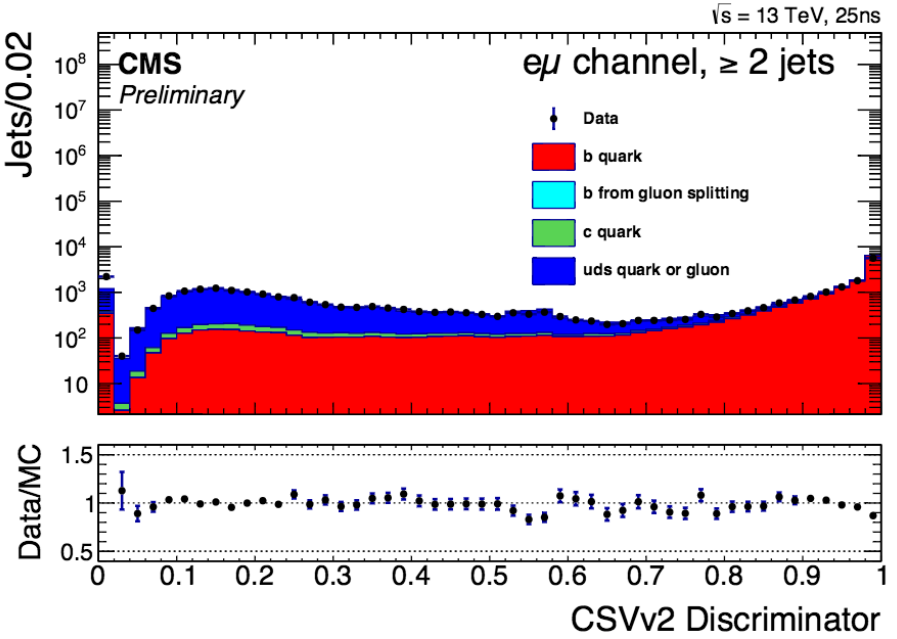




B-tag and Vertexing

- B-tagging performance with 25ns data has been documented in: **CMS DP-2015/056.**
- Released an updated version of b-tag scale factors.
- New b-tagger with significant performance improvement over the existing methods has been recently released.





Summary

- After a successful 2015 CMS is getting ready for the challenges of 2016:
  - Expected O(30 fb^{-1}) of data to analyze !
- Detector commissioning is successfully ongoing:
  - Dedicated Global Runs to test new components (e.g. new L1 system).
- The performance of our physics objects at 13 TeV has been documented and further improvements have been prepared to cope with new conditions.
- The Collaboration is finalizing Run I and 2015 analysis and is looking forward to analyze the incoming larger dataset !

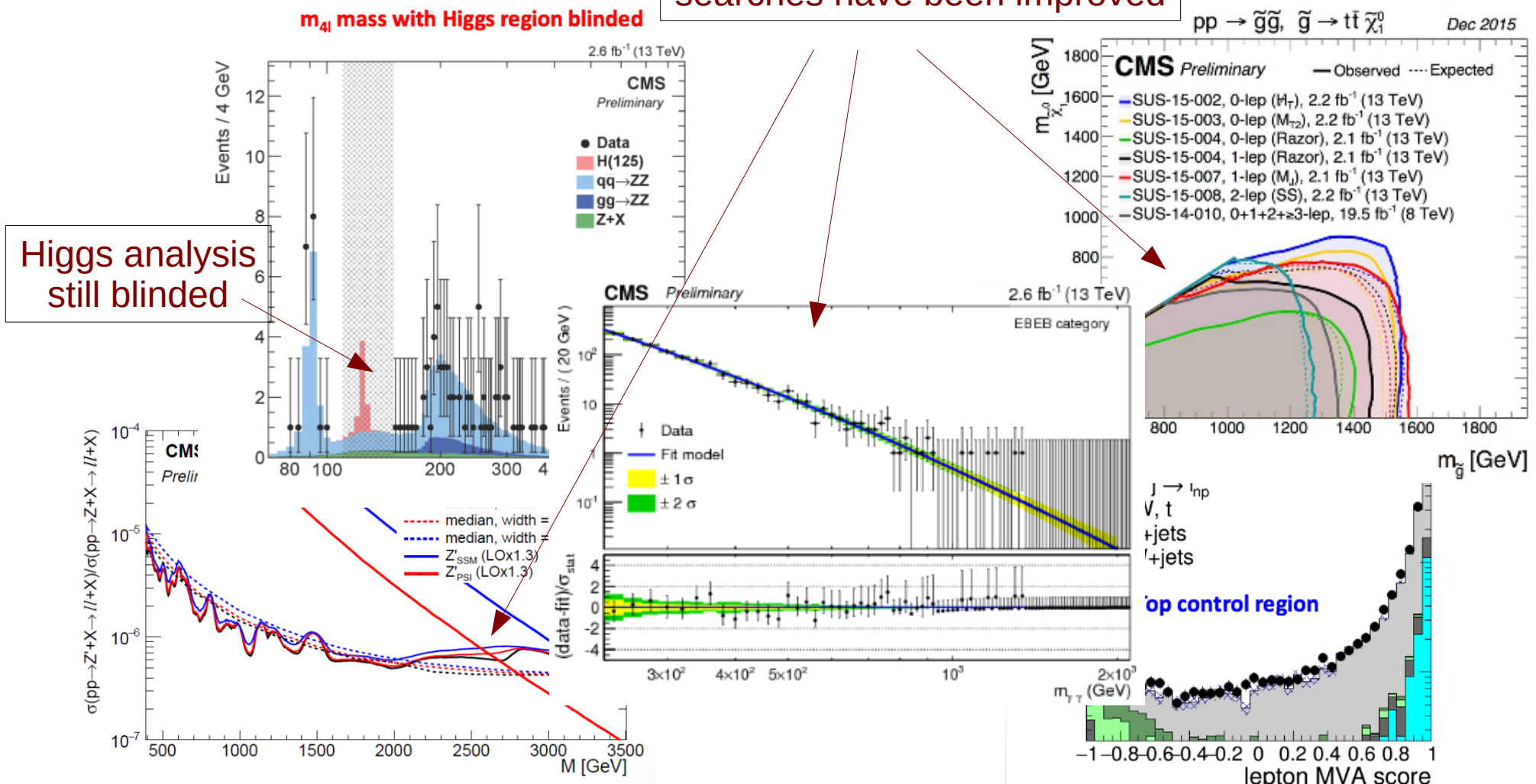
Back-up

Preparation for Moriond

- Most of the analysis are currently under scrutiny before being made public !

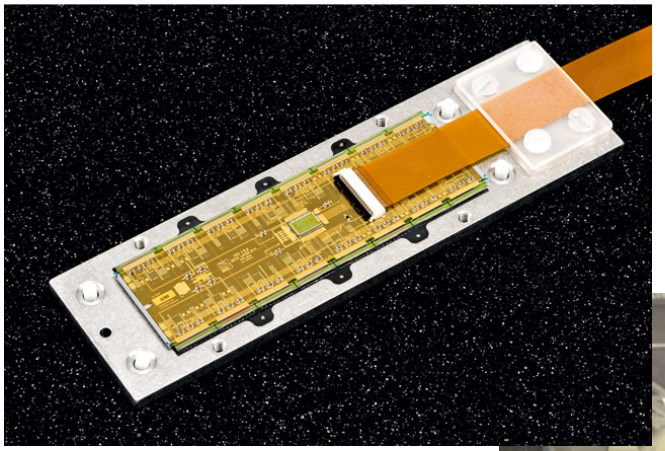
Exotica and SUSY searches have been improved

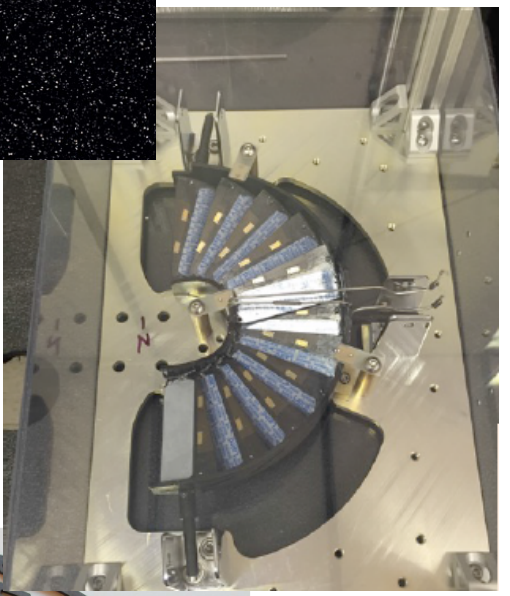
Higgs analysis still blinded

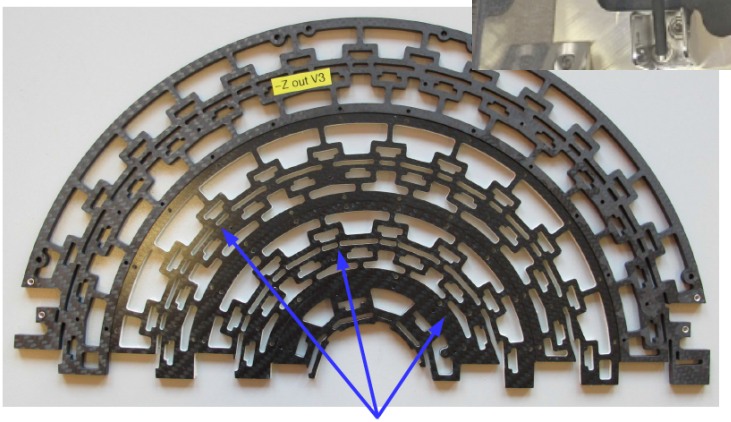


Phase 1 Pixel Upgrade

- Module production is on-going
  - Low yield for the forward disk modules being addressed
- Mechanics is being assembled
- Service electronics procurement almost completed
- Development of the firmware for uTCA readout boards in progress

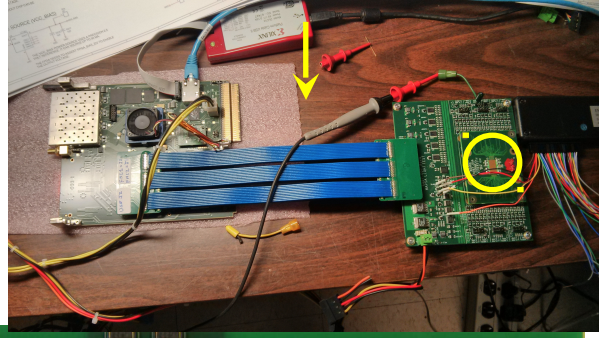


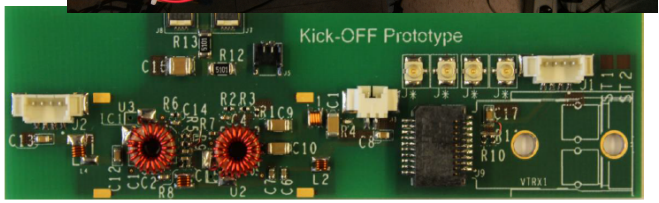


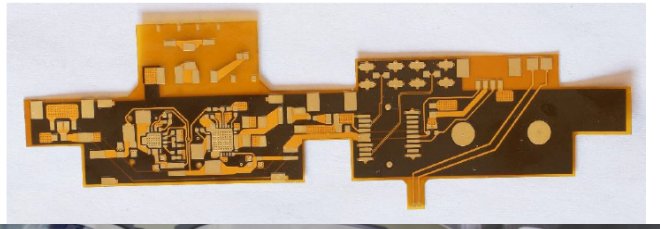


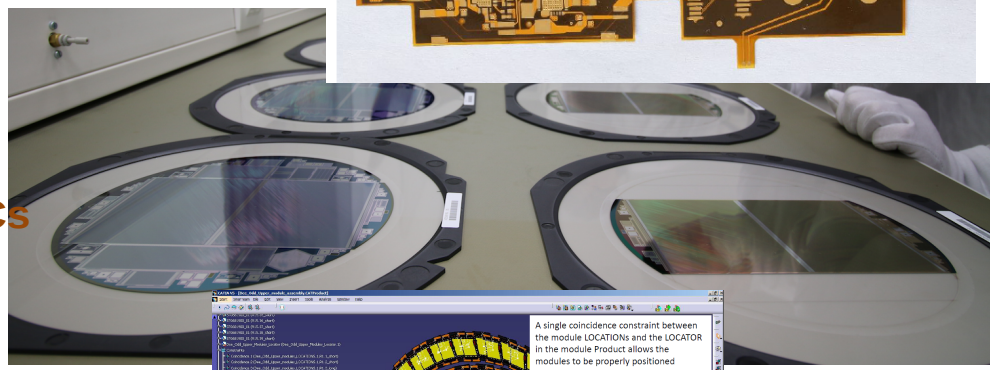
Outer Tracker – recent progress

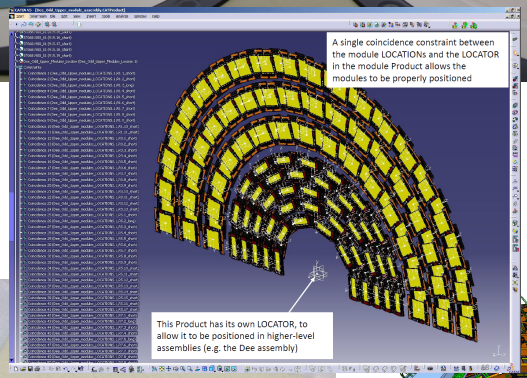
- Full-size 2S module prototype and MaPSA-light (small-size Macro-Pixel Sub-Assembly prototype) successfully tested in beam
- Further iteration: MaPSA-light successfully produced at all three assembly companies
- First prototype power chain assembled and operated successfully
- Large n-in-p sensors of 200 μm thickness produced at Infineon with very good quality
- Progressing with final design of all front-end ASICs
- Good progress in design and prototyping of mechanical structures
- L1 tracking demonstrators becoming operational
- Still working on qualifying a second source for the front-end hybrids (assembly in progress)

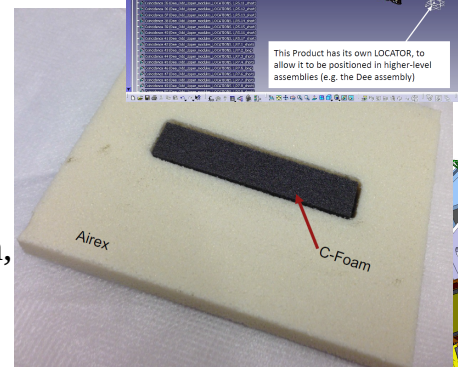


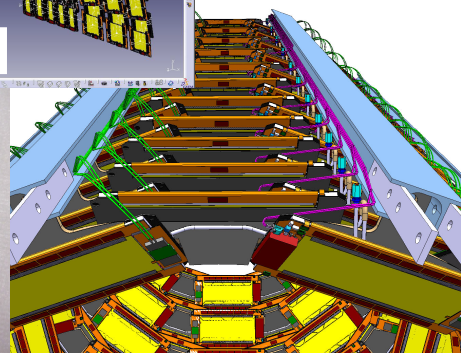












Pixel – recent progress

- **Digital radiation test chip being finalized**
  - **Joint effort RD53A, lpGBT team and CMS MPA/SSA team**
- **Study of pixel insertion scenarios and optimization of OT/Pixel boundary ongoing**
- **R&D on serial powering ongoing**
  - **Test setup operational in Florence, based on ATLAS FeI4**
  - **Simulation effort started at CERN**
- **R&D on data links continuing**
  - **Both simulations and lab tests**
  - **First encouraging results with Alu flat cable**

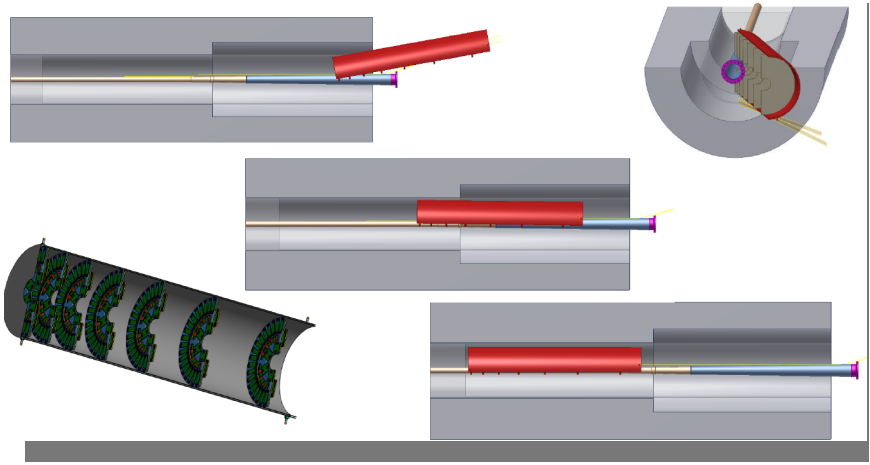
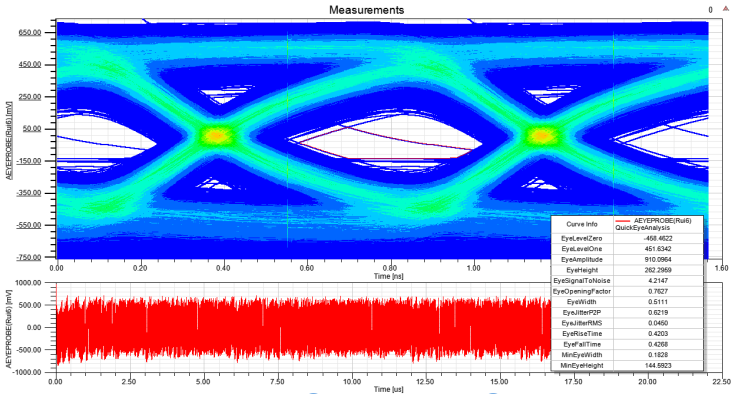
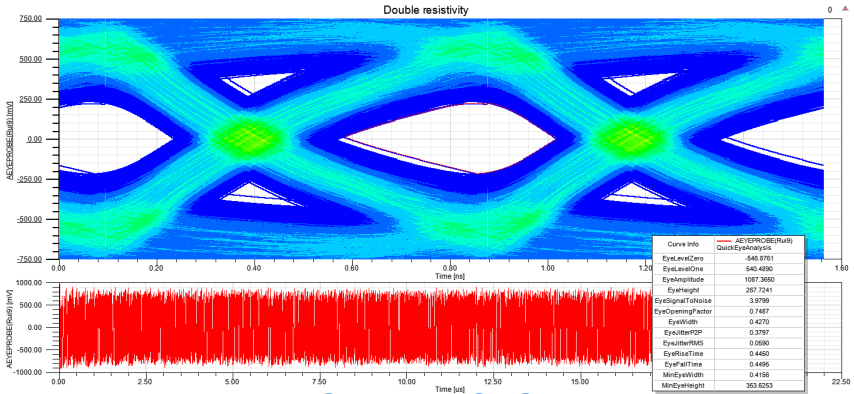


Figure from serial powering



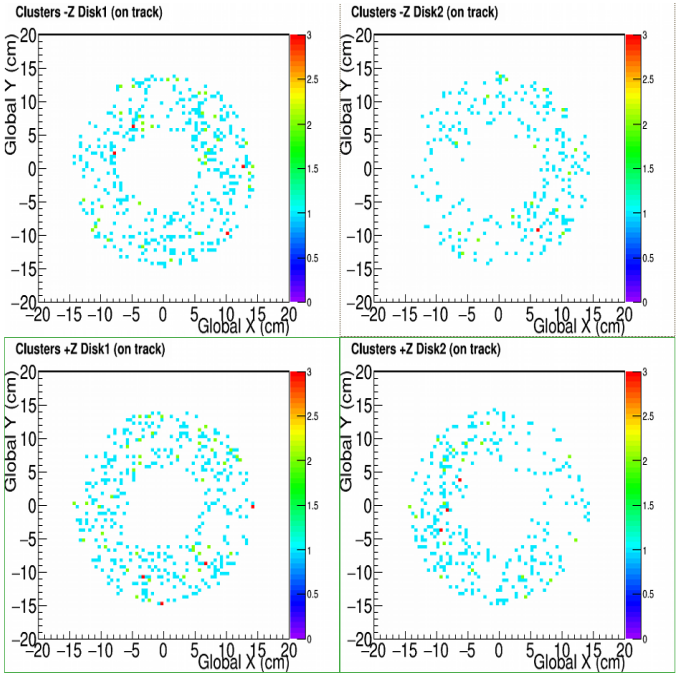
MEASUREMENTS



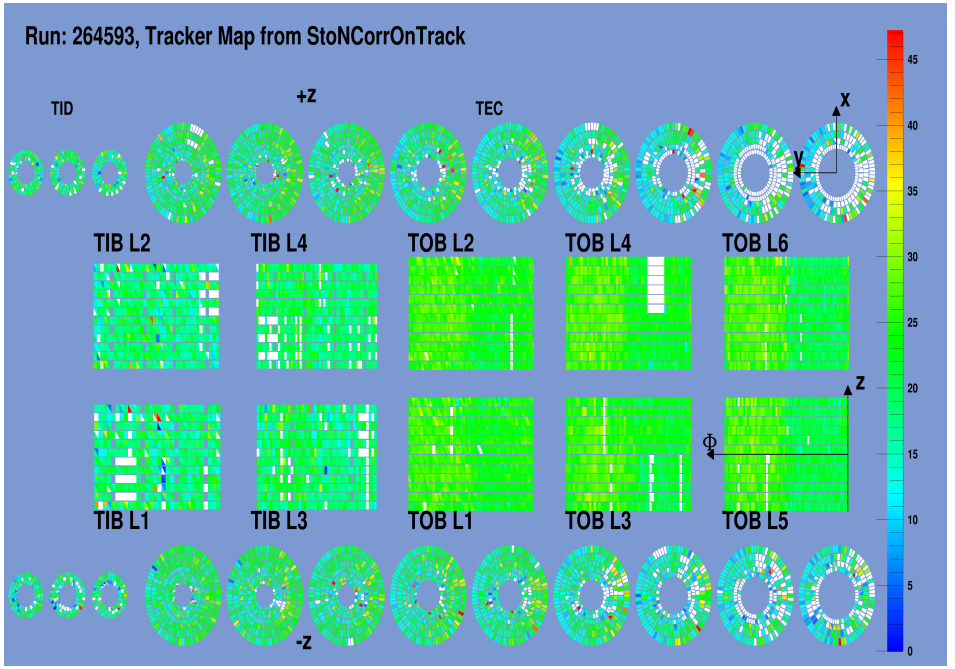
SIMULATIONS

Tracker/Tracking in Cosmic Run

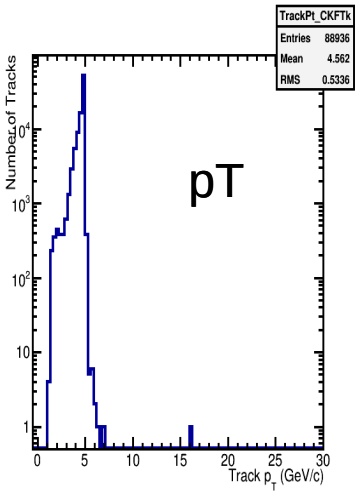
Pixel Occupancy

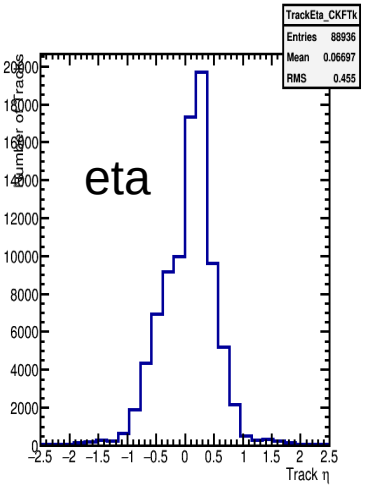


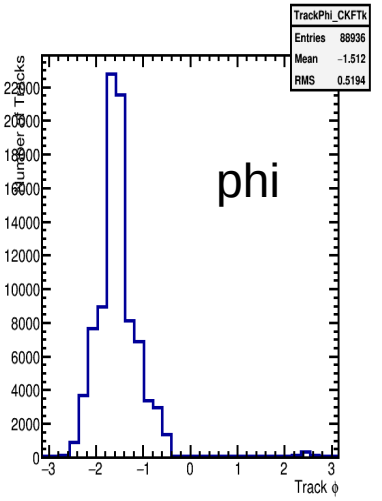
Strip detector: signal over noise map



Track reconstructed during recent Cosmic Runs



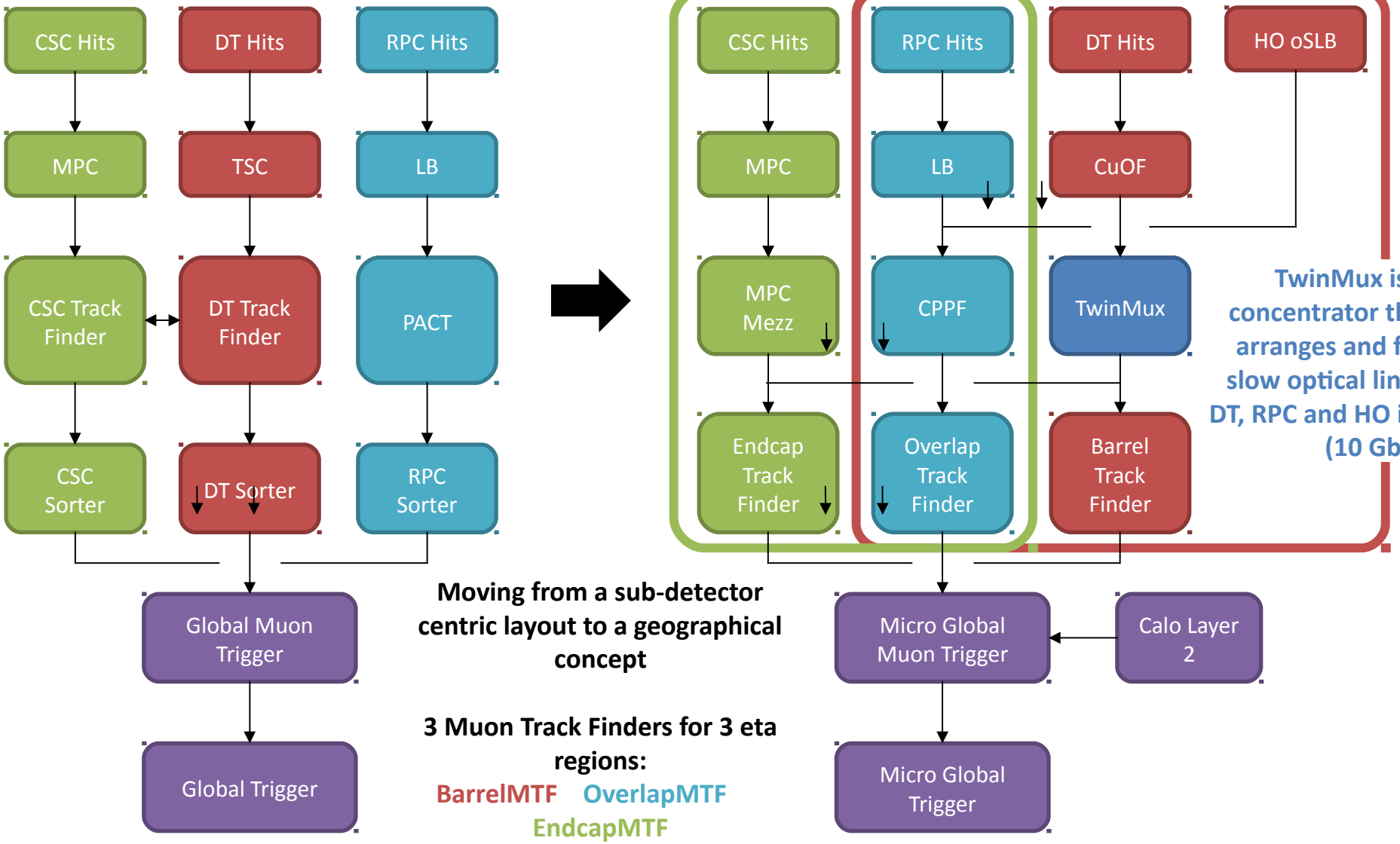




TwinMux for L1 Trigger Upgrade

PHASE 1 UPGRADE

FROM A. TRIOSSI



TwinMux is a data concentrator that merges, arranges and fan-out the slow optical links from the DT, RPC and HO in faster links (10 Gbps)

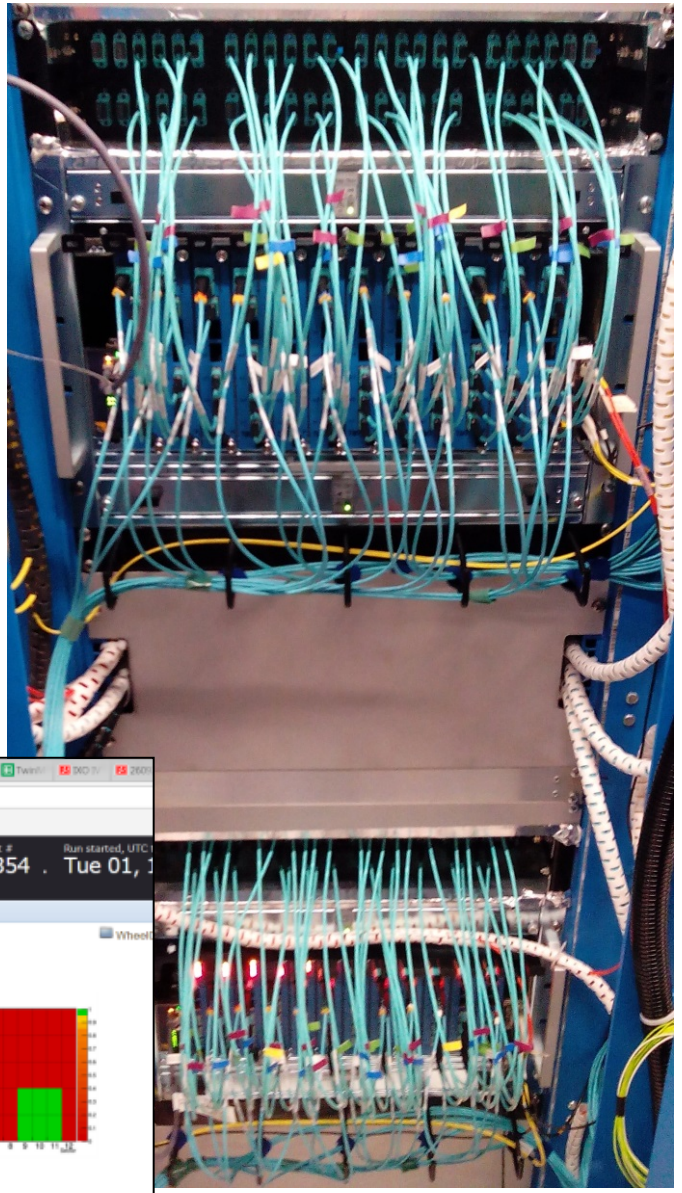
Moving from a sub-detector centric layout to a geographical concept

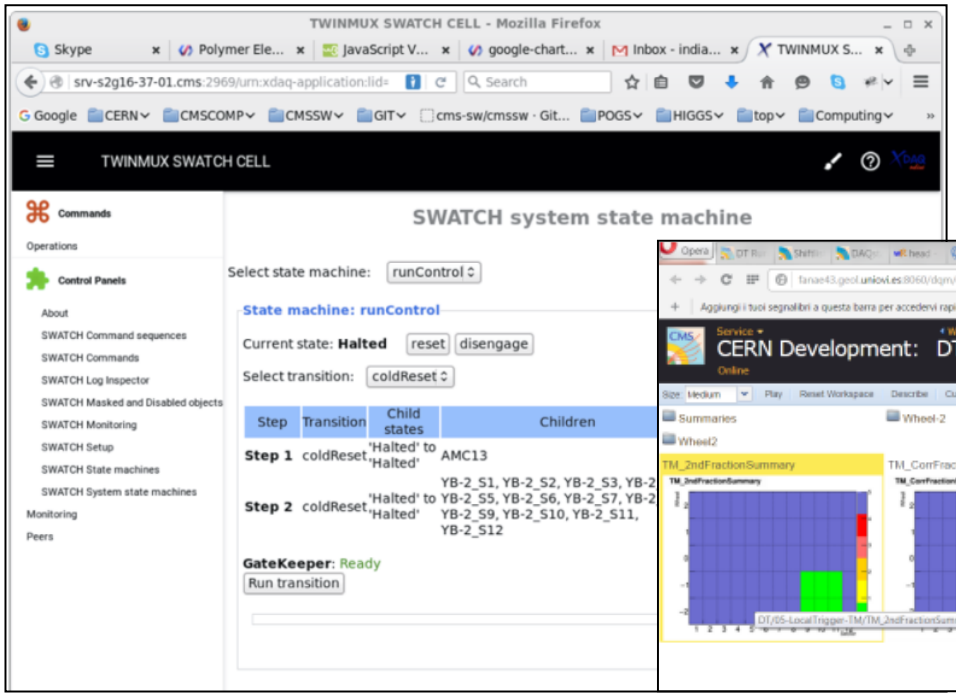
3 Muon Track Finders for 3 eta regions:

BarrelMTF OverlapMTF EndcapMTF

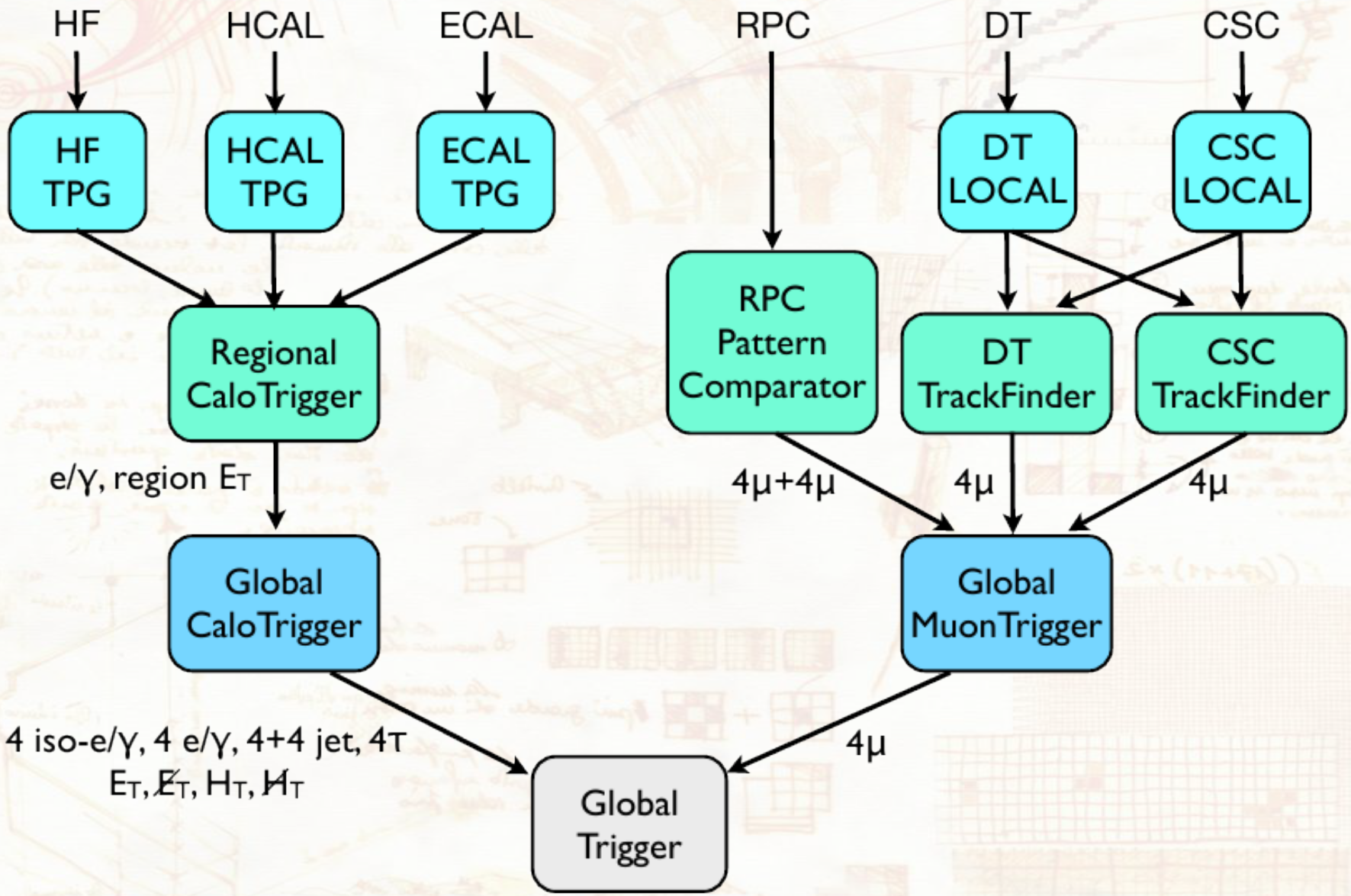
DT Phase 1 Upgrade: TwinMux

- Replacement of the second level of DT trigger electronics
- Installation during this YETS is completed:
  - 5 crates (60 TwinMux) fully equipped of MCH, AMC13, etc.
  - Input (DT+RPC) and output (to BMTF) connected
- Participation in Global Runs has been successful. Technical trigger (to the DT LPM) connected.
- Online and offline SW advancing at full speed.

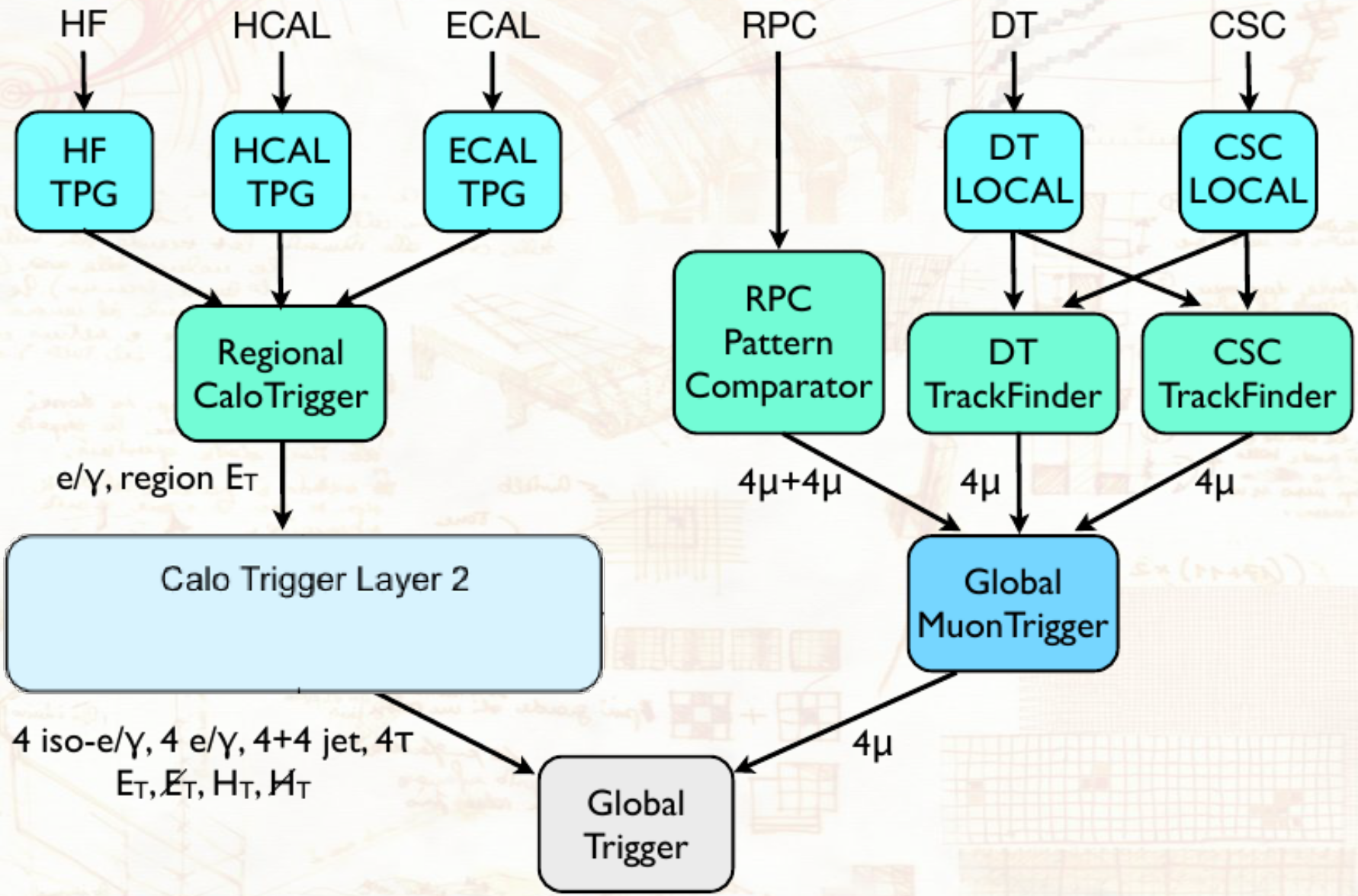




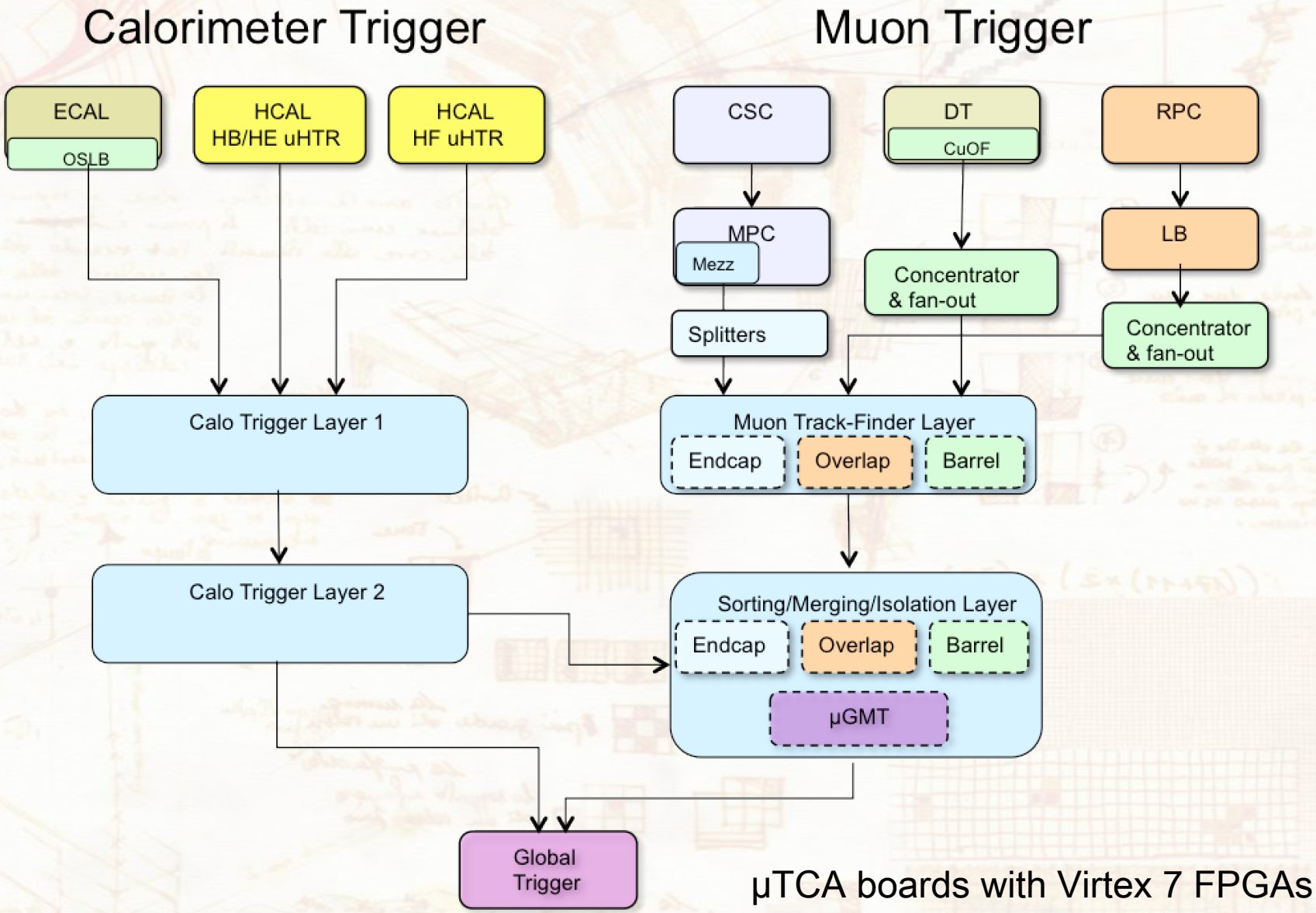
2009 – 2012


HF
HCAL
ECAL
RPC
DT
CSC
HF TPG
HCAL TPG
ECAL TPG
DT LOCAL
CSC LOCAL
Regional CaloTrigger
RPC Pattern Comparator
DT TrackFinder
CSC TrackFinder
e/γ, region ET
4μ+4μ
4μ
4μ
Global CaloTrigger
Global MuonTrigger
4 iso-e/γ, 4 e/γ, 4+4 jet, 4τ
ET, ET, HT, HT
4μ
Global Trigger

2015


HF
HCAL
ECAL
RPC
DT
CSC
HF TPG
HCAL TPG
ECAL TPG
DT LOCAL
CSC LOCAL
Regional CaloTrigger
RPC Pattern Comparator
DT TrackFinder
CSC TrackFinder
e/γ, region ET
4μ+4μ
4μ
4μ
Calo Trigger Layer 2
Global MuonTrigger
4 iso-e/γ, 4 e/γ, 4+4 jet, 4τ
ET, ET, HT, HT
4μ
Global Trigger

2016 – …



µTCA boards with Virtex 7 FPGAs