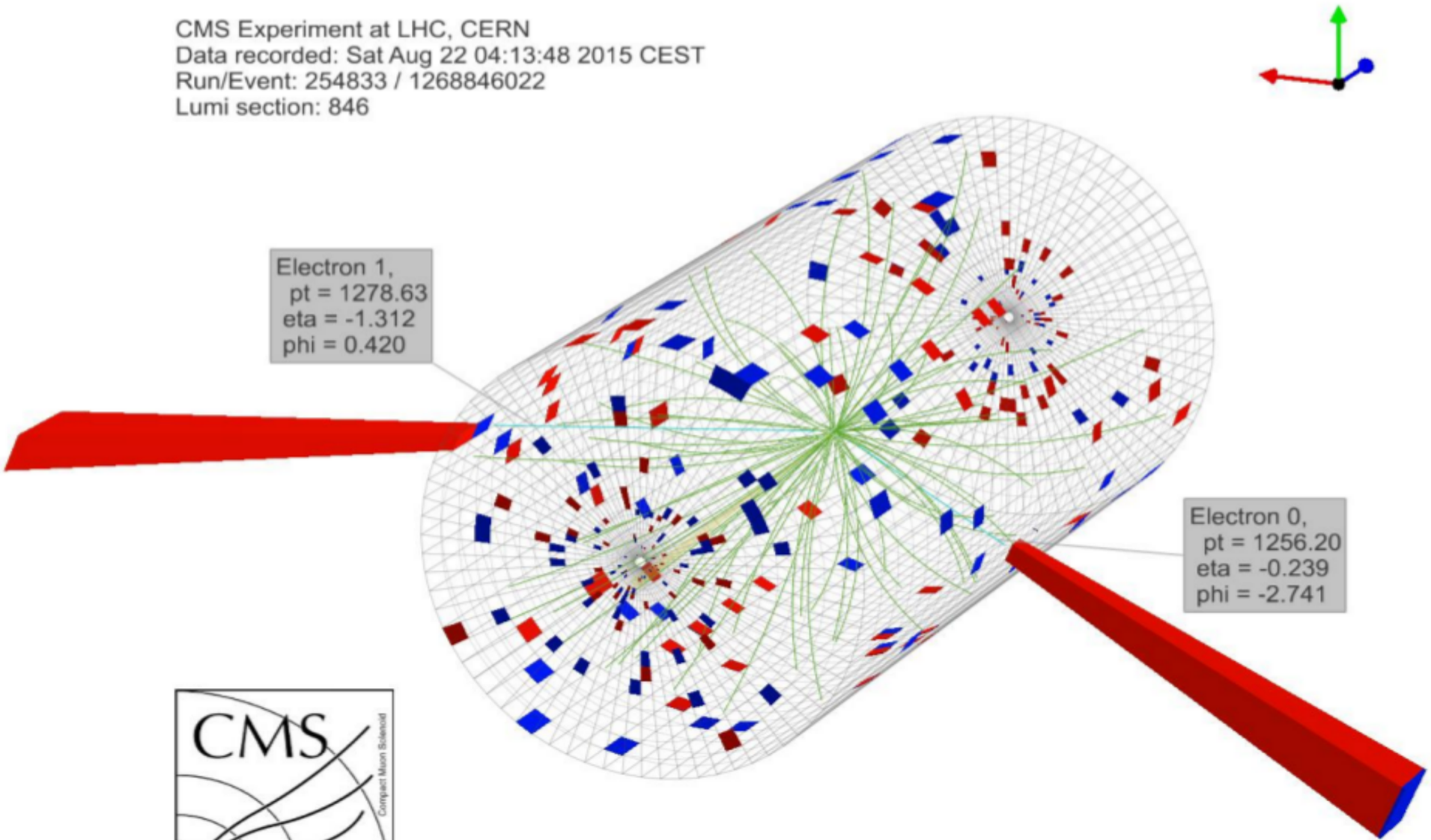
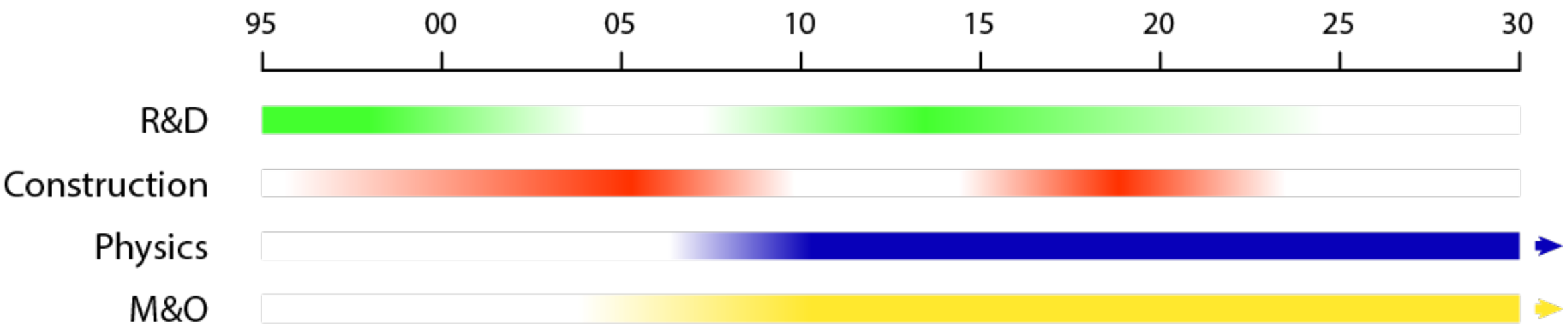
CMS Status



$m_{ee} = 2.9\text{TeV}$!

Dave Newbold
on behalf of CMSUK

The Long View



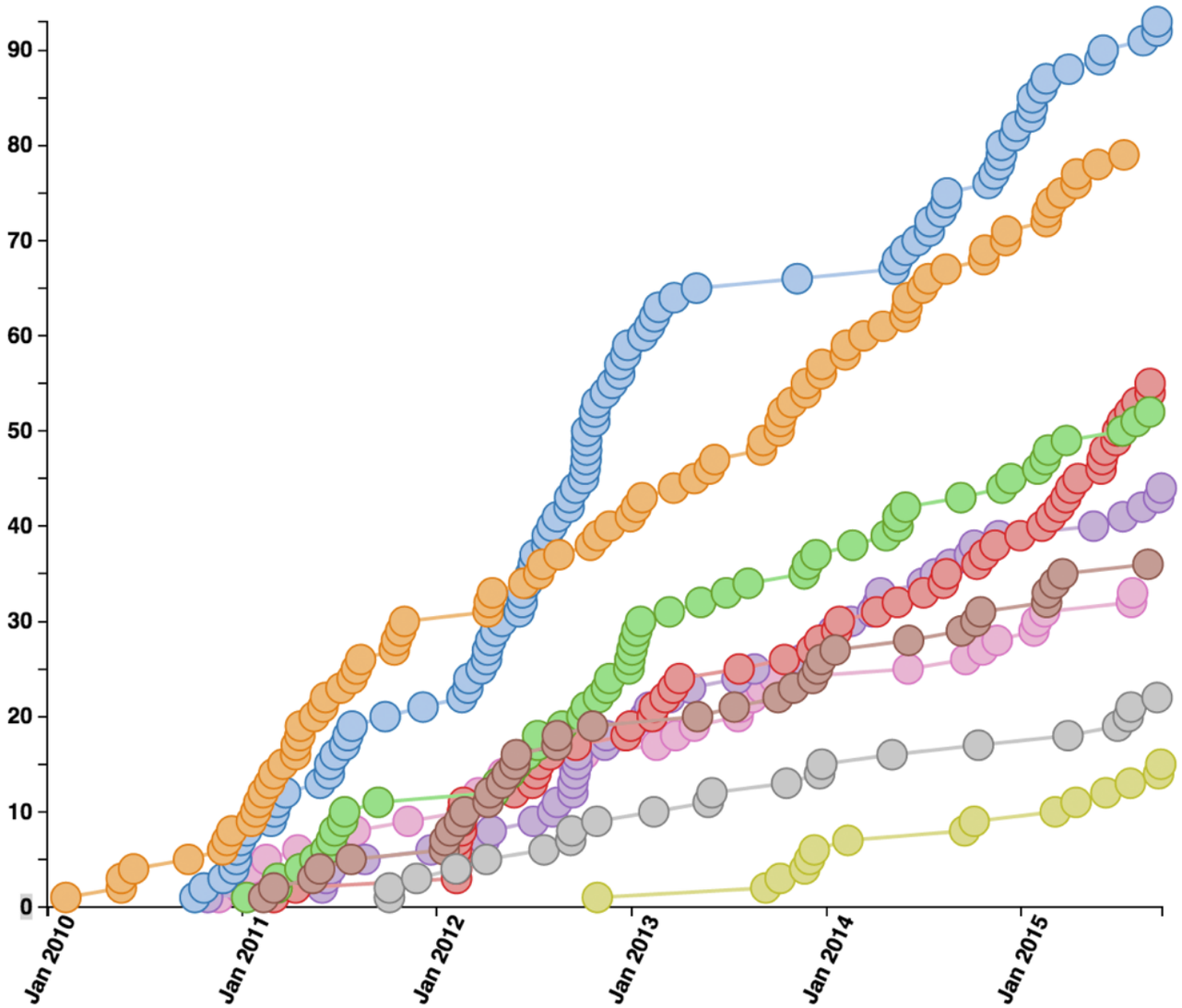
- Upcoming 'Run II' possibly *the* crucial era in the LHC programme
  - Potential for discovery is greatly enhanced in 13TeV running
  - Detectors and analysis techniques well understood; conditions relatively stable
- The challenge
  - Over 20 years, we successfully constructed detectors and then exploited them
  - In Run II: physics, R&D, construction and M&O happen in parallel
  - The load on the collaboration is now higher than ever before
- CMS is in good shape for Run II
  - However: 2015 has taught us not to take anything for granted
  - Huge work has been required for the (successful) re-commissioning of CMS

Publications to Date

Show all | Total | Exotica | Standard Model | Supersymmetry | Higgs

Top Physics | Heavy Ion | B Physics | Forward Physics | Beyond 2 Generations

428 papers submitted as of 2015-09-21



3833 papers found, 3162 of them citeable (published or arXiv)

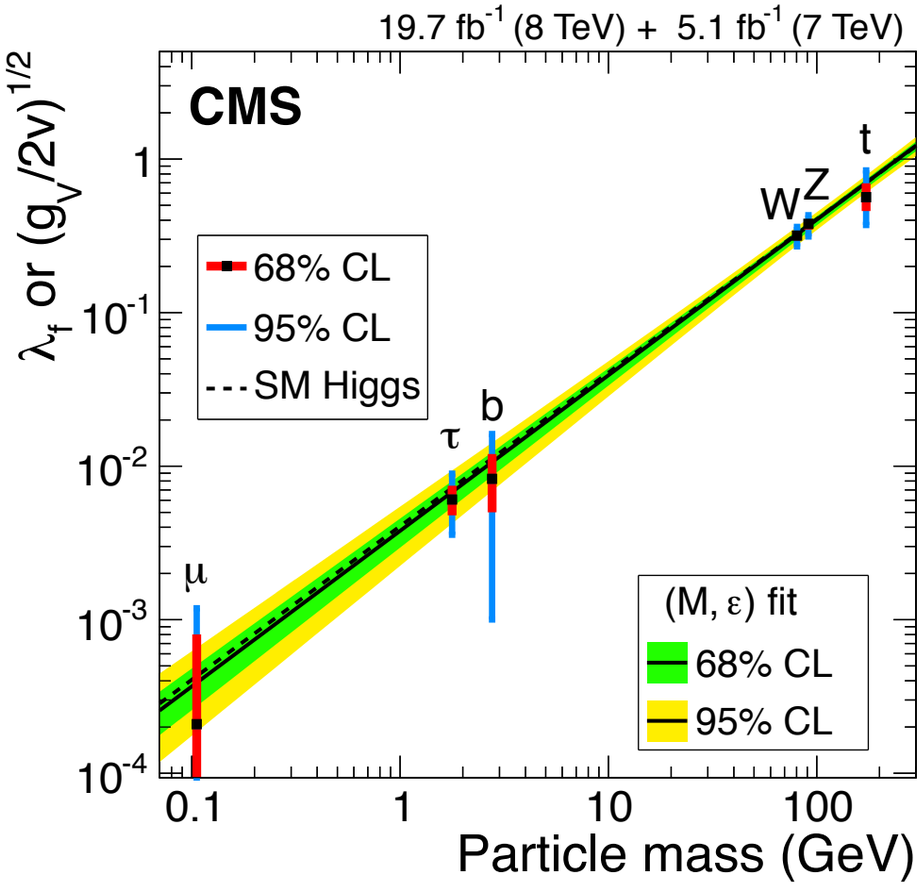
Citation summary results	Published only
Total number of papers analyzed:	655
Total number of citations:	38,718
Average citations per paper:	59.1
Breakdown of papers by citations:	
Renowned papers (500+)	5
Famous papers (250-499)	10
Very well-known papers (100-249)	70
Well-known papers (50-99)	117
Known papers (10-49)	207
Less known papers (1-9)	155
Unknown papers (0)	91
h_{HEP} index [?]	92

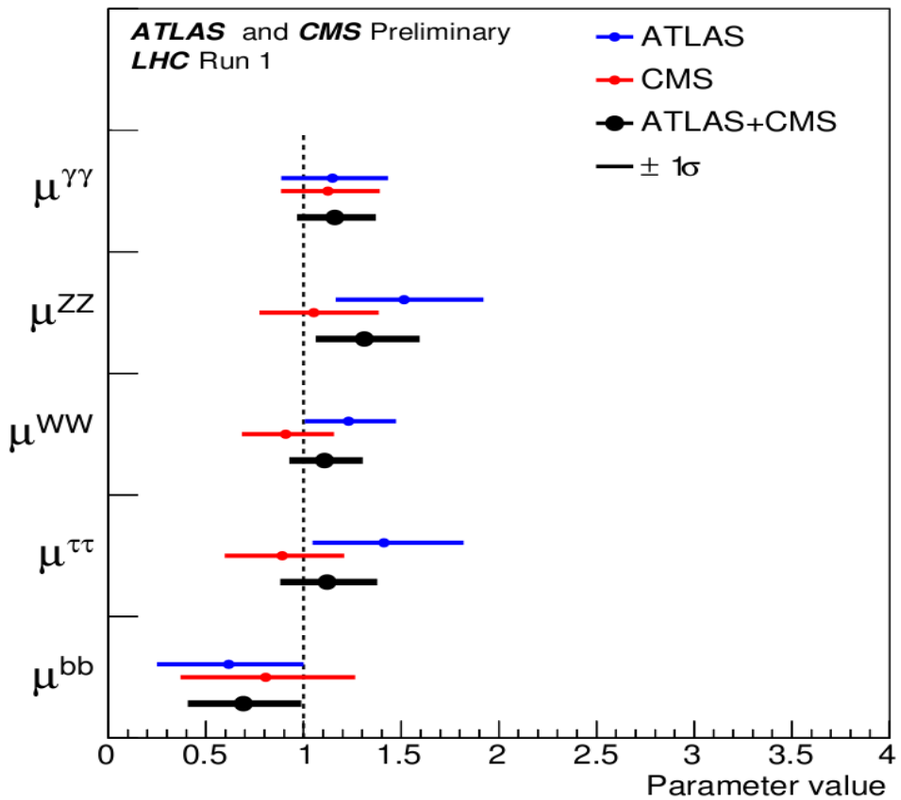
http://cms-results.web.cern.ch/cms-results/public-results/publications

Where we Stand: Higgs

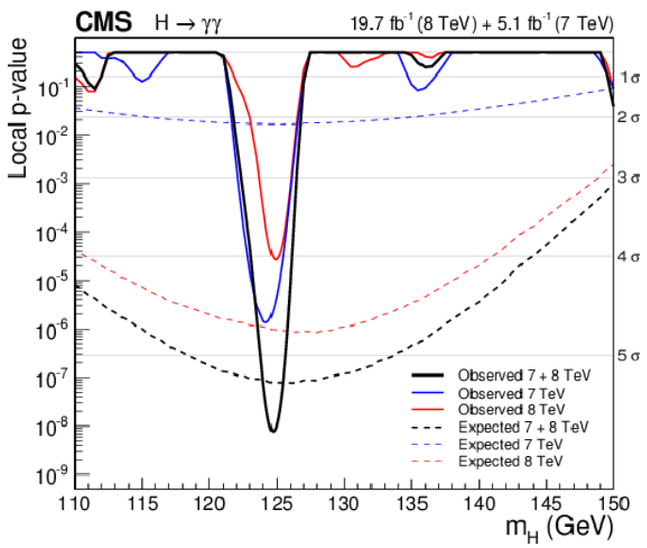
- The final story on Run I Higgs
  - Couplings are consistent with the SM; No evidence for any BSM Higgs
  - ATLAS / CMS combination paper to be submitted next month
  - Strong UK participation across the Higgs sector! (incl. BSM searches)
- Signal strength:

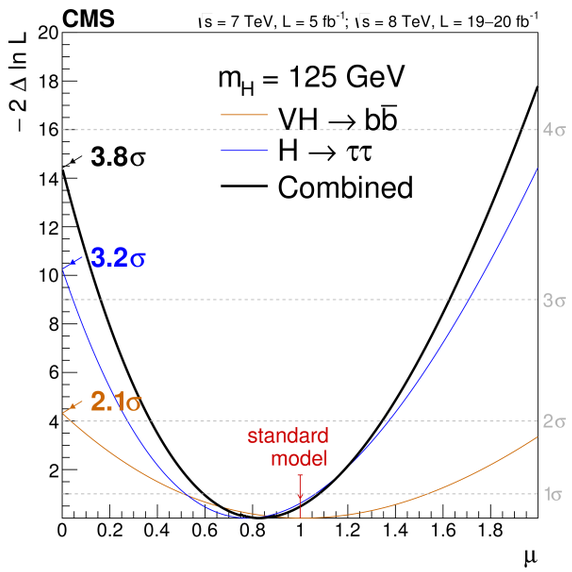
$$\mu = 1.09^{+0.11}_{-0.10} = 1.09^{+0.07}_{-0.07}\,(\text{stat})\,^{+0.04}_{-0.04}\,(\text{expt})\,^{+0.03}_{-0.03}\,(\text{thbgd})^{+0.07}_{-0.06}\,(\text{thsig})$$

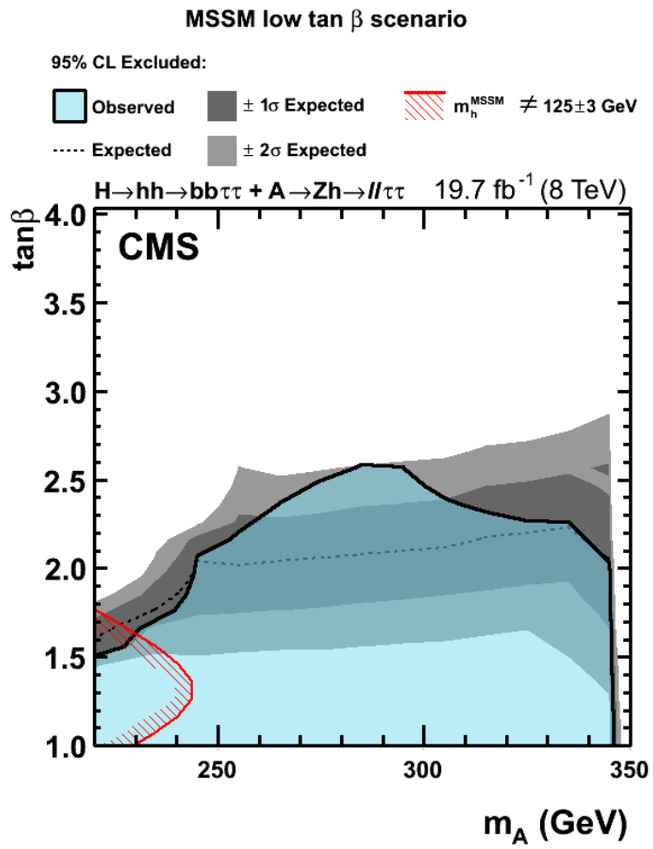


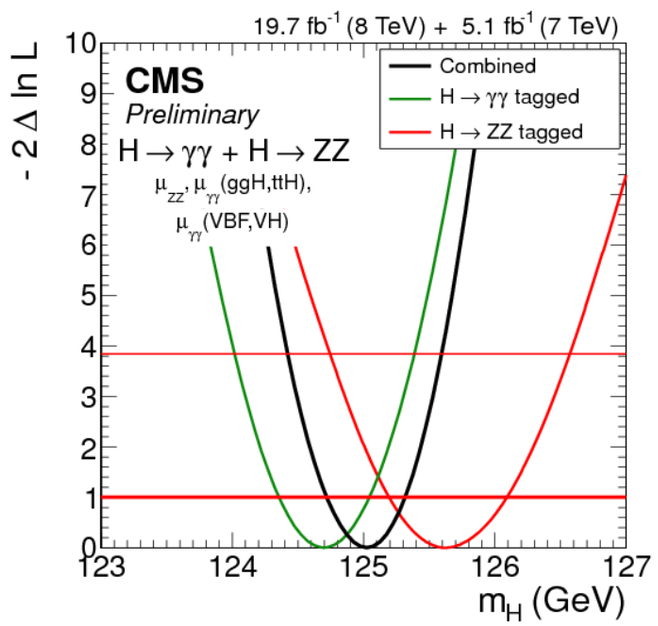


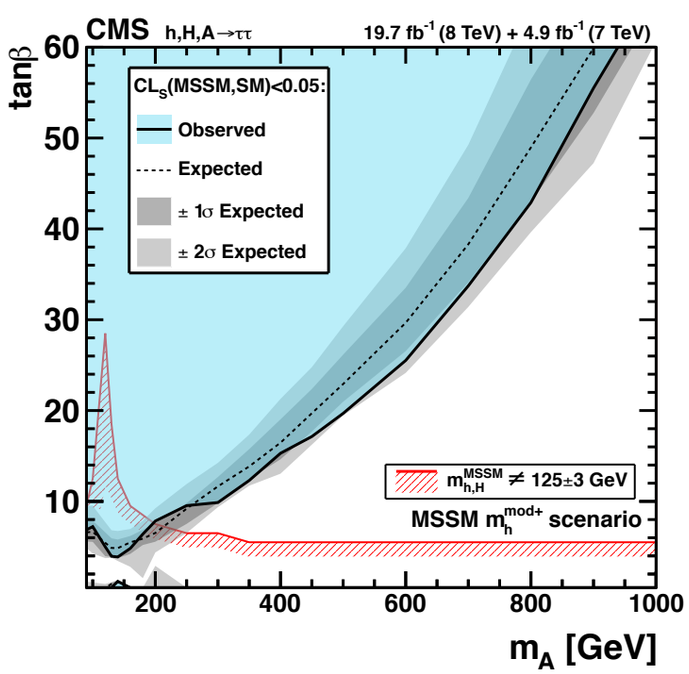
Higgs: Not Just Discovery…

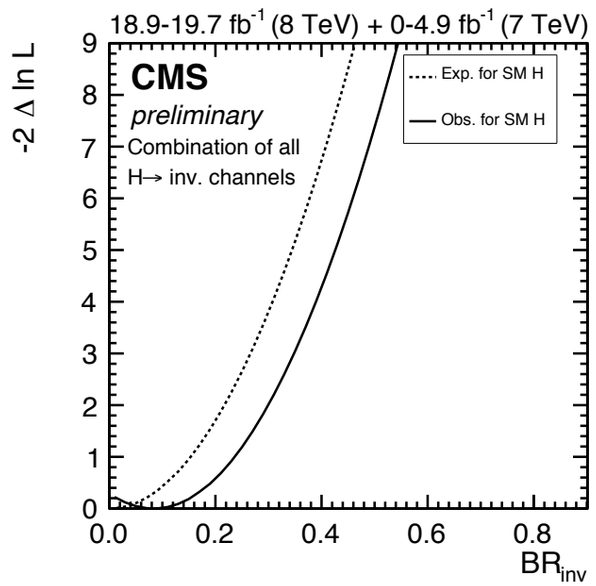










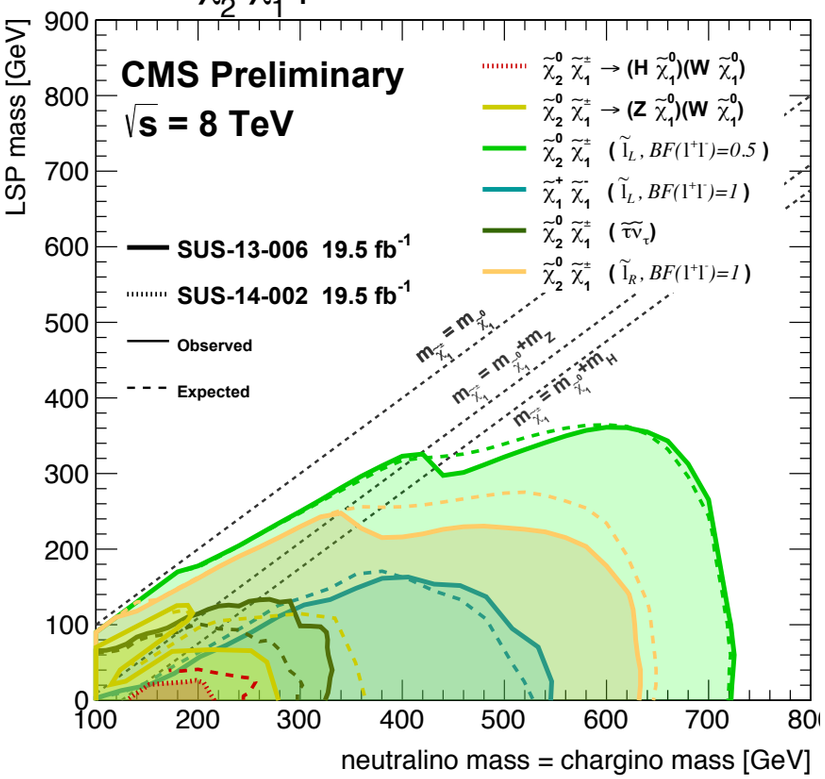


- UK-led results: Discovery -> Precision measurement -> BSM

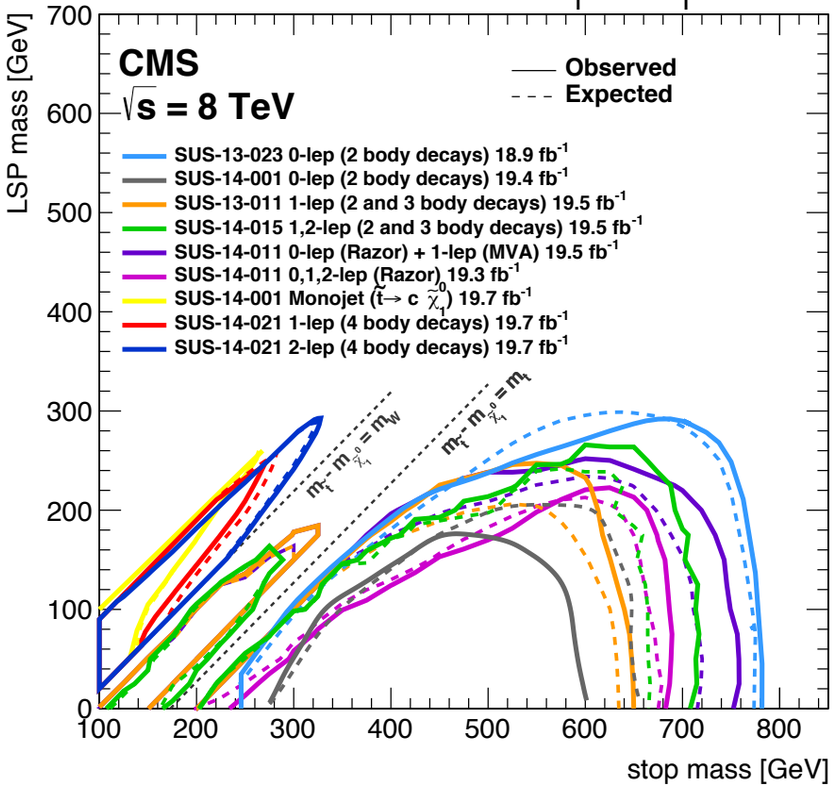
Where we Stand: SUSY

- Comprehensive CMS search for supersymmetry
  - From model-independent inclusive searches to specific decay modes
  - Covering a large number of signatures and final states
  - EWKino production, 3rd generation squarks, gluinos and heavy squarks
- For pedestrians: SUSY is > ~1TeV, or good at hiding

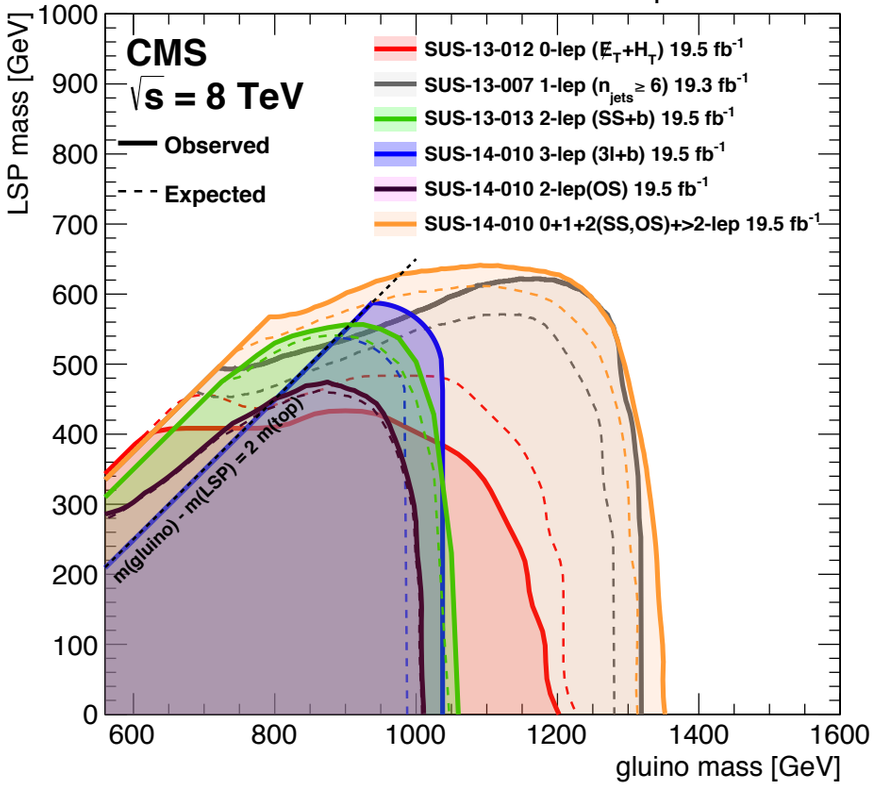
$\tilde{\chi}_2^0$-$\tilde{\chi}_1^\pm$ production



$\tilde{t}$-$\tilde{t}$ production, $\tilde{t} \to t\,\tilde{\chi}_1^0 / c\,\tilde{\chi}_1^0$

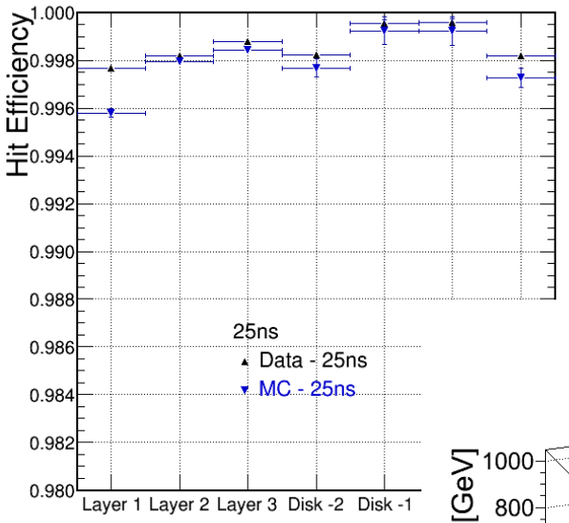


$\tilde{g}$-$\tilde{g}$ production, $\tilde{g} \to t\,\bar{t}\,\tilde{\chi}_1^0$



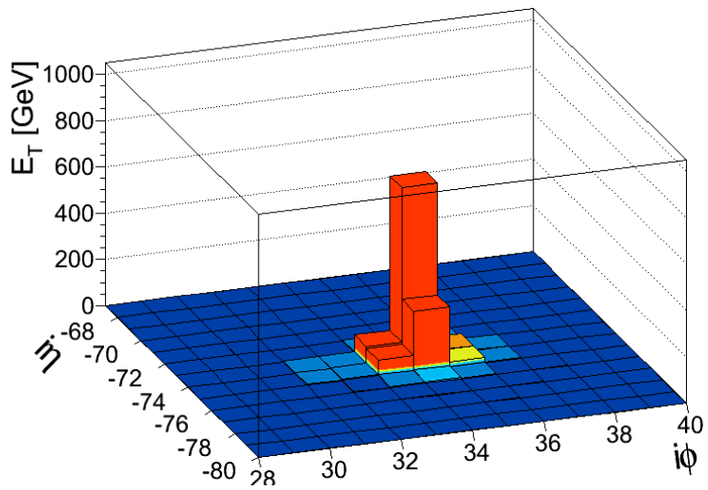
Activities during LS1

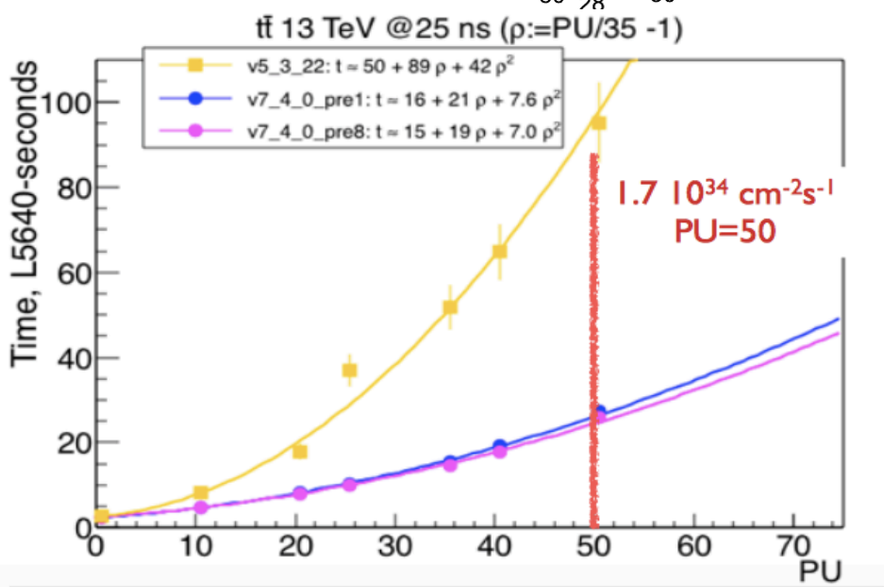
- New beam pipe
- Tracking and muon systems
  - Move to low temp. tracker running UK
  - 4th endcap muon station 'restored'
- Calorimetry
  - New HCAL readout system installed
  - Improved ECAL and HCAL online calibration UK
- New luminosity monitor systems
- Online systems:
  - New DAQ front end / new timing system UK
  - New L1 calo trigger for PP and HI running
    - Full trigger upgrade for 2016 UK
- HLT / Computing
  - Bring offline-style pileup mitigation to HLT
  - CPU / memory savings for high PU reco UK



Pixel hit efficiency

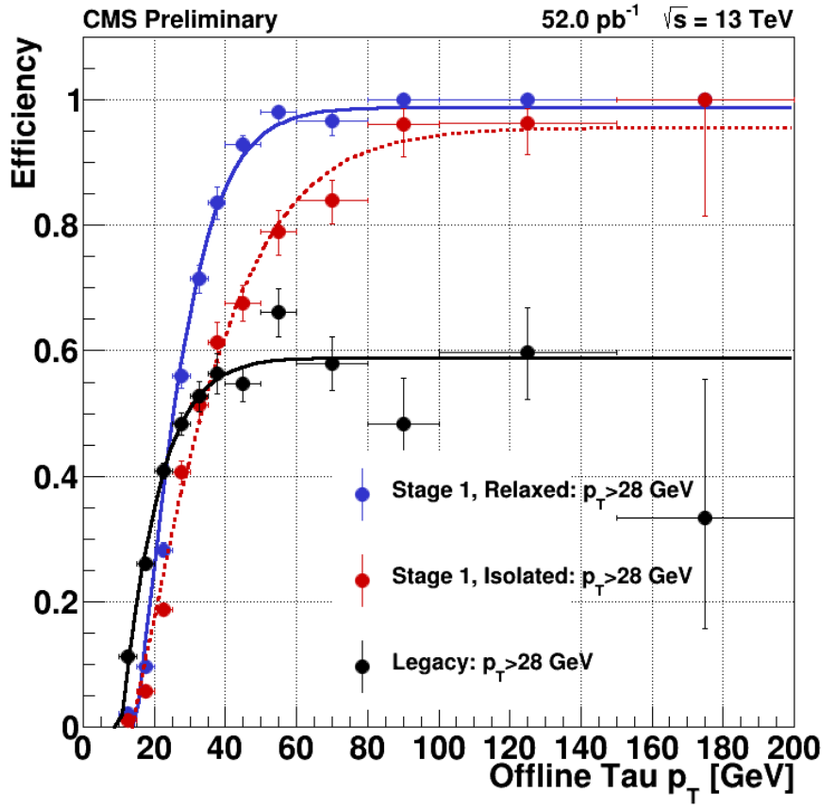
1.2TeV electron in ECAL

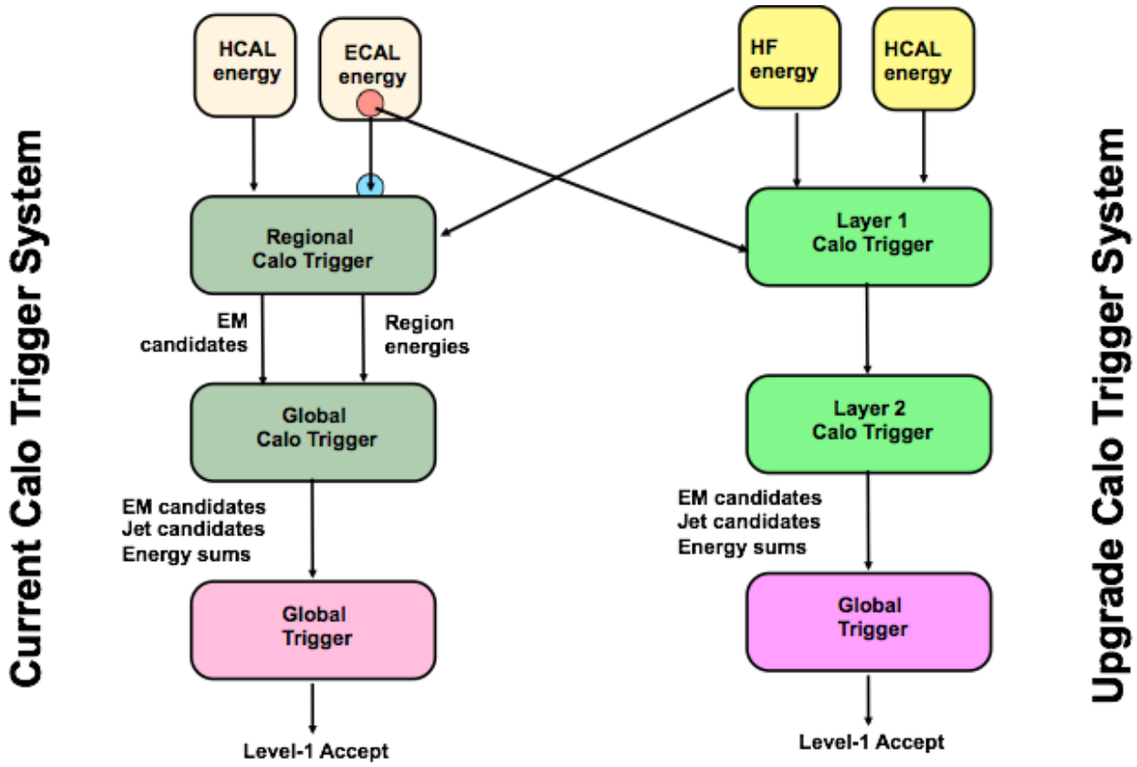




Reco time improvements

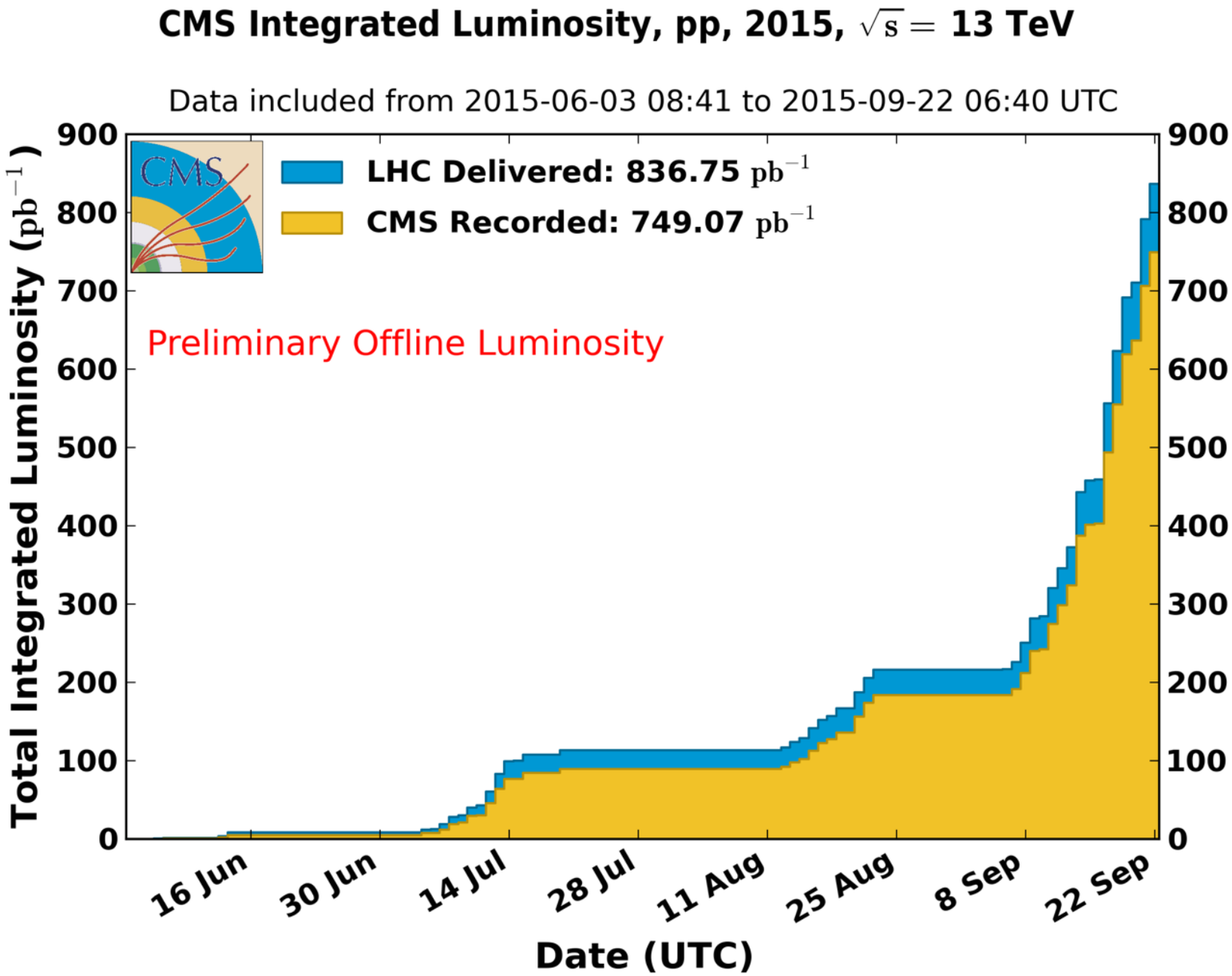
New L1 Calo Trigger





- Interim L1 calo for PP and HI
  - Improved tau trigger
  - PU subtraction for jets and energy sums
  - Installed and triggering CMS since August
  - Key proof of principle for major 2016 L1 trigger upgrade

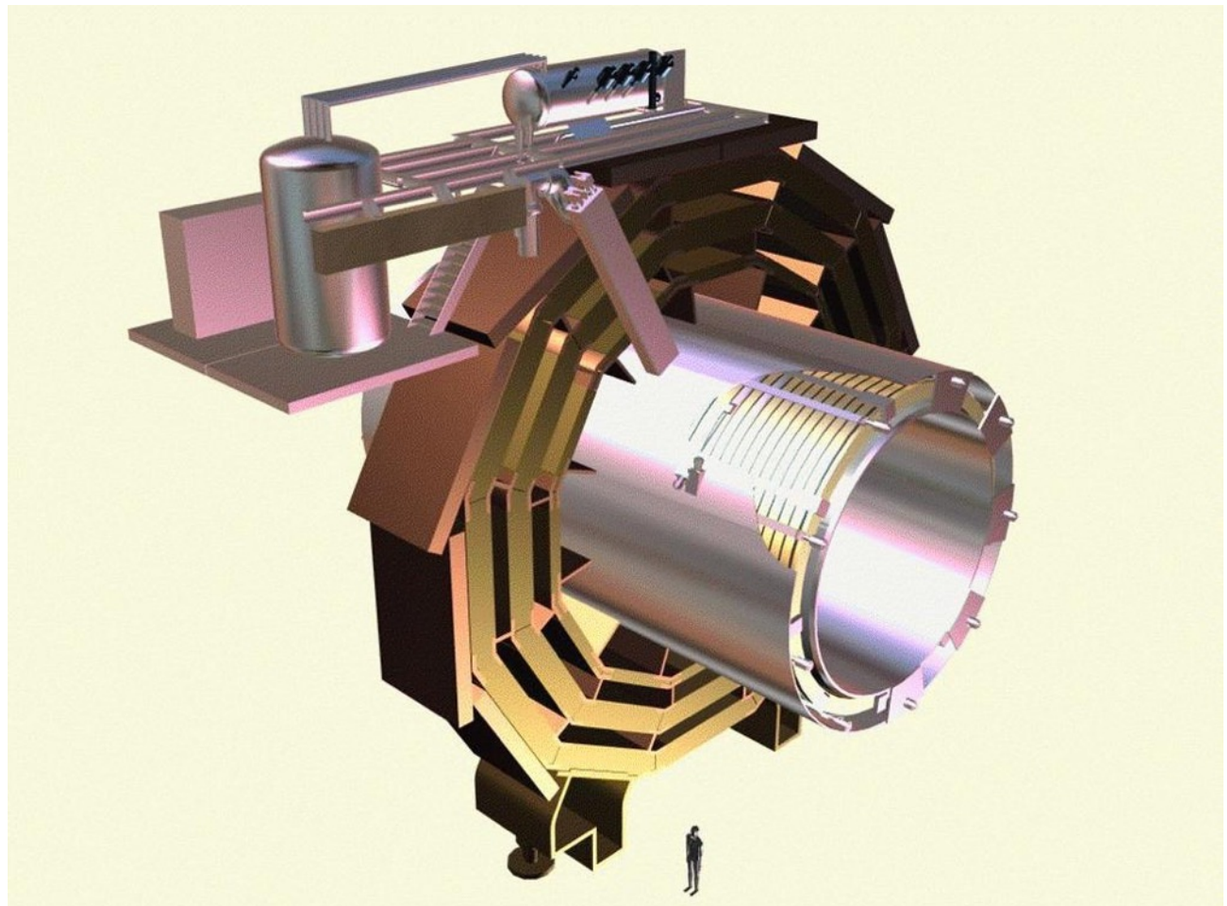
Data at 13TeV

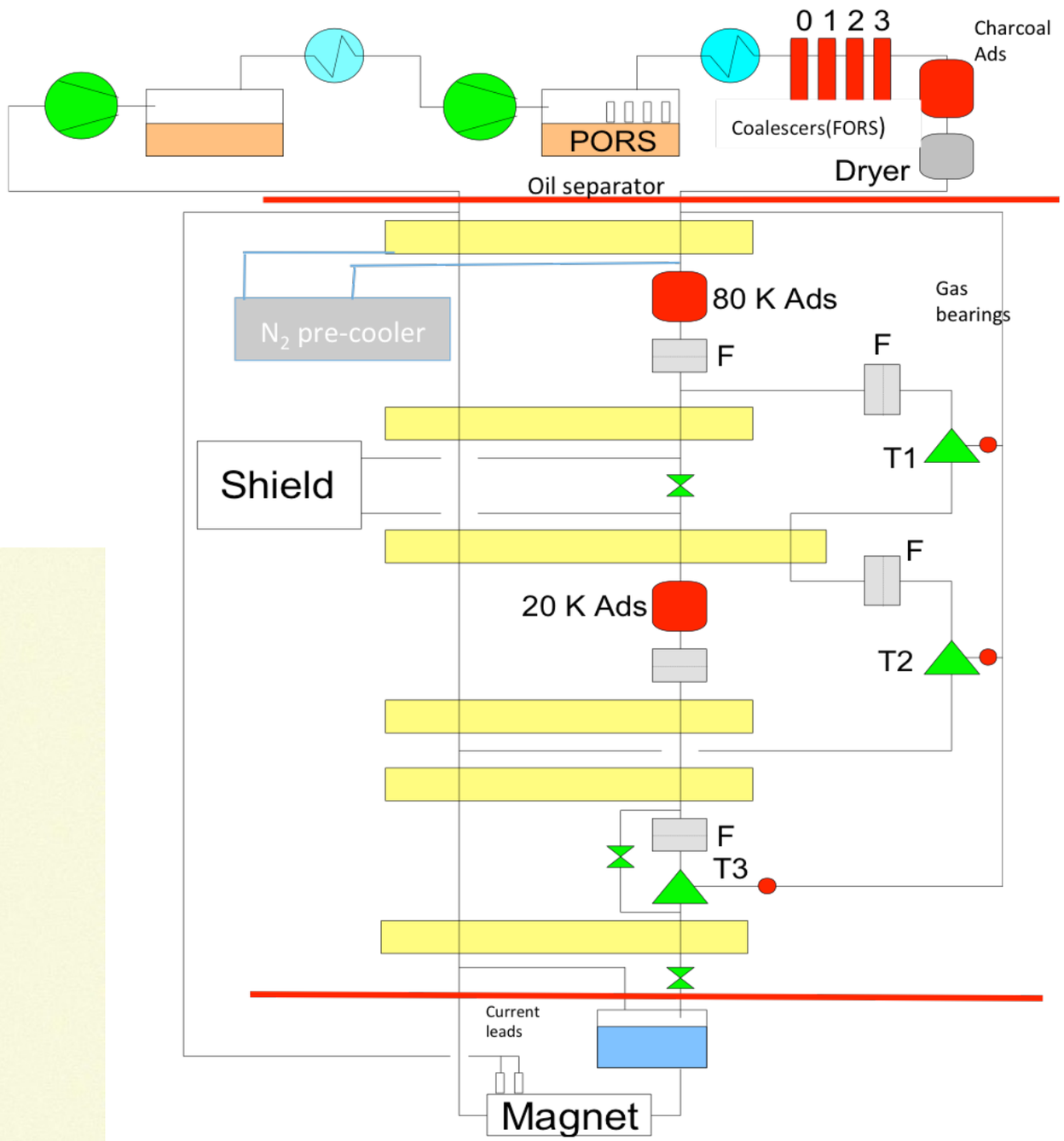


- At full CMS field: 0.42/fb delivered, 0.38/fb recorded
  - Running efficiency is now over 90%

CMS Magnet Cryo Systems

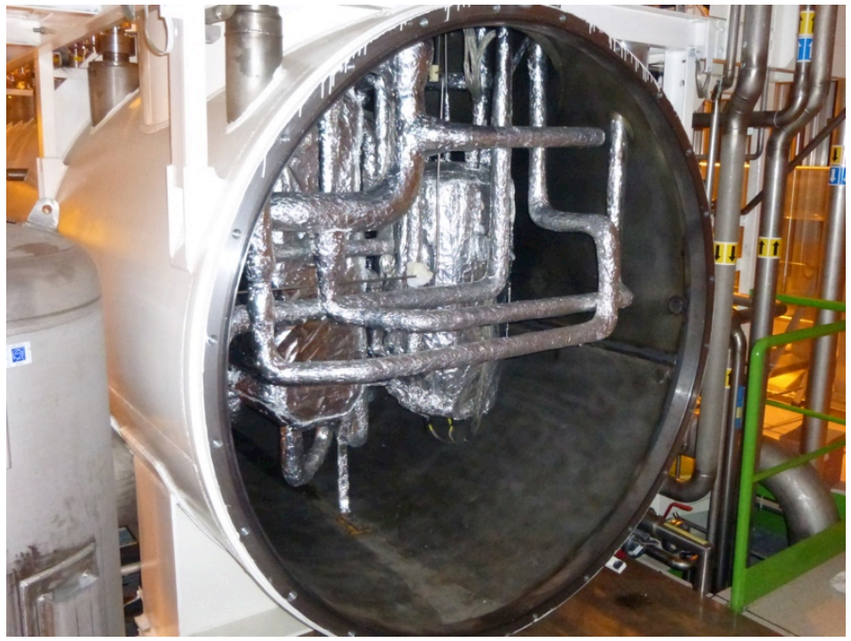
- Complex underground cryogenic system
- A series of issues with helium contamination observed during 2015





Cryo Status

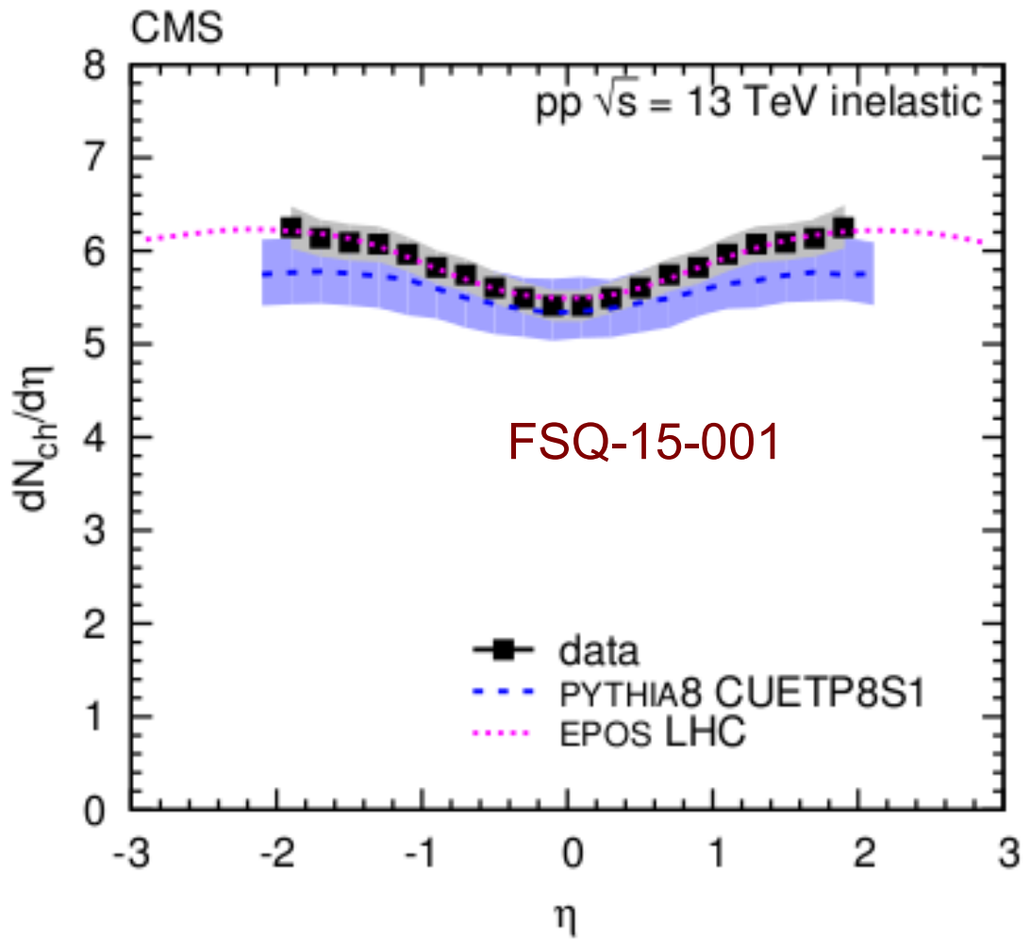
- Symptoms
  - Frequent clogging of filter components requires more regular maintenance
  - Requires cold-box stop, and ramp-down
  - The solenoid itself is *not* the concern
  - Magnet-off periods synchronised with LHC to avoid data loss

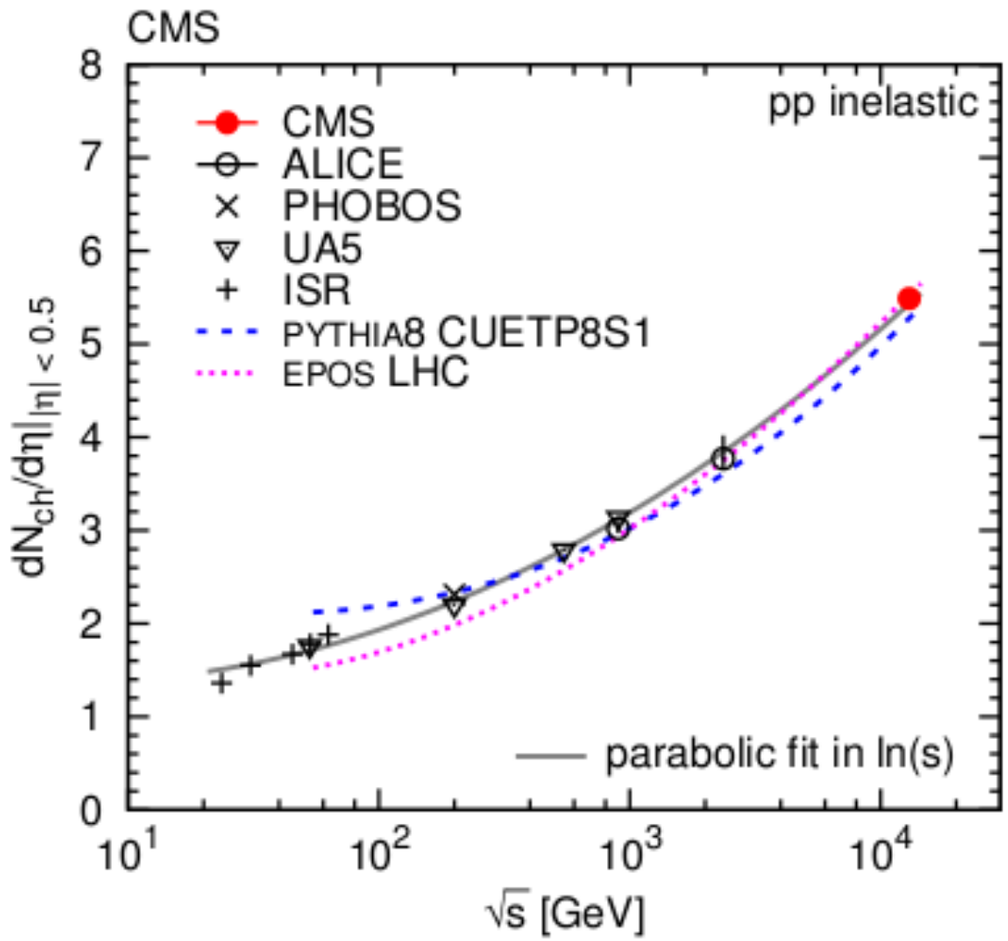


- Interventions
  - Several complex / invasive modifications made to cold box – non trivial
  - Some signs of improvement in last weeks
  - CERN tech support has been exceptional

- Longer term solution
  - Complete solvent cleaning and/or replacement of components in YETS 15-6

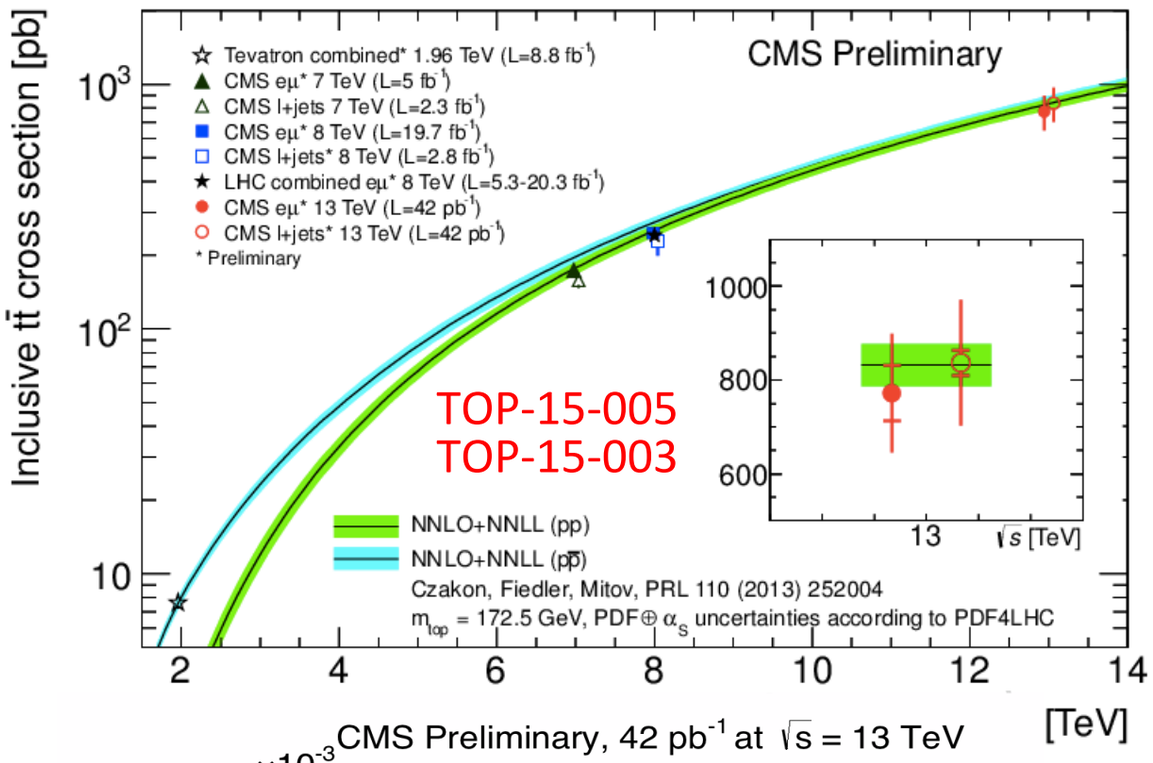
13TeV Results: QCD



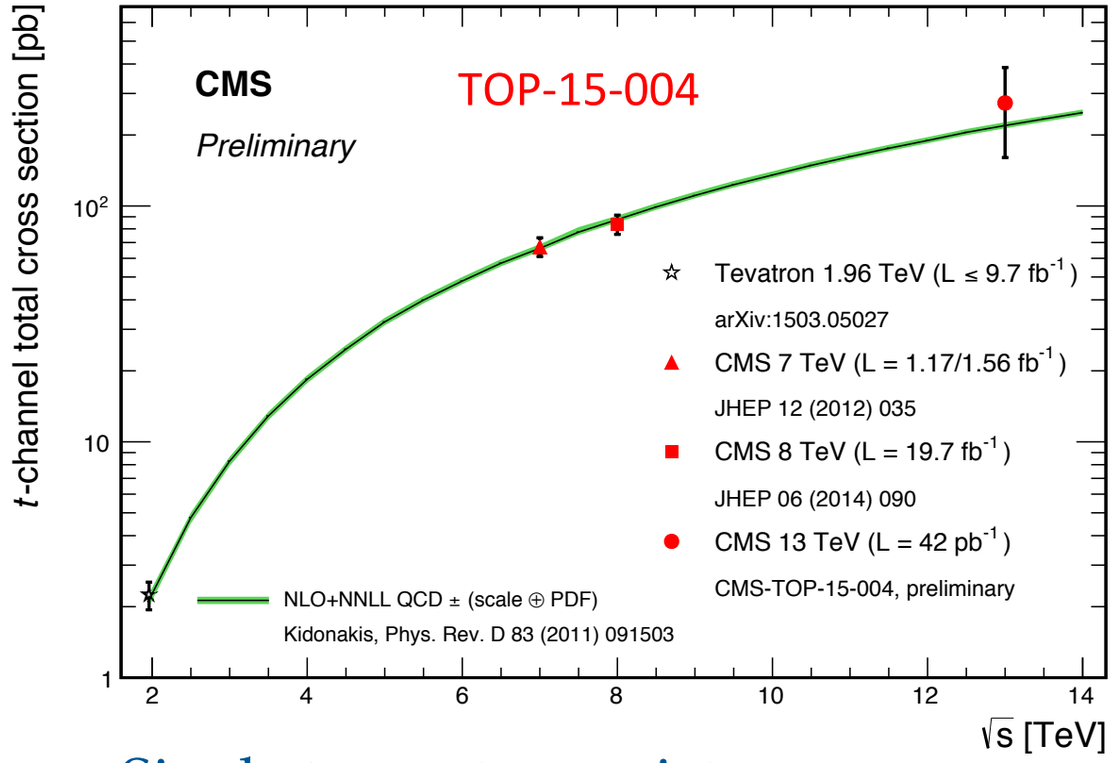


- dn/dη: the traditional first paper
- This analysis without magnetic field using pixel detector
- (Some) generators still work at 13TeV…

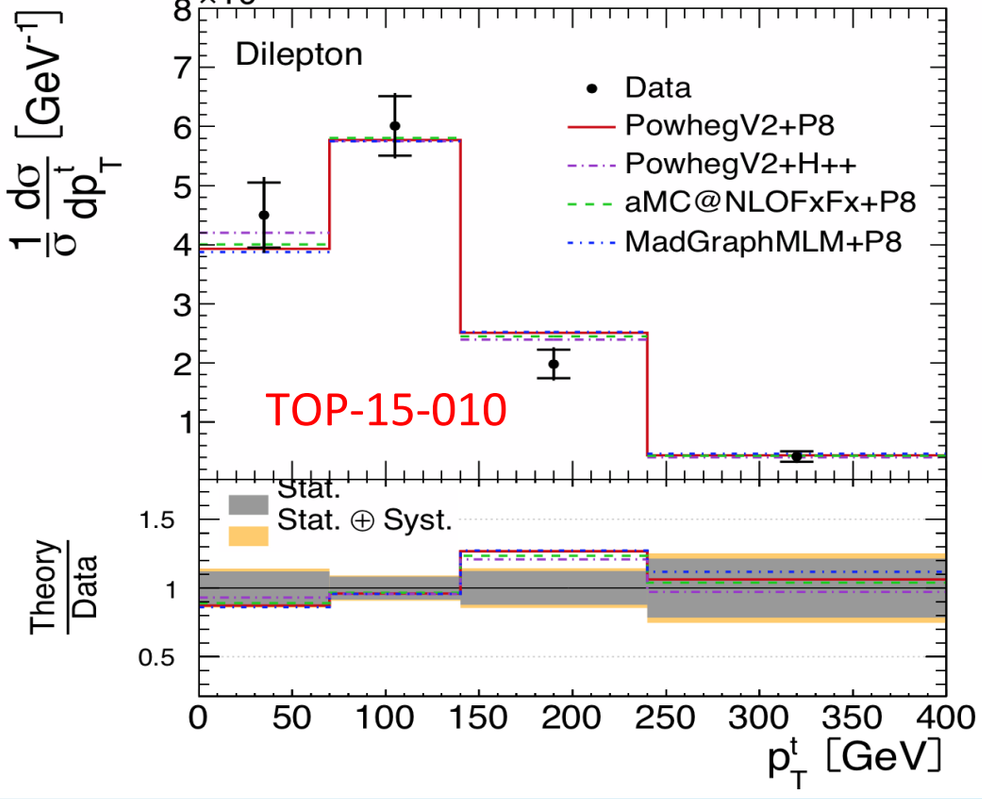
13TeV Results: Top



Incl. σ ttbar → eμ, semi-leptonic

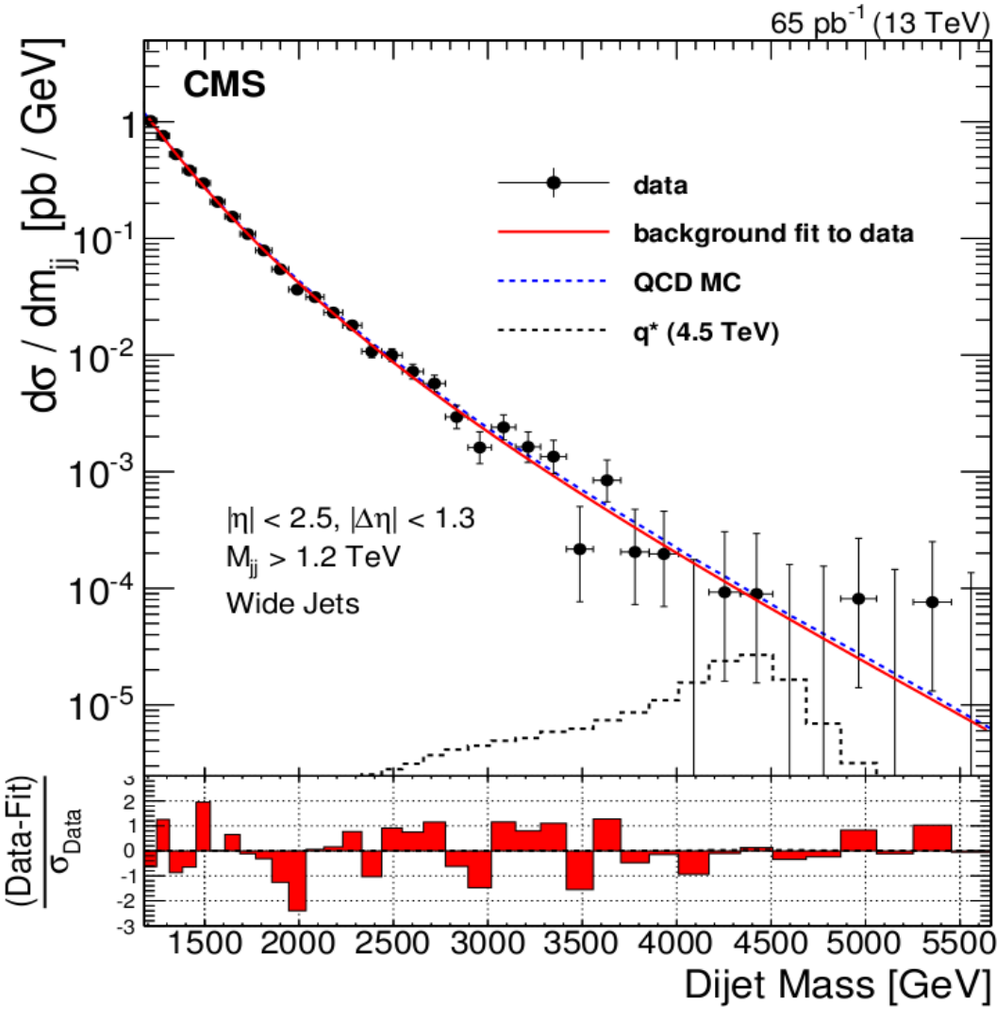


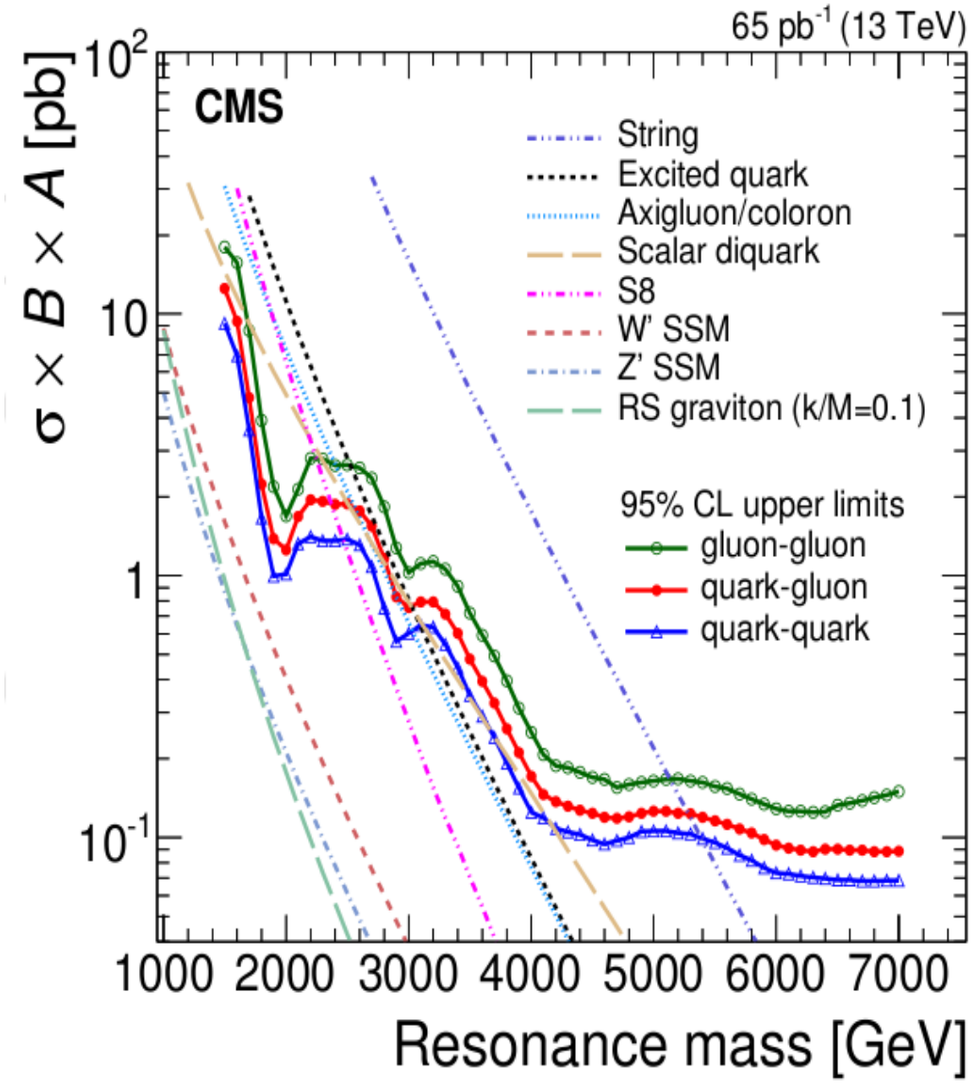
Single top σ, t → μ+jet



Diff. σ ttbar → dilepton, semi-leptonic

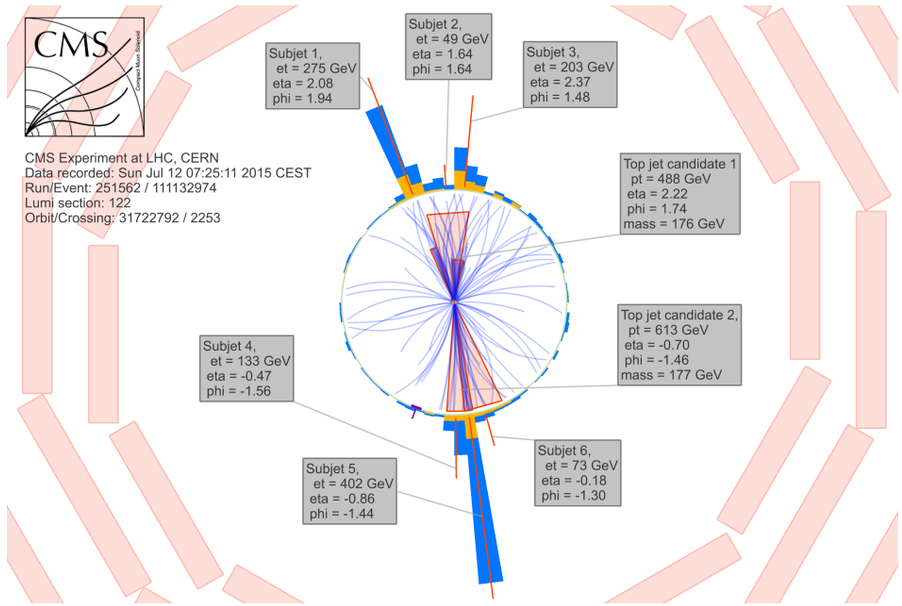
13TeV Results: Searches



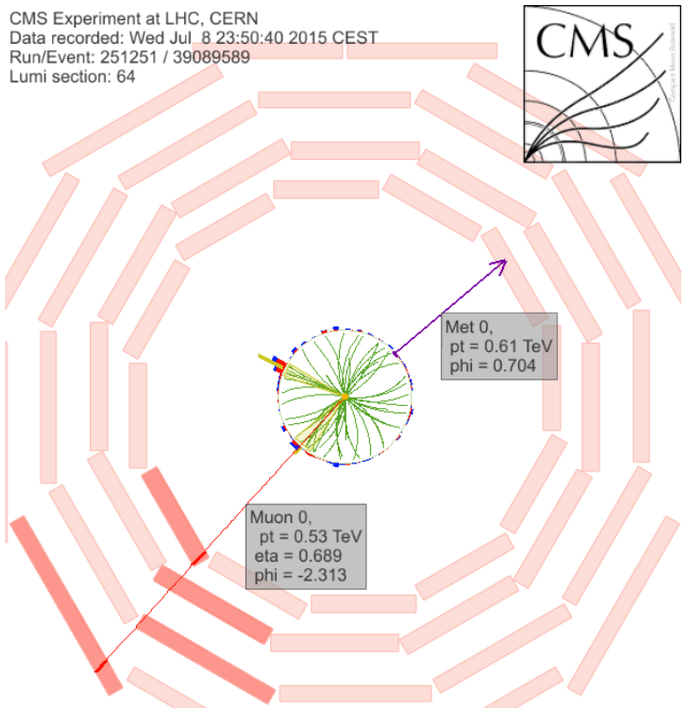


- Dijet resonance search
  - Constrains many different models (strings, q*, W' / Z', etc)
  - 65/pb string limits already more stringent than Run I!

(Much) More to Come

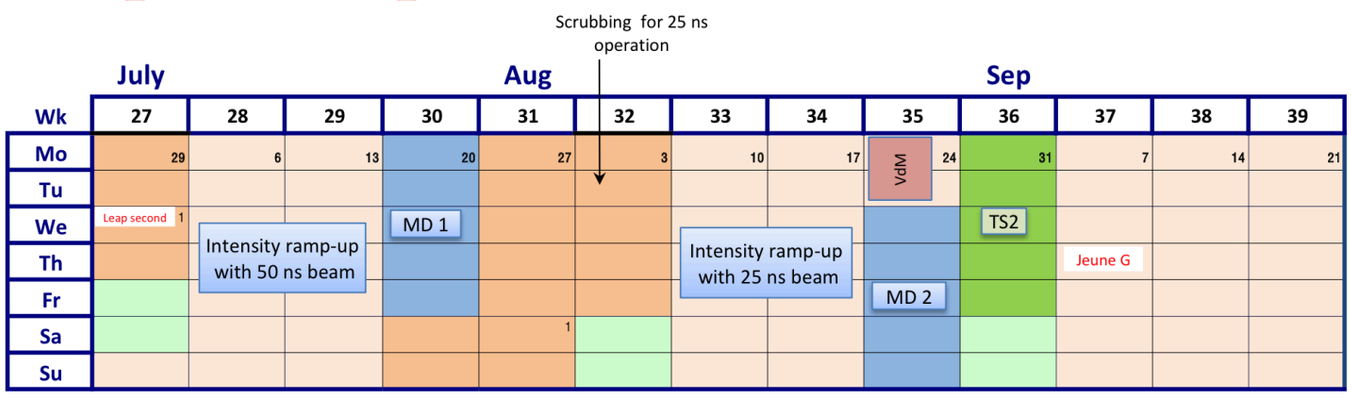


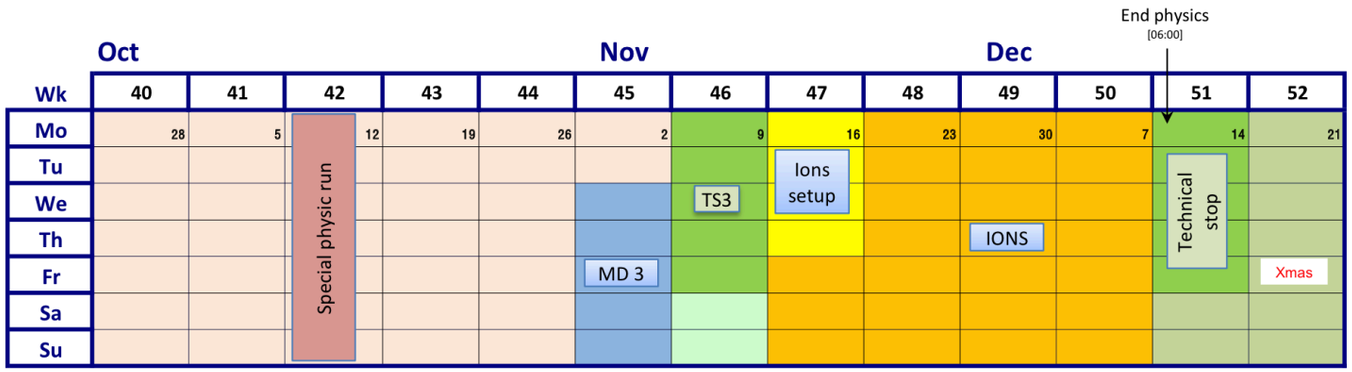
m_{tt}=2.5TeV



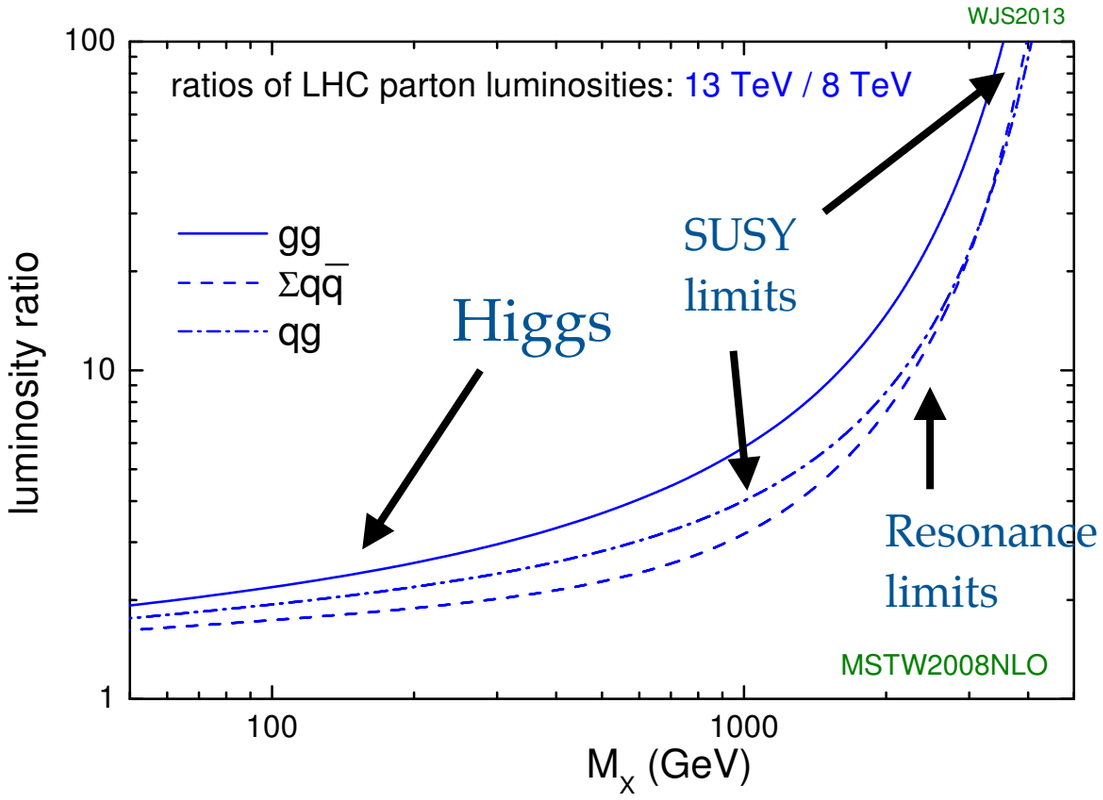
μ+MET, m_T=1.1TeV

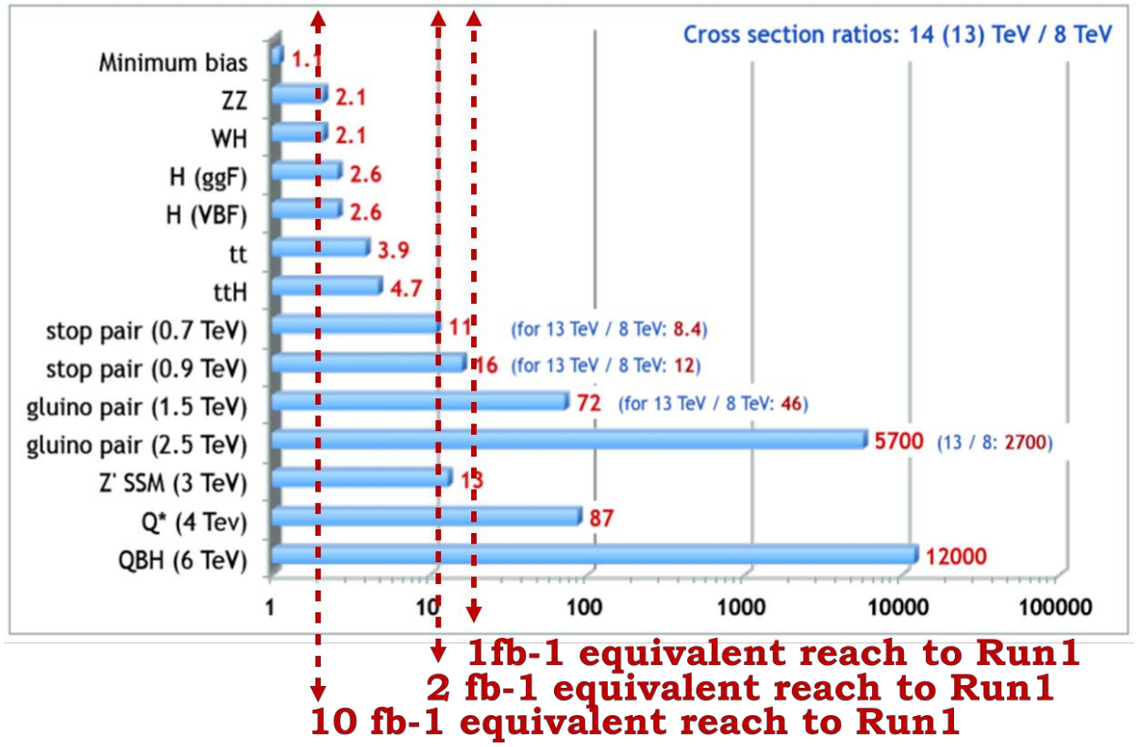
- 2015: 5/fb?
- 2016: 35/fb?
- Run II: 100/fb?



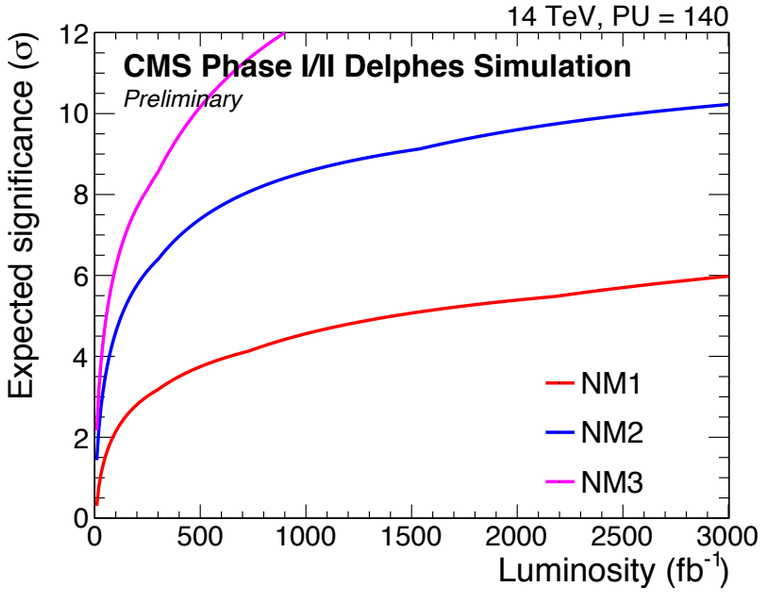


Prospects

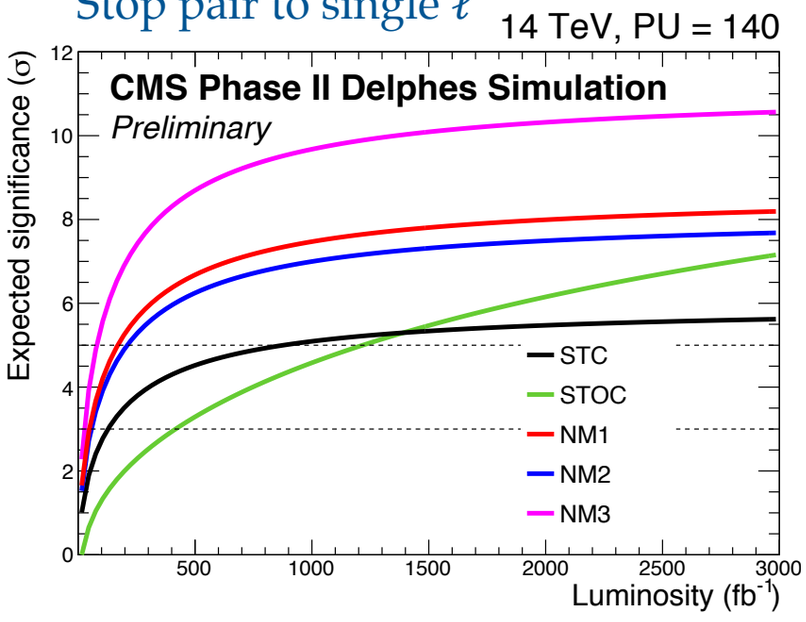




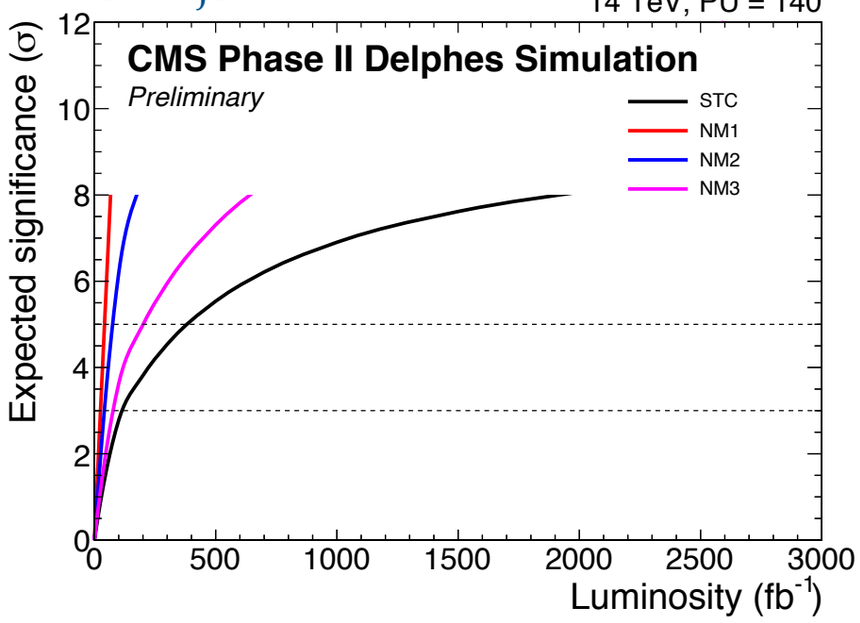
Inclusive hadronic



Stop pair to single ℓ

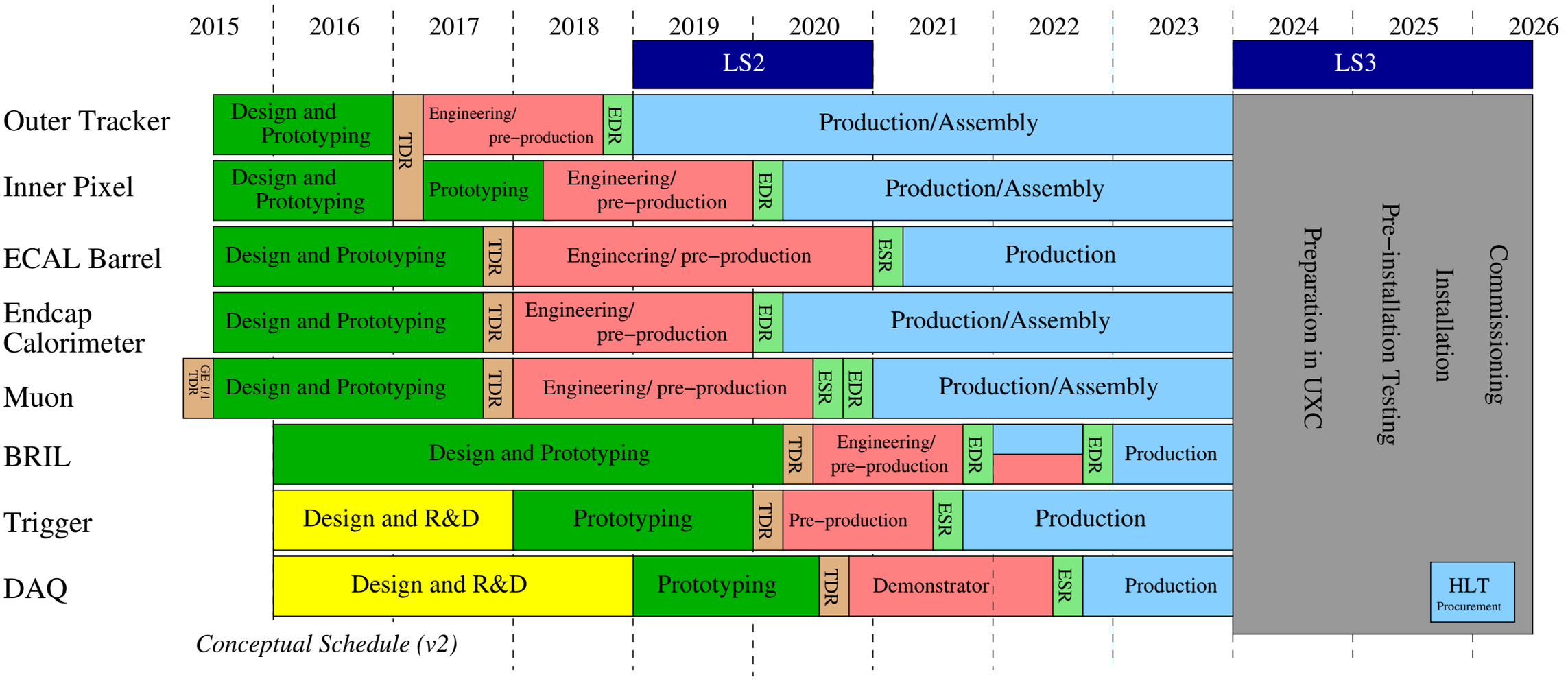


3ℓ+bjet



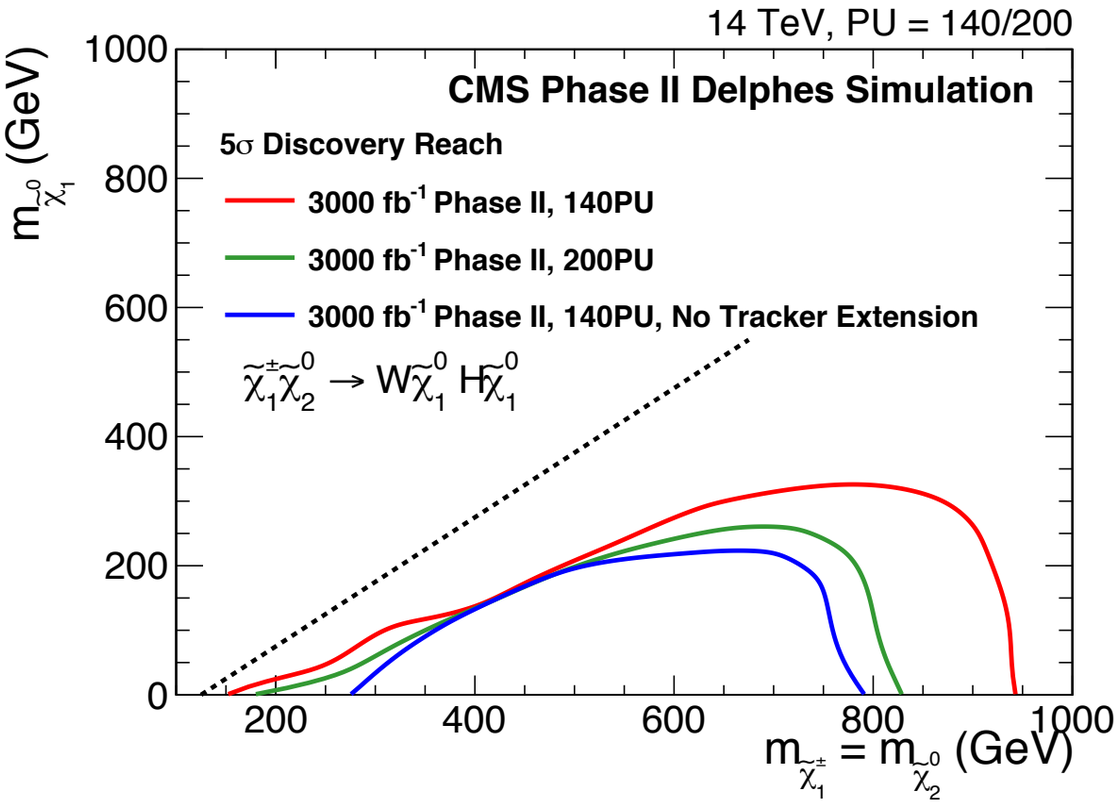
3 'natural' pMSSM models all with LHC-discoverable 1.7 TeV gluino

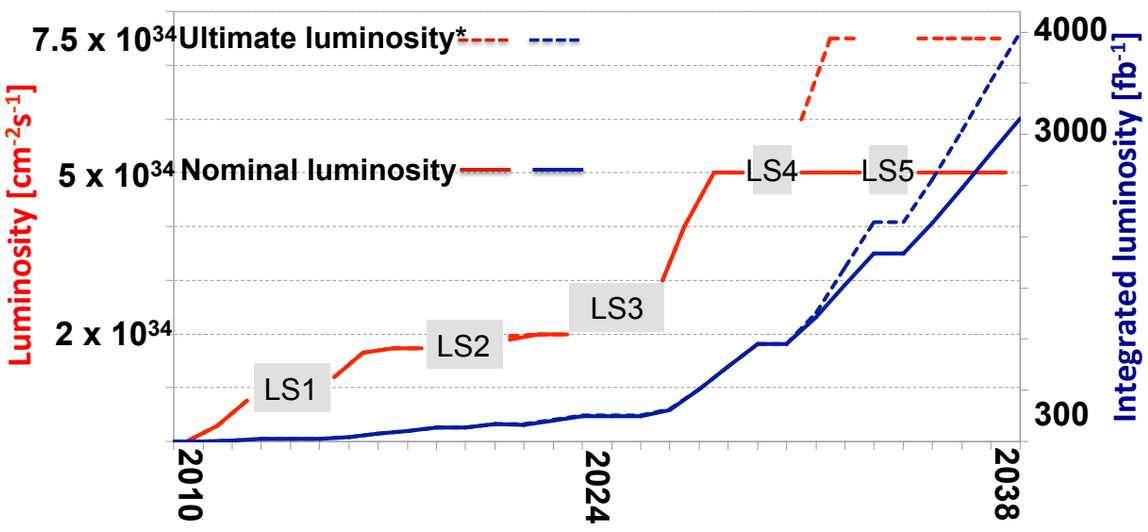
Phase-2 Upgrade Programme

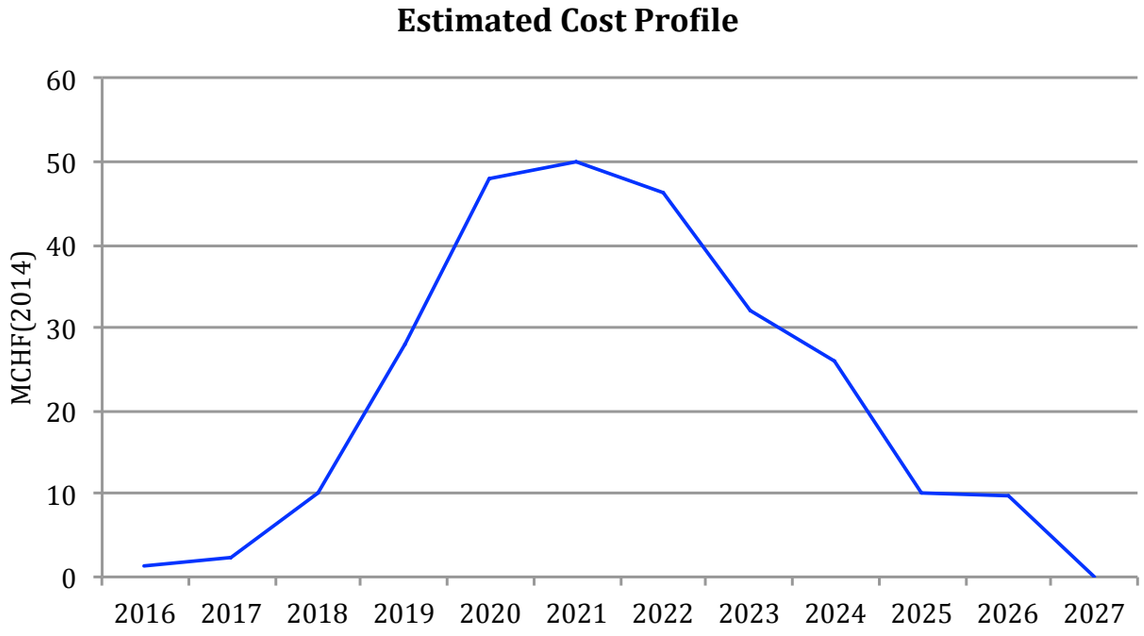


- CMS Phase-2 upgrade 'Scope Document' now finalised
  - Three scenarios for upgrade, and the physics consequences of each
  - Examination of the implications of <PU> = 200
  - Next step is indication of the cost envelope & global detector optimisation
- Timeline has key TDRs scheduled ~18 months from now

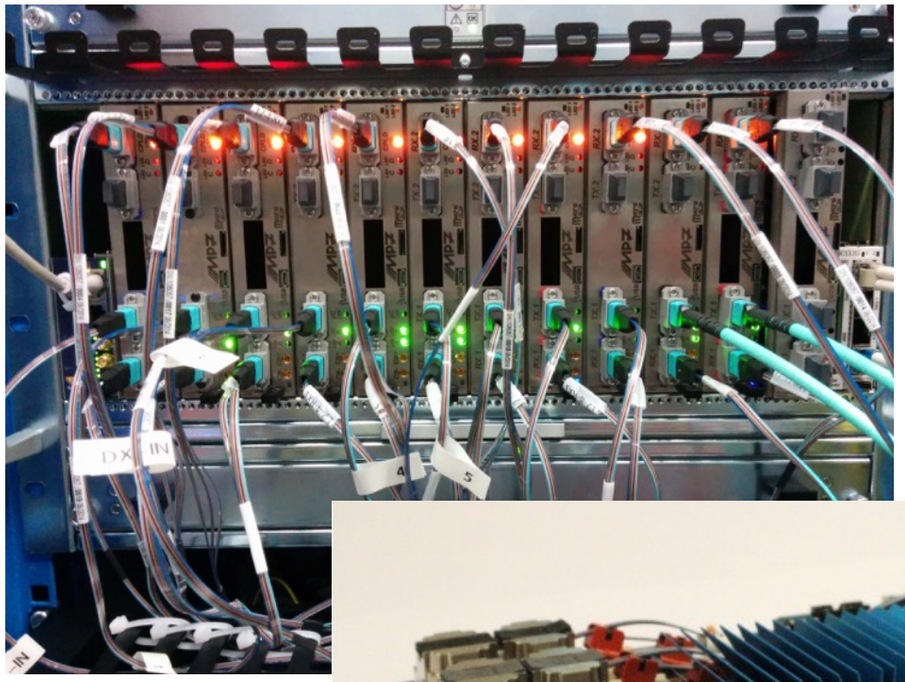
Phase-2 Scope Studies



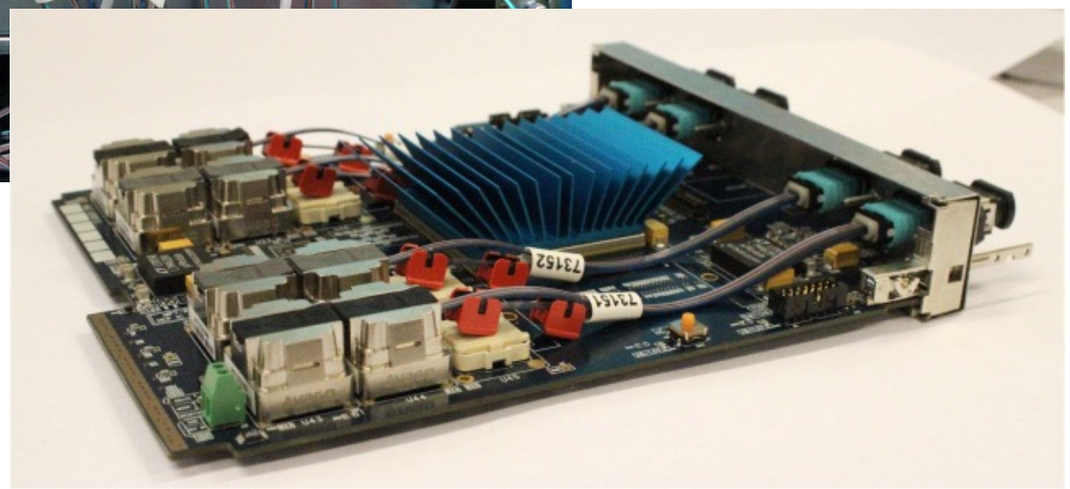


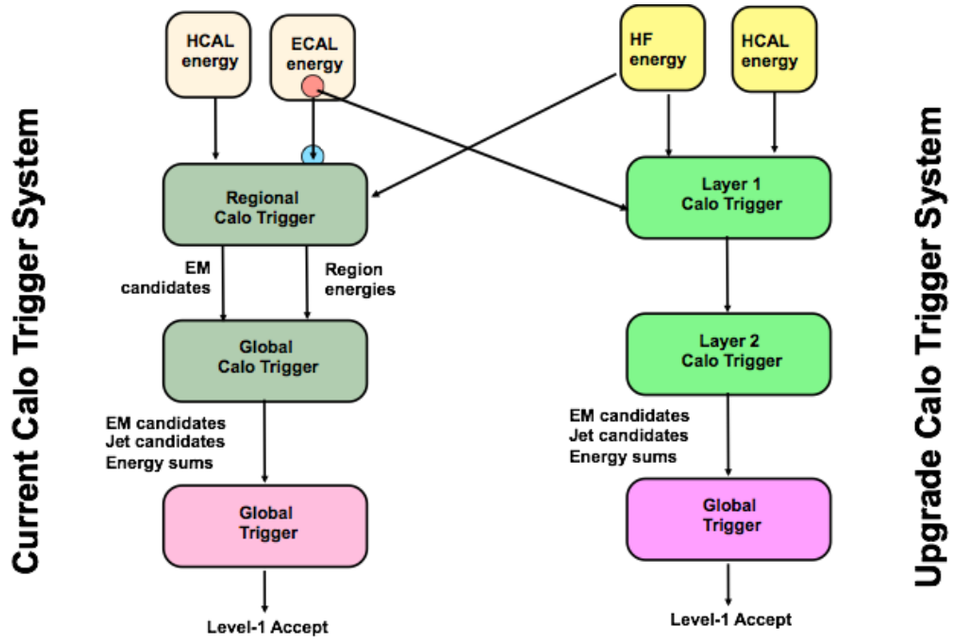


UK R&D: Trigger



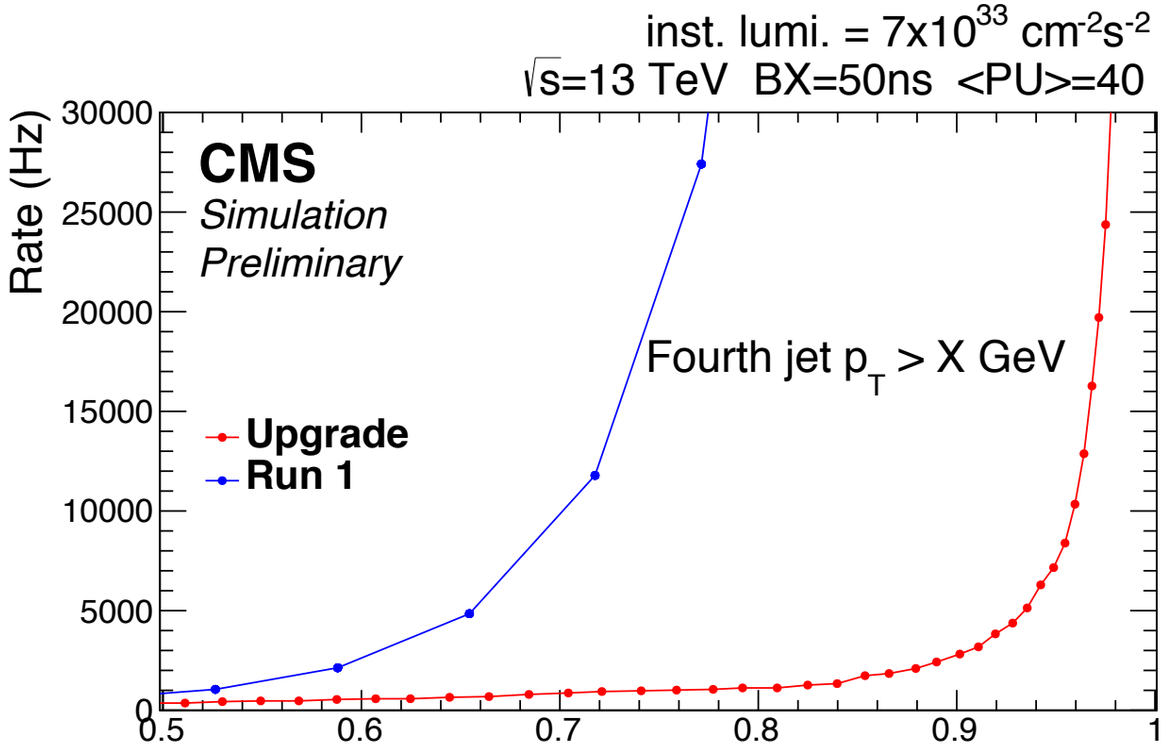
MP7 processor



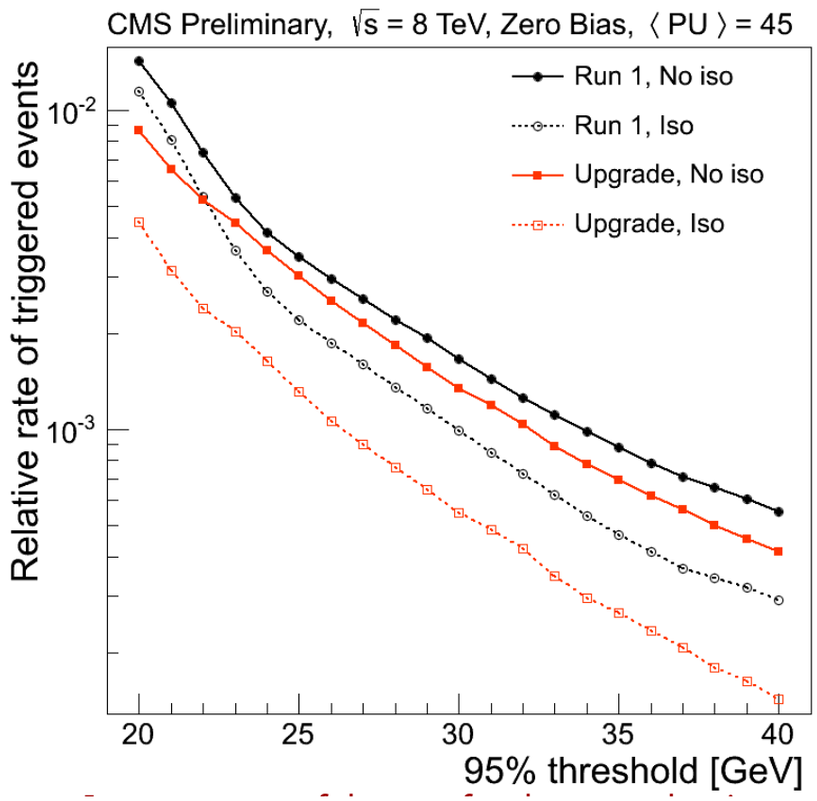


- Hardware for 2016 calorimeter trigger is now operational
  - Parallel running with existing trigger system in coming weeks
- New trigger utilises advances in FPGA & optolink technology
  - Significant improvements in all trigger algorithms at high pileup

UK R&D: Trigger



Pileup subtraction for hadronic triggers



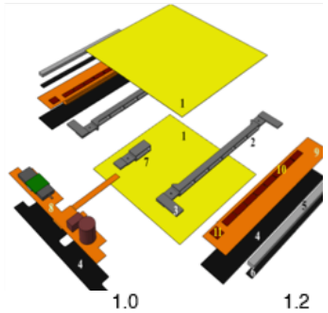
Improved clustering and isolation for e/g

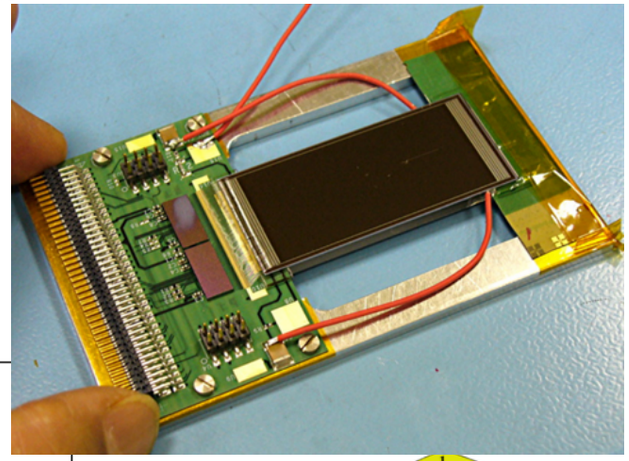
- Entire trigger is now in programmable logic
  - Continuous improvement and tuning of algorithms will be needed
- R&D for longer term upgrades is now under way
  - Optimal correlation of tracking, ECAL/HCAL, HGC and muon objects
  - Propose to exploit new generation of flexible processor platform

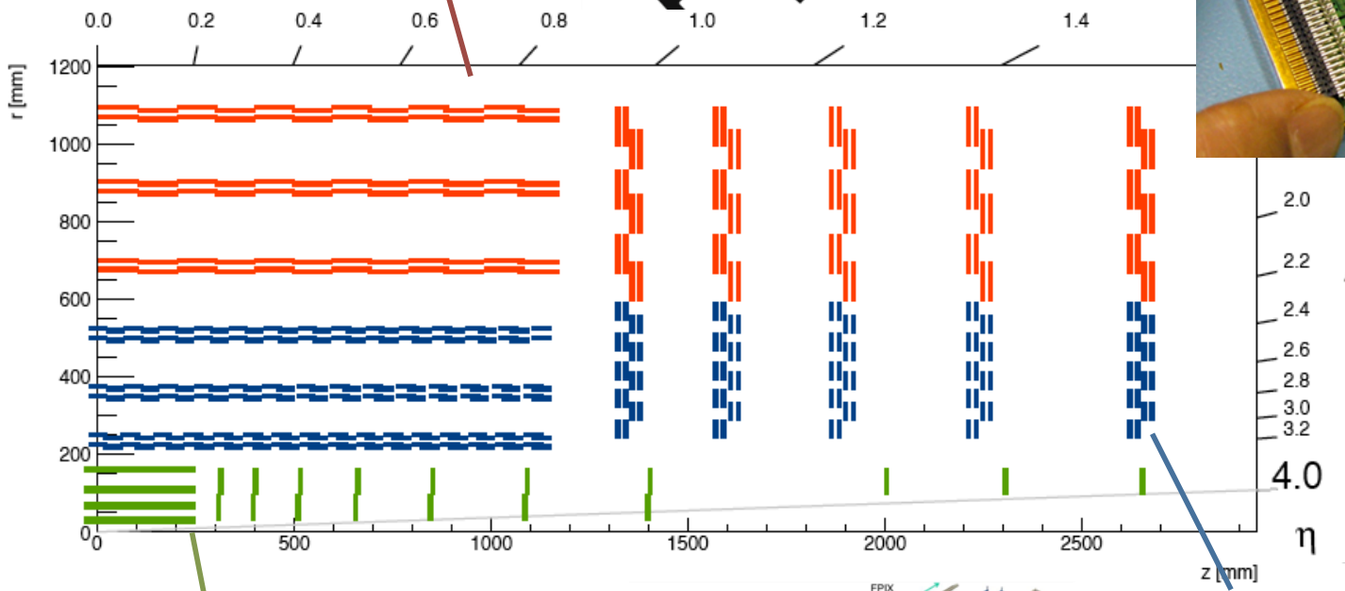
UK R&D: Silicon Tracker Upgrade

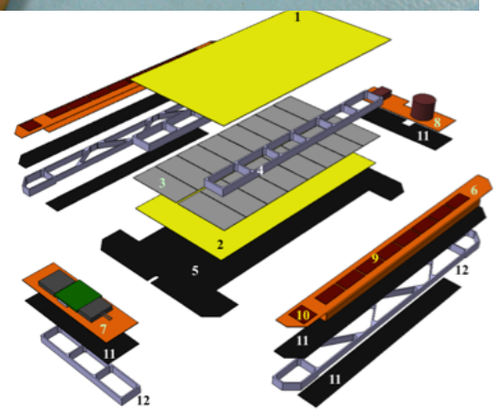
Silicon tracker with trigger-stub capability

Strip/Strip Modules
90 μm pitch/5 cm length

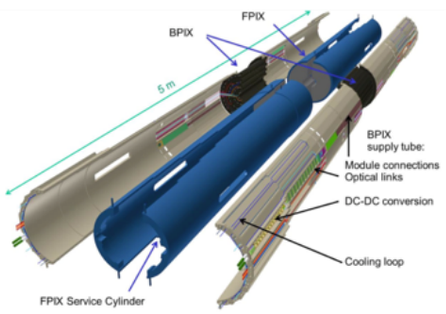








Inner Pixel
Covers up to η=4.0

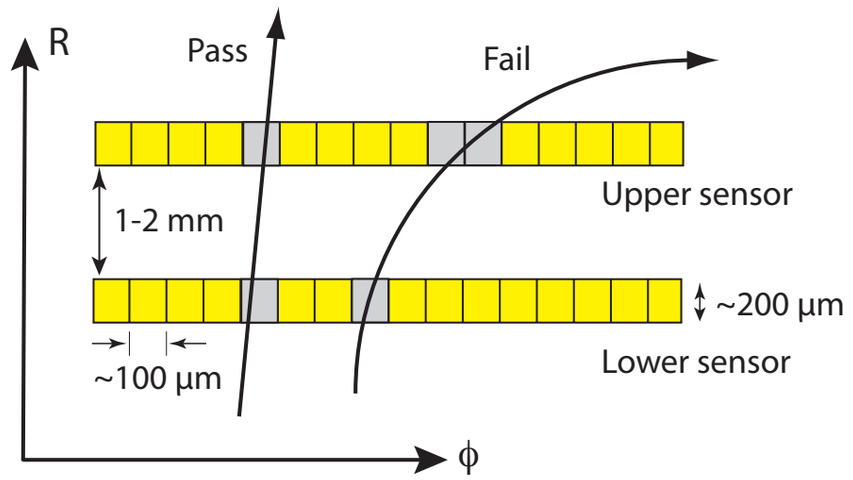


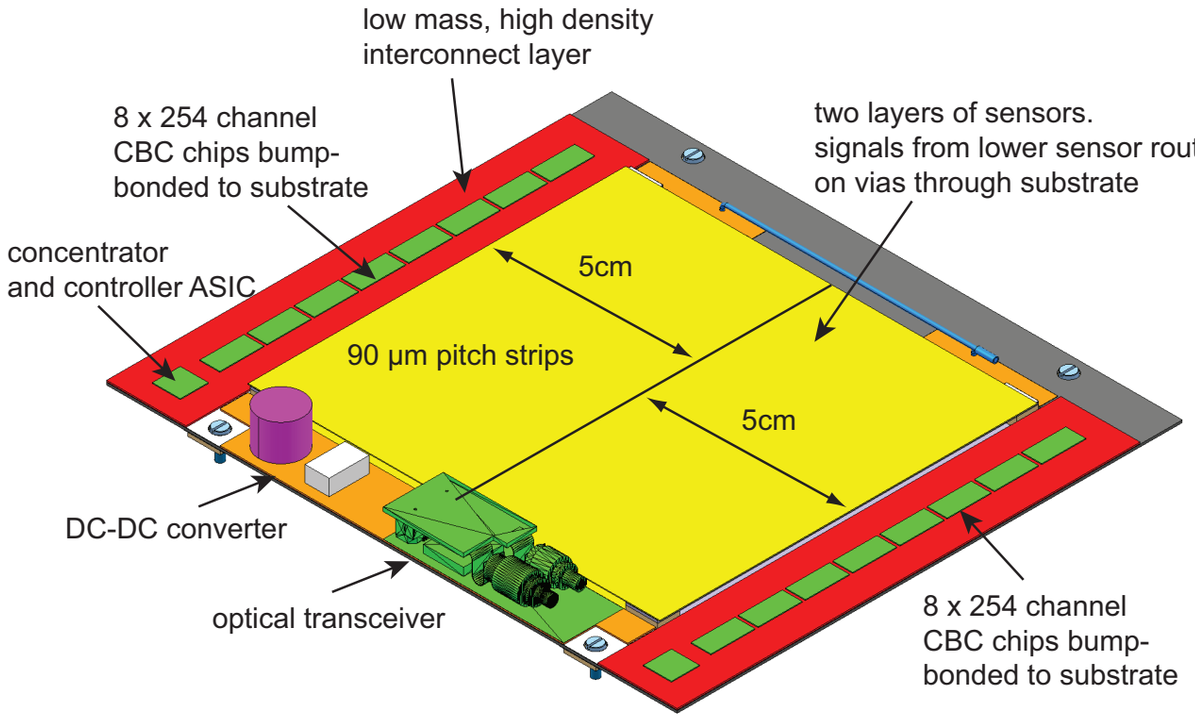
Strip/Pixel Modules
100 μm pitch/2.5 cm length
100 μm x 1.5 mm "macropixels"

- UK deliverables
  - CBC low-power readout ASIC; Off-detector track trigger processor

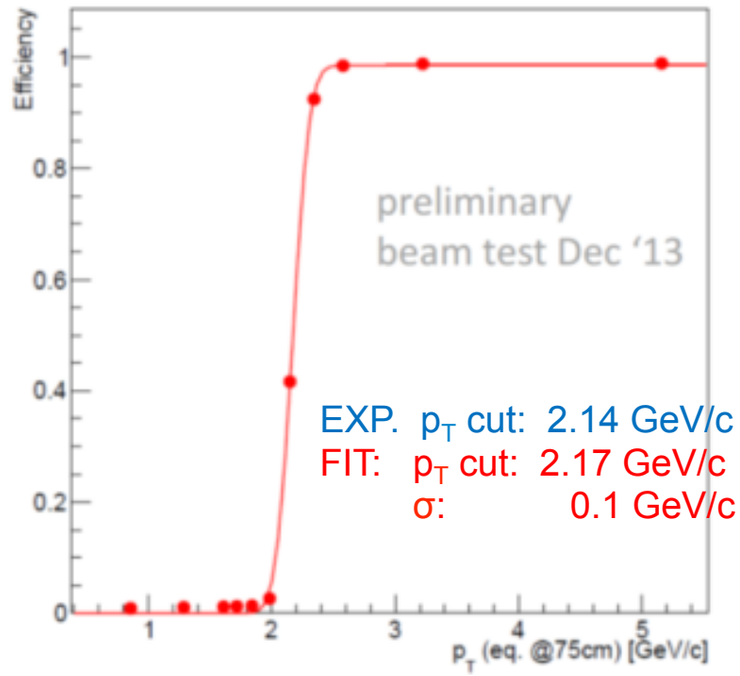
UK R&D: Tracker Module Tests

- ~15000 modules transmitting
  - p_T-stubs to L1 trigger @ 40 MHz
  - full hit data to HLT @ 0.5-1 MHz





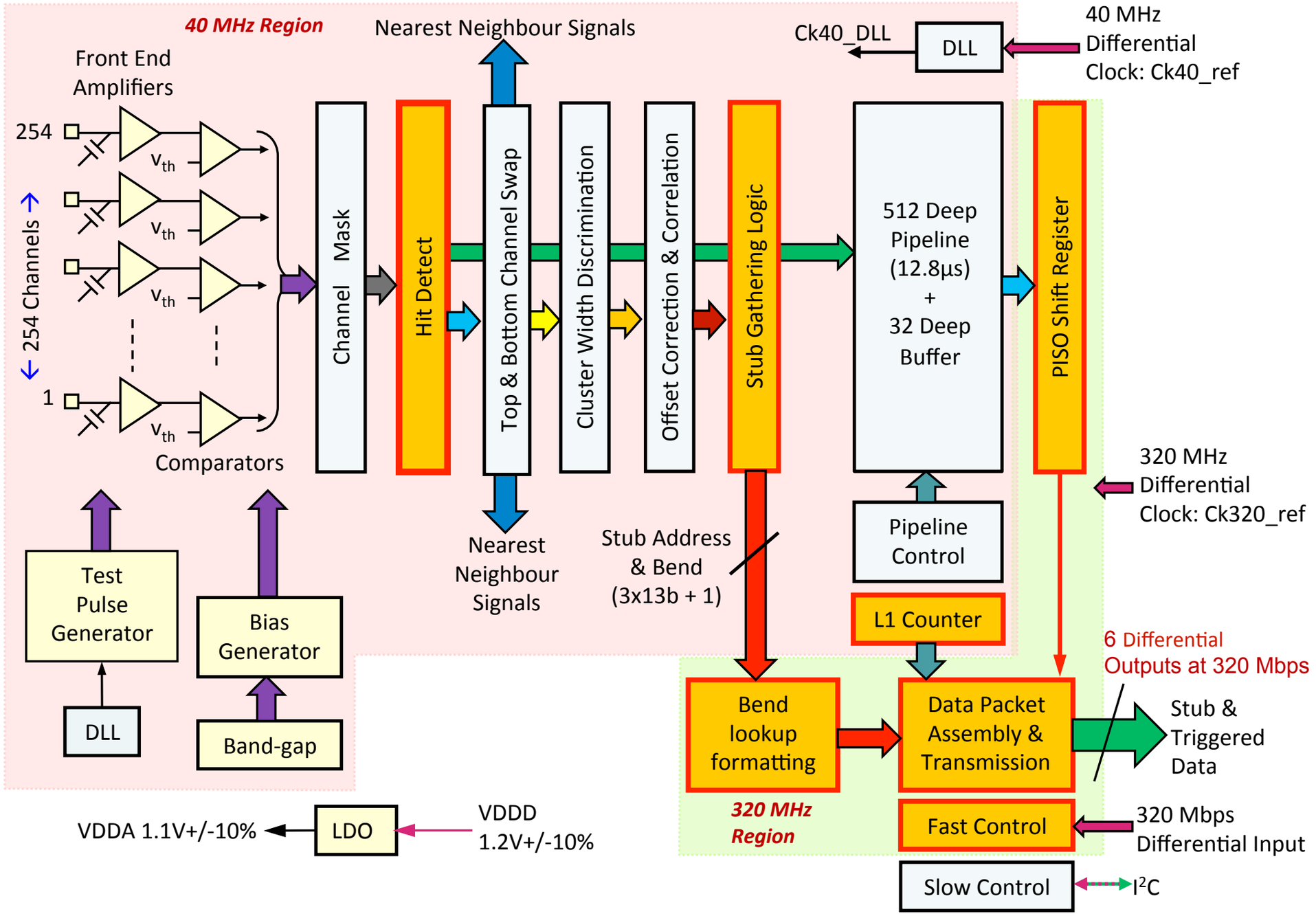
~8400 2S-modules



reconstructed p_T cut of r=75cm layer

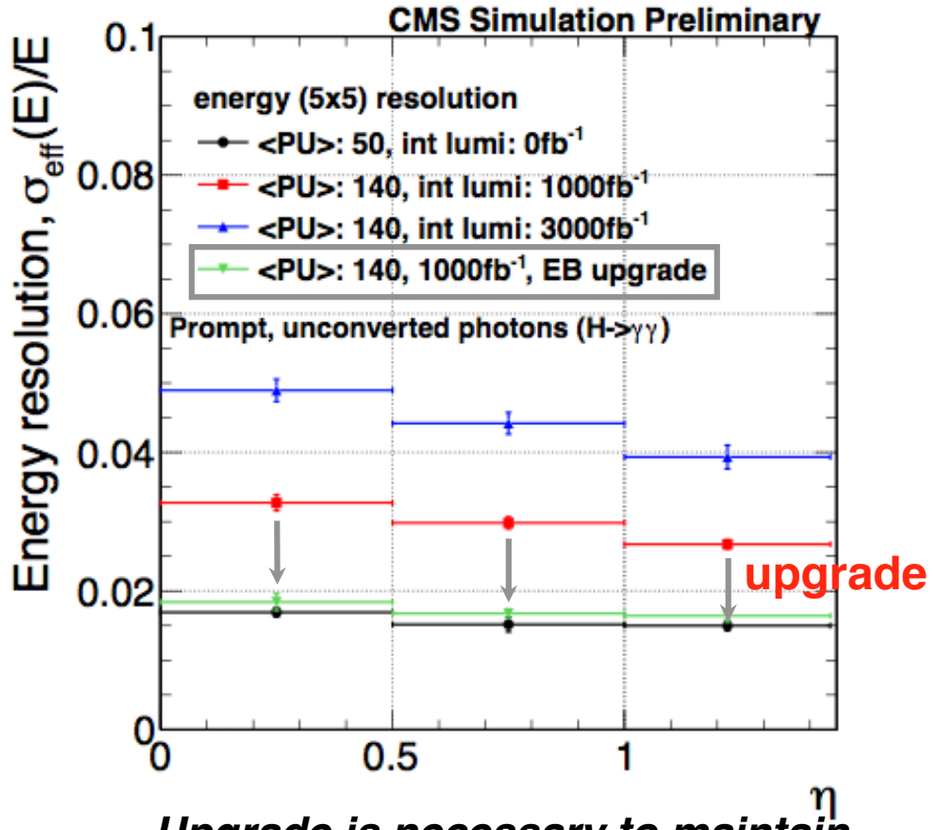
- Successful beam test of first 'stacked' module prototypes

UK R&D: CBC3 Design Progress

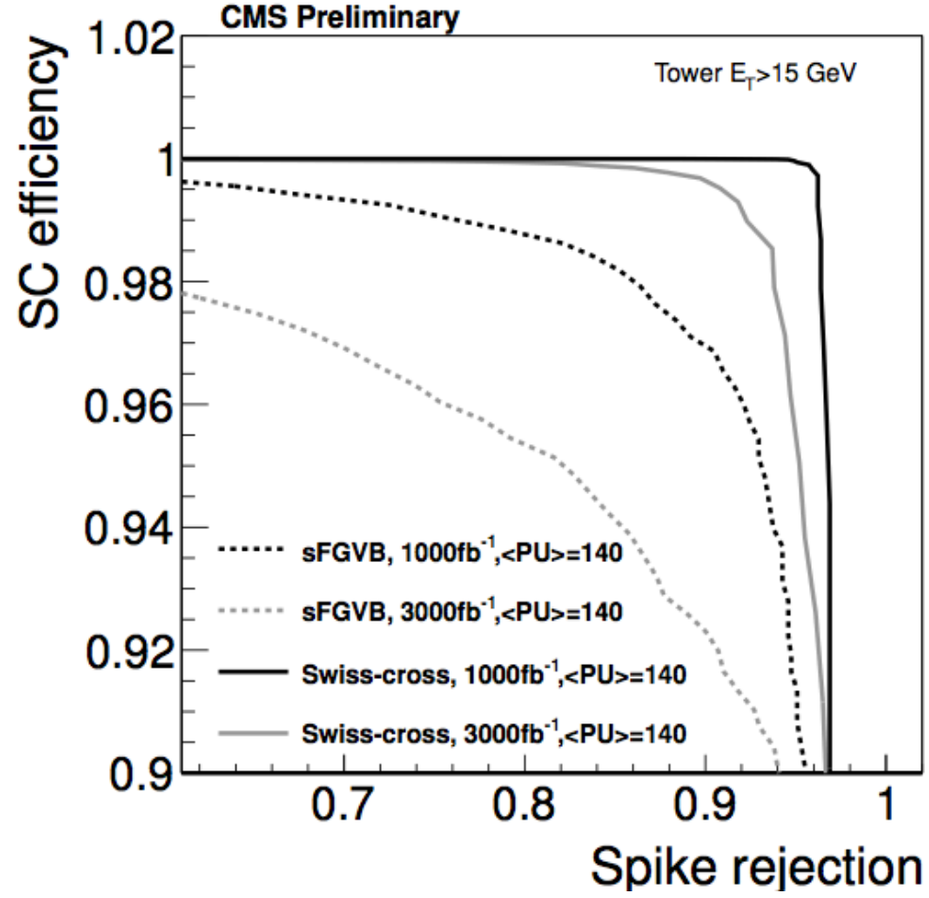


Almost complete. Areas outlined in red, where work is in final stages.

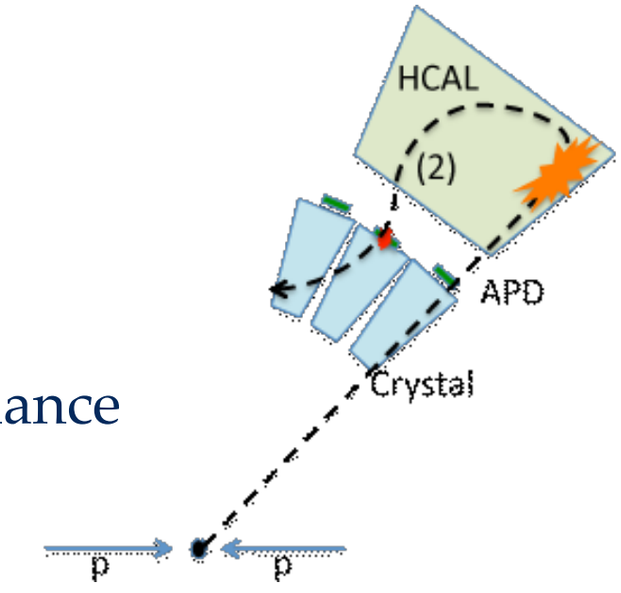
UK R&D: ECAL



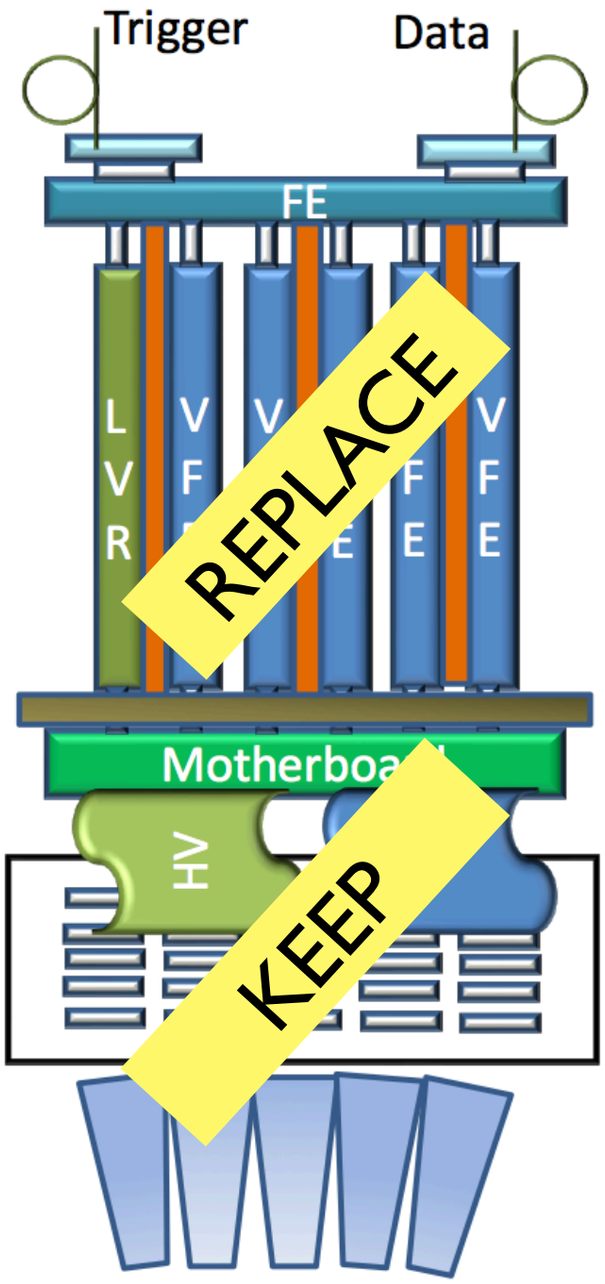
Upgrade is necessary to maintain good photon resolution in Phase II



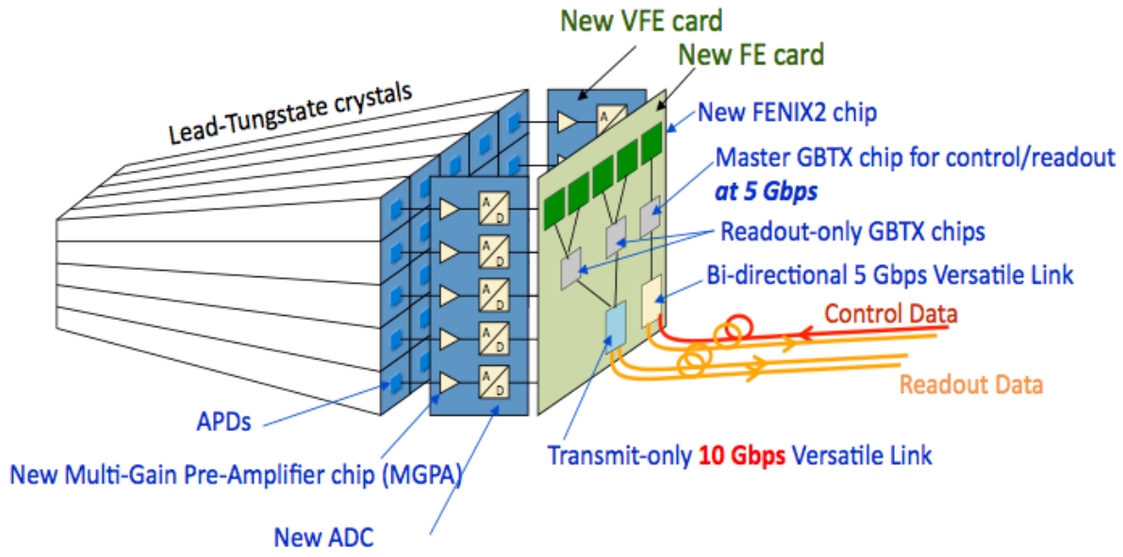
- Energy resolution
  - Mitigate APD dark current noise via cooling and new FE ASIC
- Trigger performance
  - Crystal-level granularity readout for maximum trigger performance
    - Including PU rejection and matching with L1 tracks
  - Suppression of spikes in new ASIC and off-detector electronics



UK R&D: ECAL

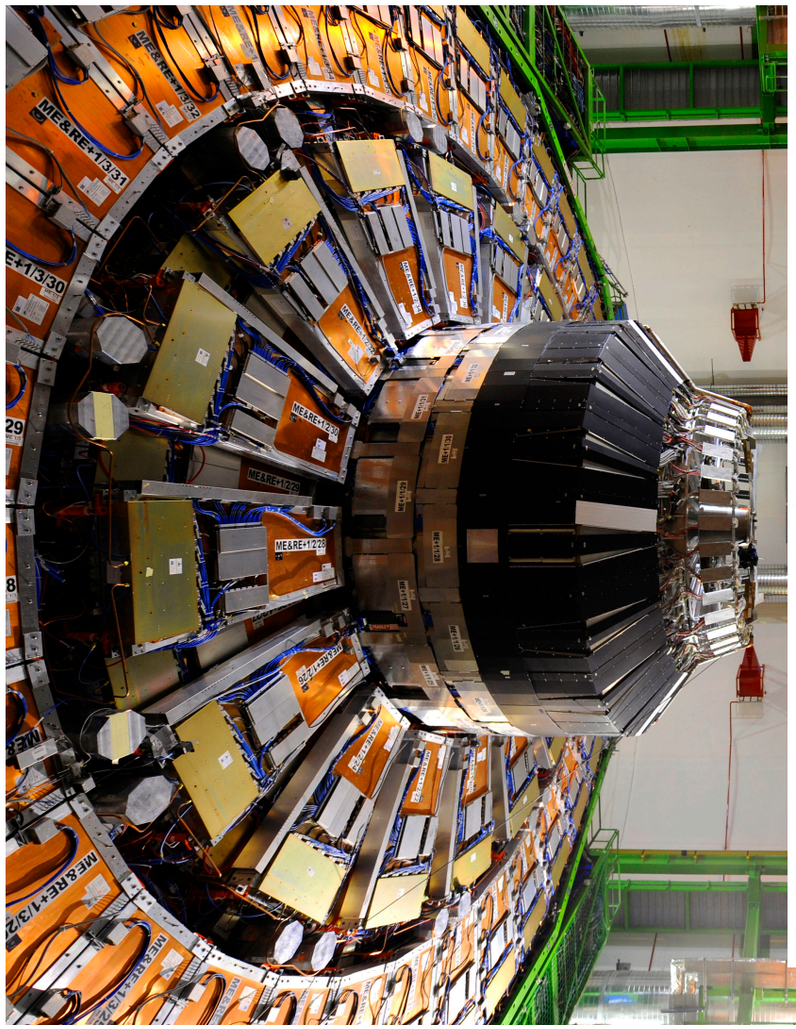


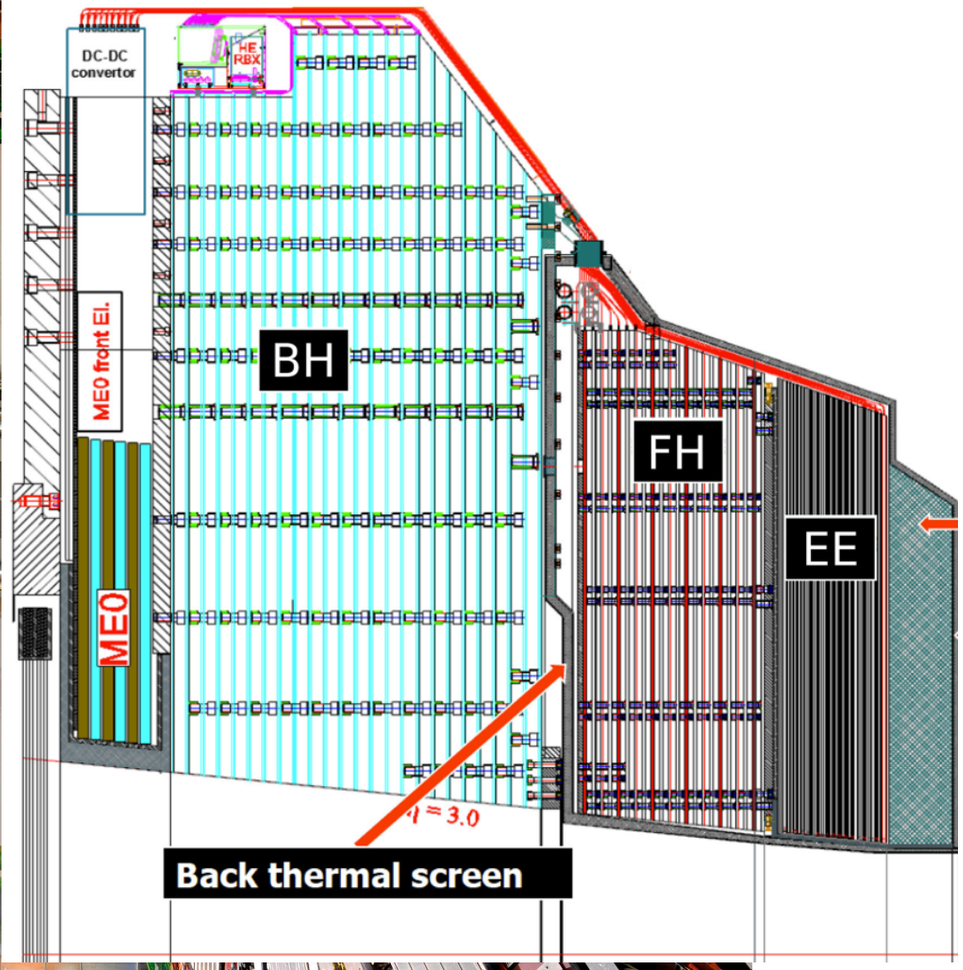
- Extract all 36 barrel supermodules
  - Replace all FE and VFE electronics cards
  - New system reads out full data from detector



Science & Technology Facilities Council Rutherford Appleton Laboratory
University of BRISTOL

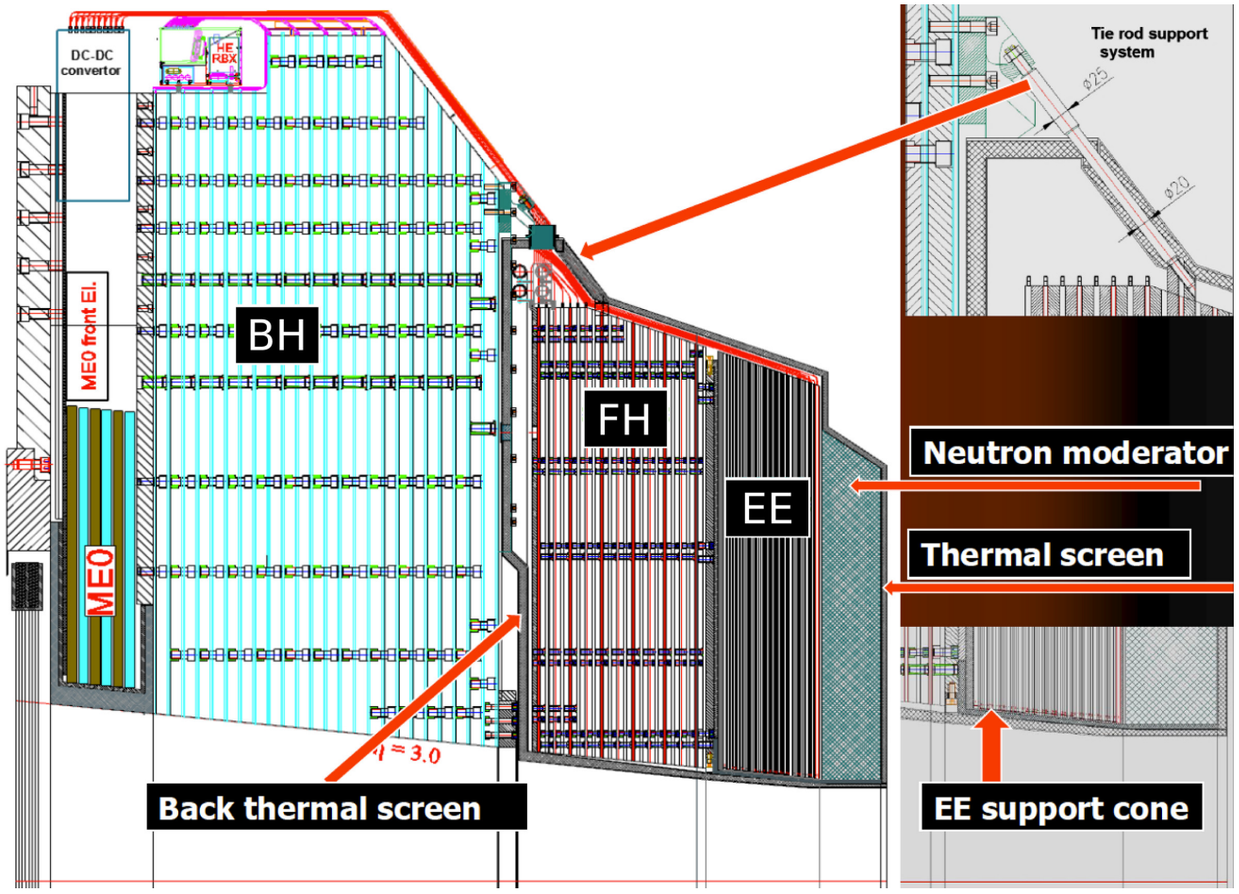
UK R&D: High-Granularity Calorimeter





- Current endcap calorimetry will not remain performant in LS3
  - Due to combination of radiation damage and high pileup conditions
- Plan to replace by integrated high-granularity calorimeter
  - Sampling calorimeter with silicon sensors, optimised for high pileup
  - High granularity readout (~1cm^2) + precision timing capability (<50ps)

UK R&D: HGC



Construction:

- *Hexagonal Si-sensors built into modules.*
- *Modules with a W/Cu backing plate and PCB readout board.*
- *Modules mounted on copper cooling plates to make wedge-shaped cassettes.*
- *Cassettes inserted into absorber structures at integration site (CERN)*

Key parameters:

- *593 m^2 of silicon*
- *21,660 modules*
- *92,000 front-end ASICS.*
- *Power at end of life 115 kW.*

System Divided into three separate parts:

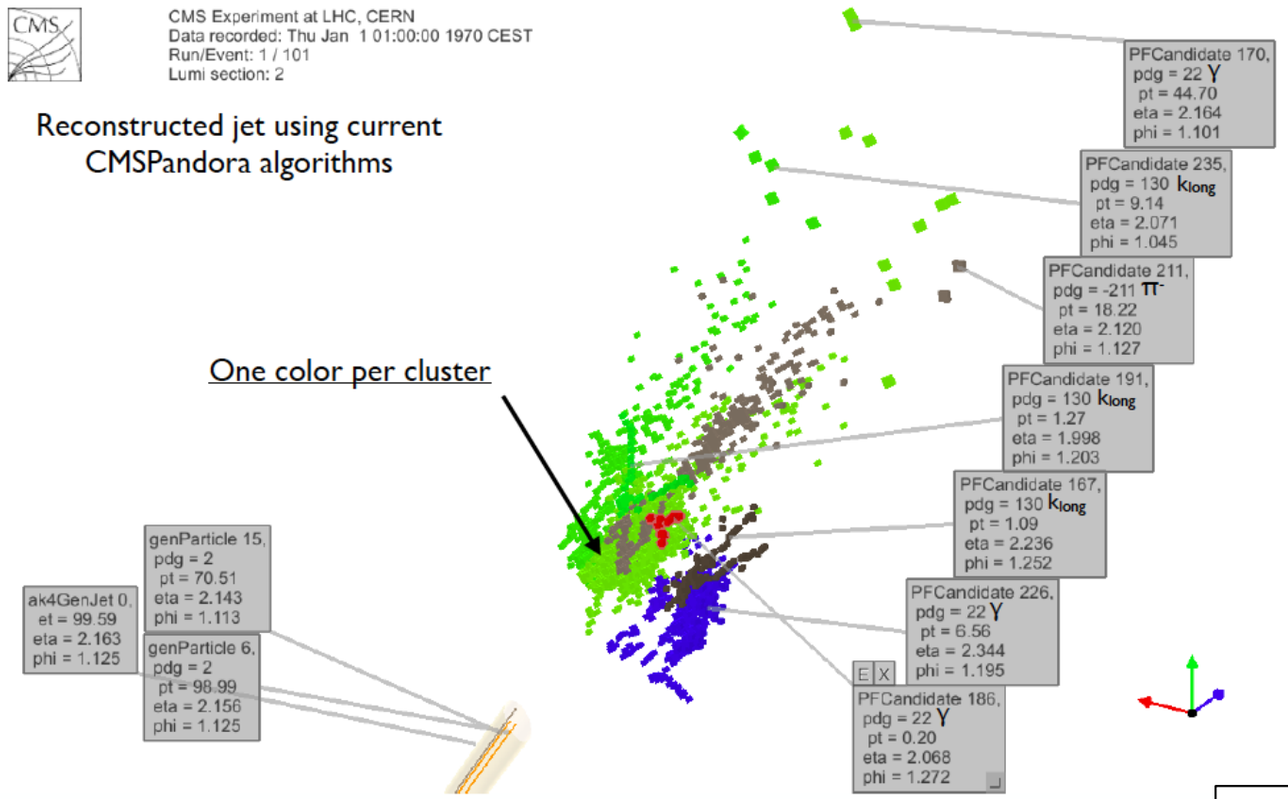
EE – Silicon with tungsten absorber – 28 sampling layers – 25 X_o + ~1.3 λ

FH – Silicon with brass absorber – 12 sampling layers – 3.5 λ

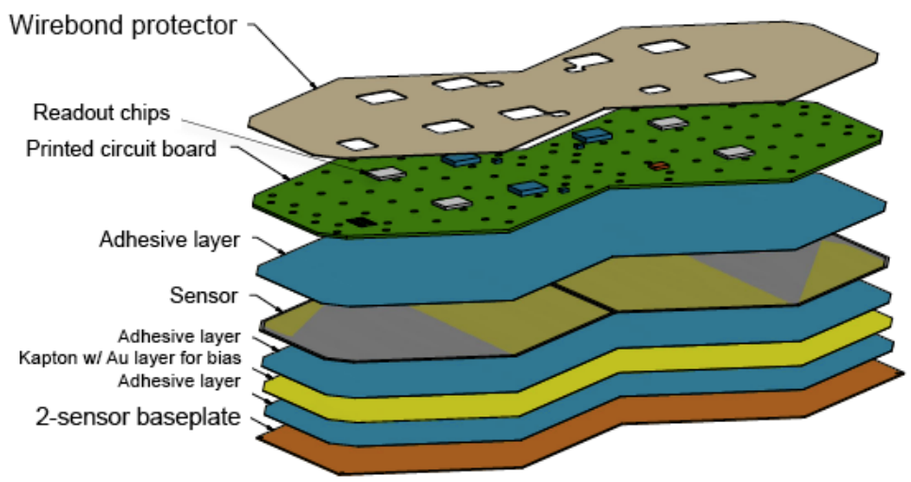
BH – Scintillator with brass absorber – 11 layers – 5.5 λ

EE and FH are maintained at – 30°C. BH is at room temperature.

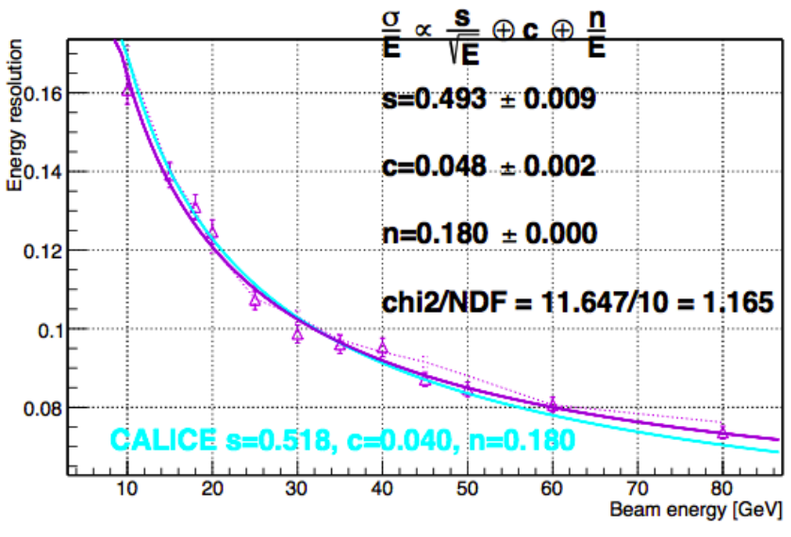
UK R&D: HGC



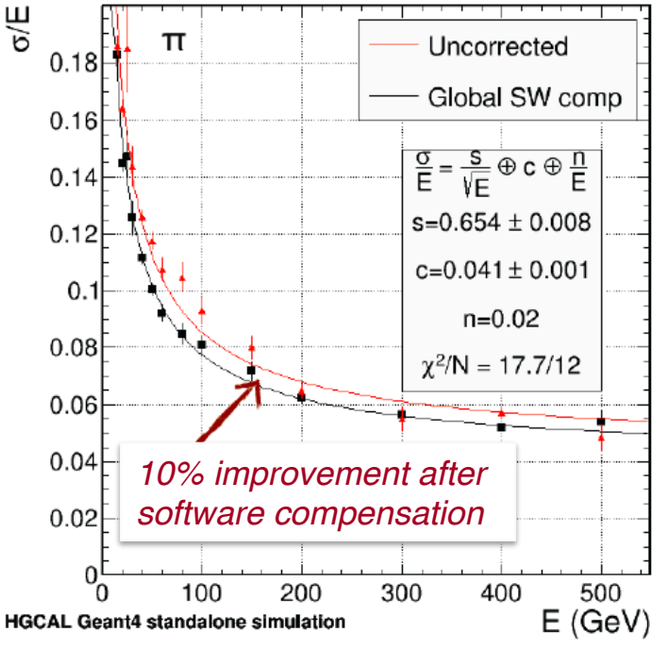
HGC: Module using two 6” sensors



Energy Resolution: CALICE



Energy Resolution: HGC



Summary

- A crucial new era for LHC is about to start
  - 13TeV energy at high lumi offers enormous scope for discovery
- CMS is ready for Run II
  - Well understood detector and conditions, already allowing rapid physics output
  - A rich physics programme is now just ahead of us
- Challenges for coming years
  - Operating, rebuilding and exploiting highly complex detector, all in parallel
  - We should not be complacent about the need for ongoing expert effort
- The long-term future
  - CMS upgrade programme taking firm shape for the next ten years
  - Investment of time and resources required to unlock Phase-2 physics
- The LHC will drive the physics direction in the medium term
  - Results vital in informing the full breadth of the future field
  - Detector upgrades vital for long-term scientific return from CERN
  - Vibrant CMSUK effort vital for the health of UK particle physics

Backup

Phase-2 Upgrade

Performance/ Physics	Higgs VBF H→$\tau\tau$	Higgs H→μμ	Higgs H→ZZ→4l	Higgs HH→bbγγ	Higgs HH→bb$\tau\tau$	SMP VBS	SUSY VH(bb) +MET	EXO A_{fb} (Z')	EXO Dark Matter	EXO HCP	BPH $B_{s,d}$→μμ
Tracker											
Performance		*mass resolution*	mass resolution	*b-tagging*	*b-tagging*						*mass resolution*
Extensions	*forward jets / MET*		*acceptance*		*MET resolution*	*forward jets*	*MET resolution*	*acceptance*	*acceptance*		
Trigger											
Bandwidth	*acceptance*				*acceptance*						
Track Trigger	*background rejection*				*background rejection*						*background rejection*
Calorimeter											
ECAL	*forward jets / MET*		*acceptance*	*acceptance*	*MET resolution*	*forward jets*	*MET resolution*	*acceptance*	*acceptance*		
HCAL	*forward jets / MET*				*MET resolution*	*forward jets*	*MET resolution*				
Muons											
Extension			*acceptance*					*acceptance*	*acceptance*		

SUSY Projections

Based on:
arXiV:1409.4075v2.pdf

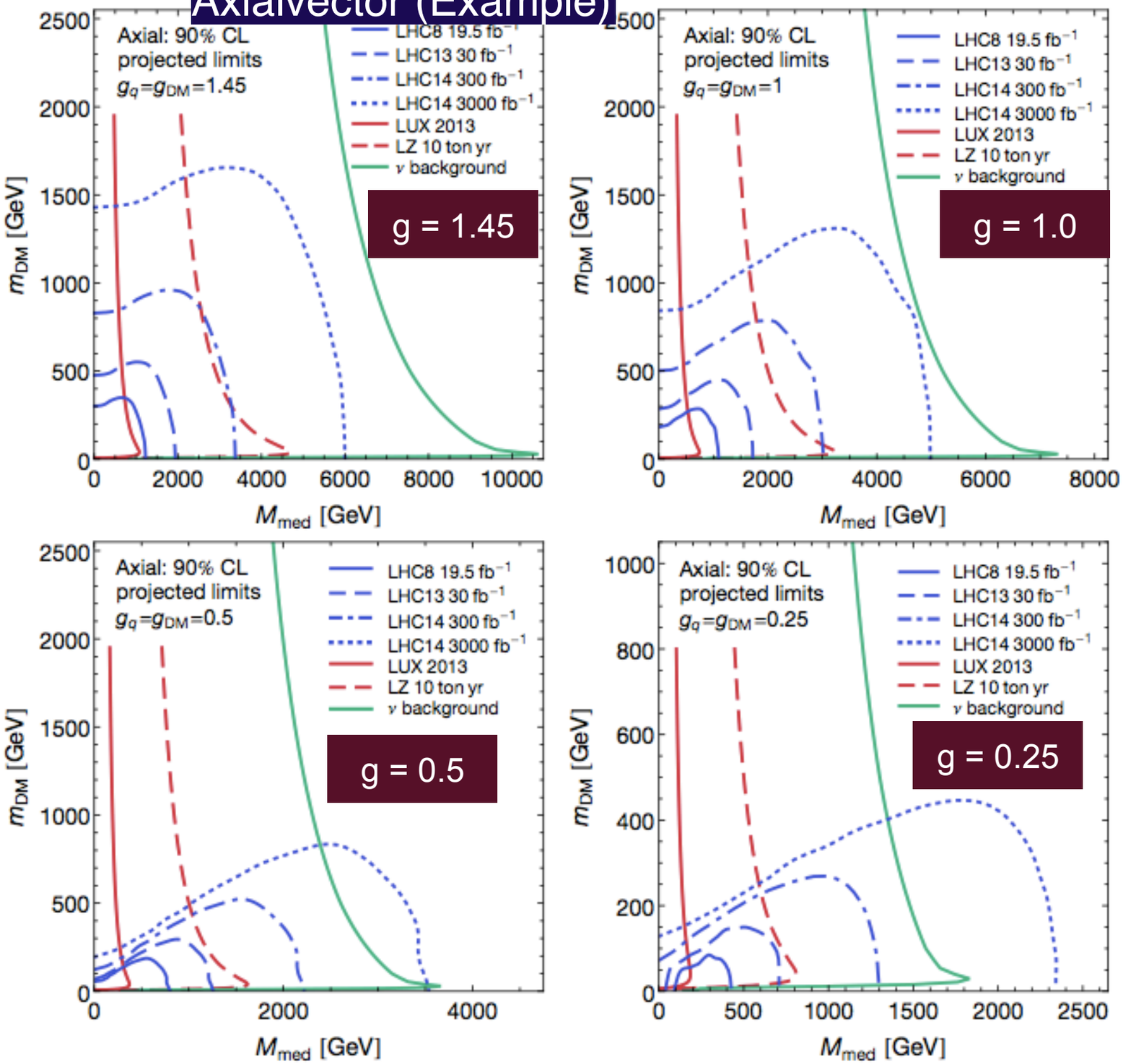
Limits from 8 TeV monojet search and projected limits for 3 LHC scenarios:
- 13 TeV 30 fb^{-1}
- 14 TeV, 300 fb^{-1}
- 14 TeV, 3000 fb^{-1}

LUX 2013 limits and projected limits for LZ assuming 10 tonne-year exposure

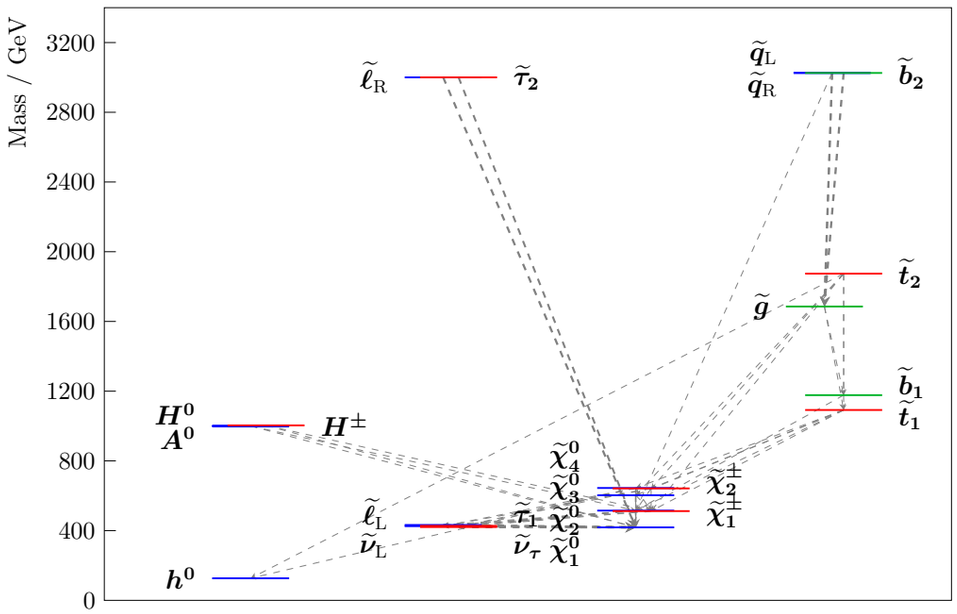
Discovery reach accounting for coherent neutrino scattering

O. Buchmuller

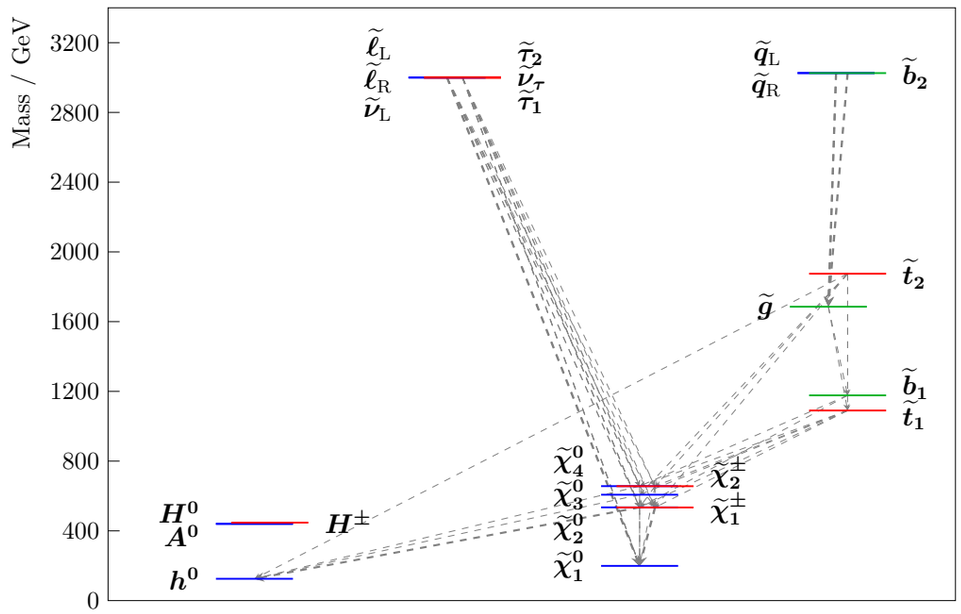
Axialvector (Example)



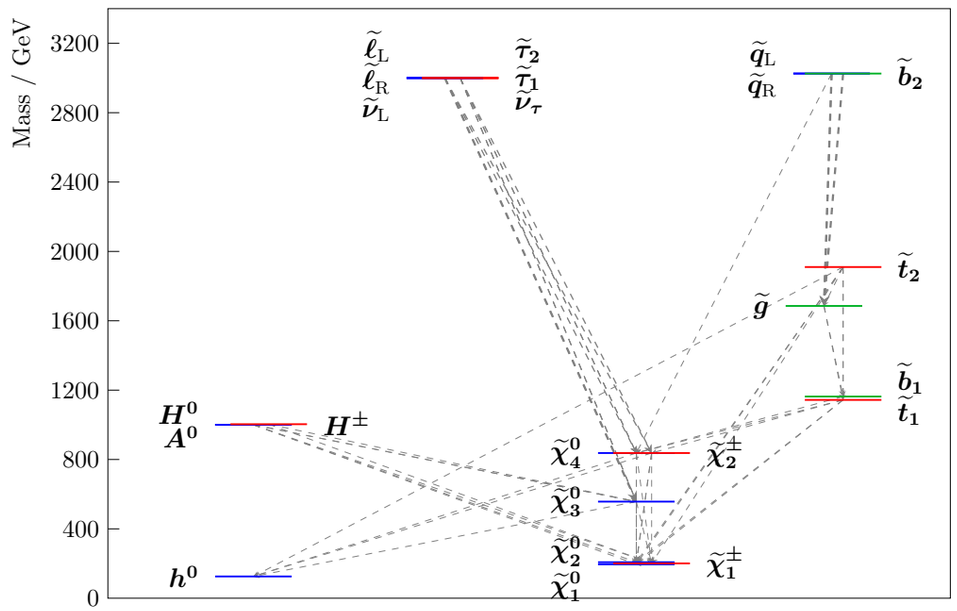
SUSY Benchmark Models



(a) NM1



(b) NM2



(c) NM3