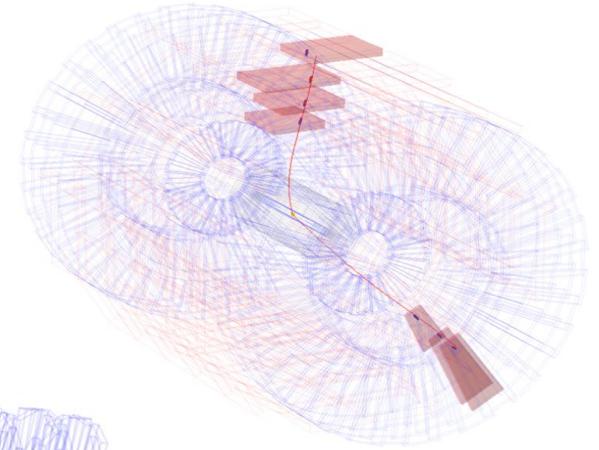
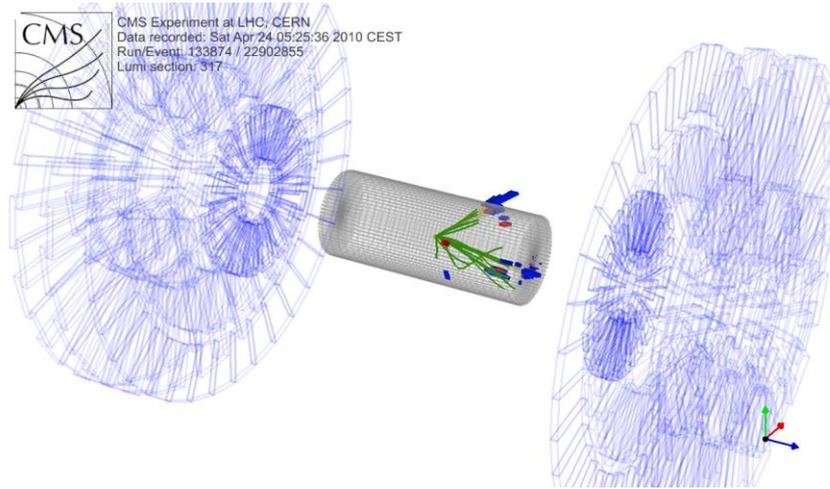



 CMS Experiment at LHC, CERN
 Data recorded: Sat Apr 24 05:25:36 2010 CEST
 Run/Event: 133874 / 22902855
 Lumi section: 317

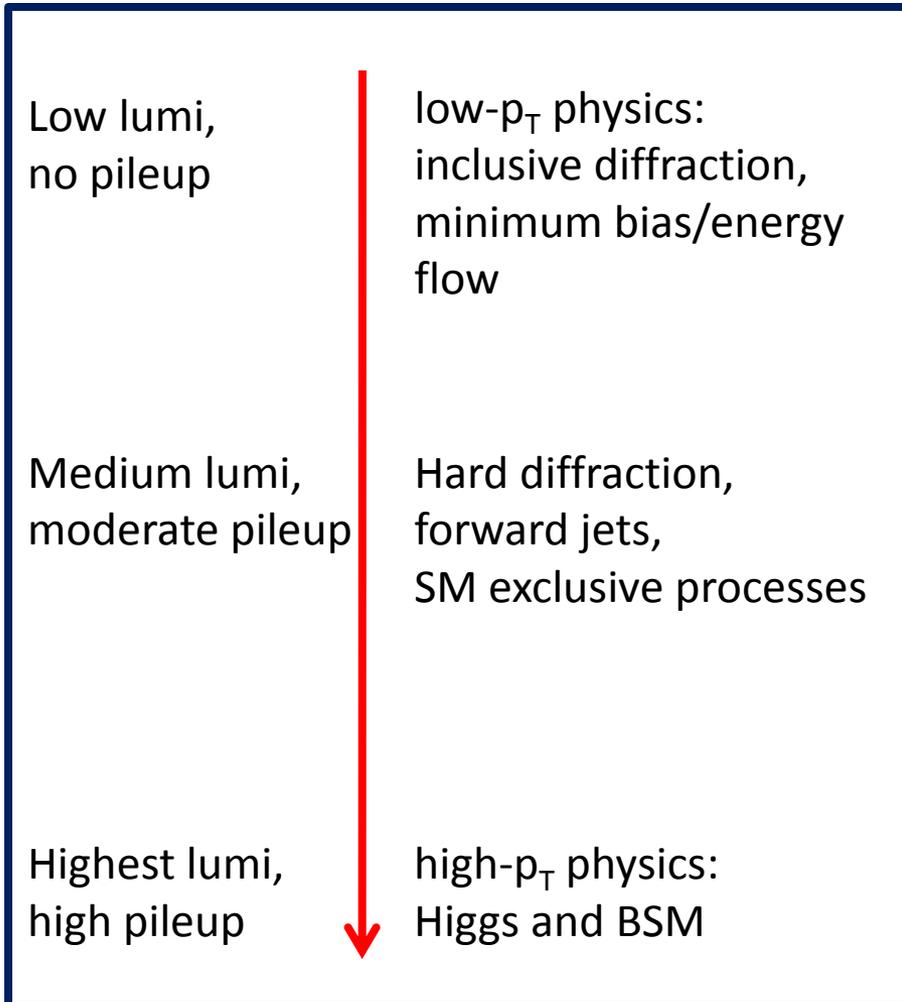


Diffraction at CMS

Status and plans for 2011/2012

Jonathan Hollar (UCLouvain)
for the CMS Collaboration

Diffraction and forward physics at CMS



- CMS has a diverse diffractive & forward physics program
- Designed to evolve with changing LHC conditions
 - With earliest data: “rediscovery” of diffraction and minimum bias energy flow measurements
 - Higher luminosities: repeat and extend the Tevatron/HERA programs of exclusive & hard diffractive processes, forward jets
 - At the highest luminosities: Explore new territory with BSM physics

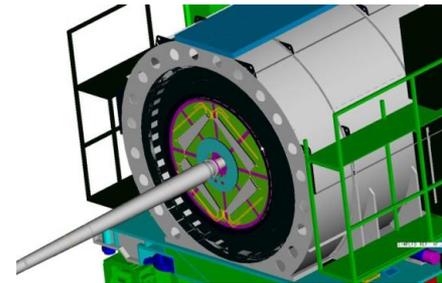
Early forward/trigger detectors

Hadronic Forward Calorimeter (HF)



- Cerenkov calorimeter located 11.2m from IP5
- Covering $3 < |\eta| < 5$

BSC



- Scintillator trigger counters 10.9m from IP5

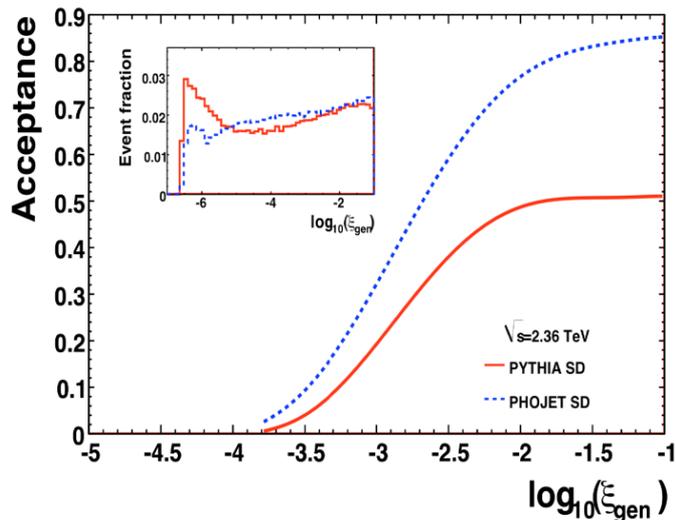
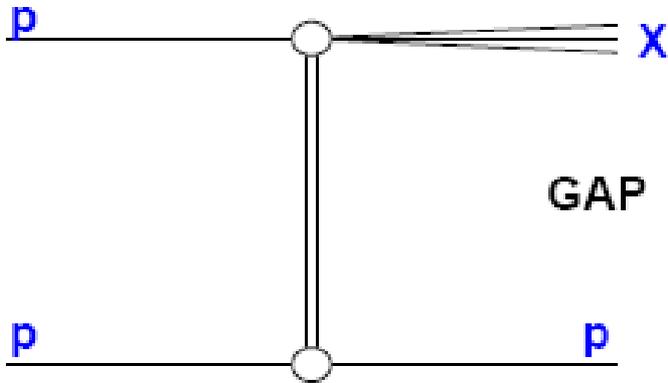
BPTX



- Beam current pickups, 175m from IP5

Inclusive diffraction

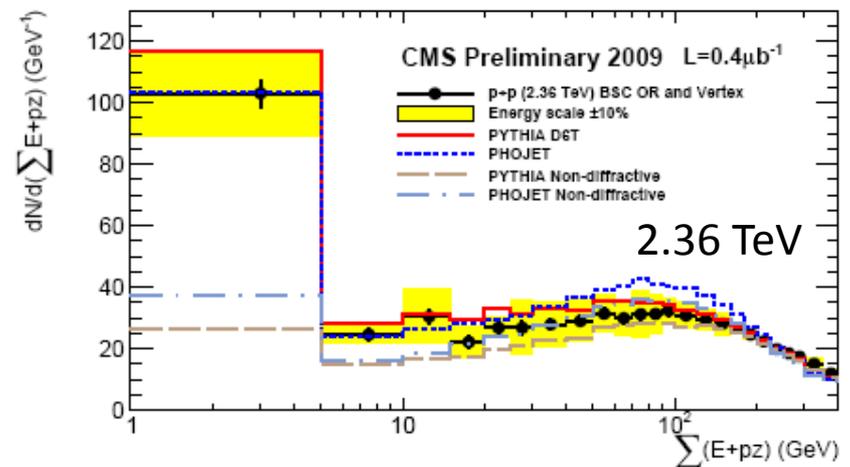
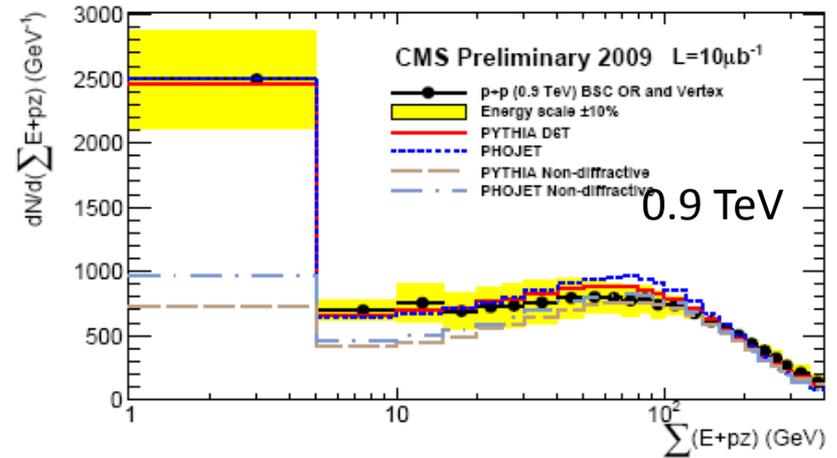
Rediscovery of single diffraction



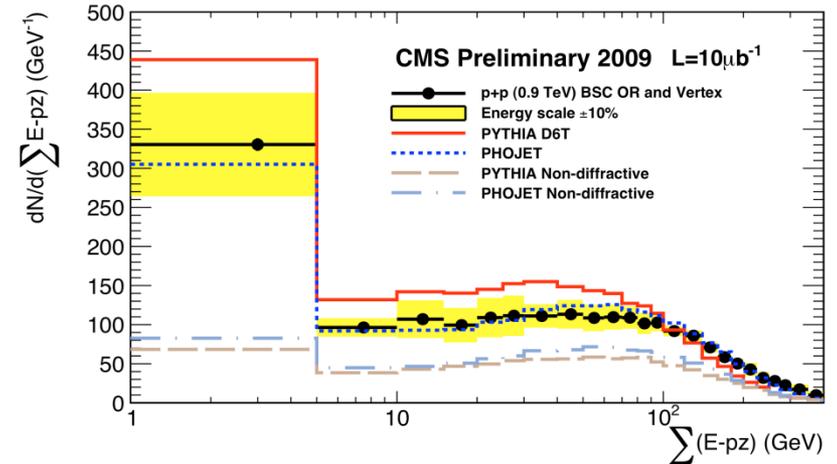
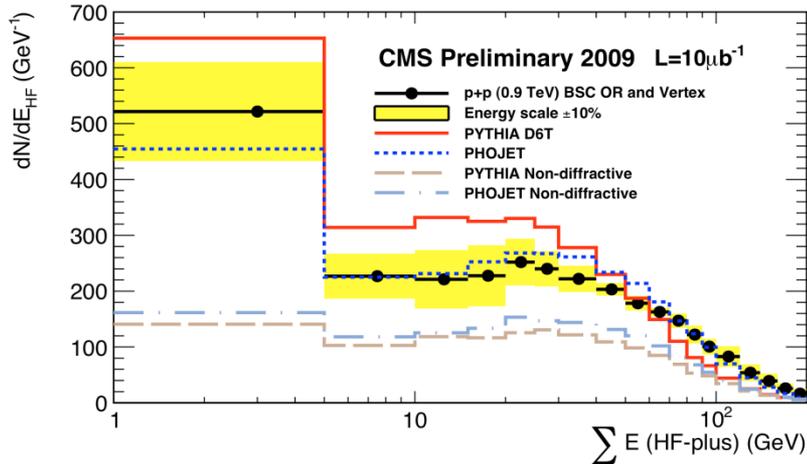
- Selection
 - Trigger on beam crossings (BPTX), with hits in at least one of the BSC detectors
 - Select events with a vertex consistent with collisions
 - Reject known noise/beam-halo signatures
- Trigger efficiency and residual beam-backgrounds checked using ZeroBias samples
- Overall efficiency for single diffraction $\sim 20\text{-}35\%$
 - Significant difference between Pythia 6 and Phojet

Diffraction at 0.9 and 2.36 TeV

- Plot variables sensitive to the presence of Large Rapidity Gaps
 - $\Sigma(E+p_z)$
 - Number of HF towers over threshold (4 GeV)
 - All distributions uncorrected
- Large excess of events with low $\Sigma(E+p_z)$, 0 towers compared to non-diffractive MC
 - Observation of single diffraction at 0.9 and 2.36 TeV



Diffraction-enhanced samples

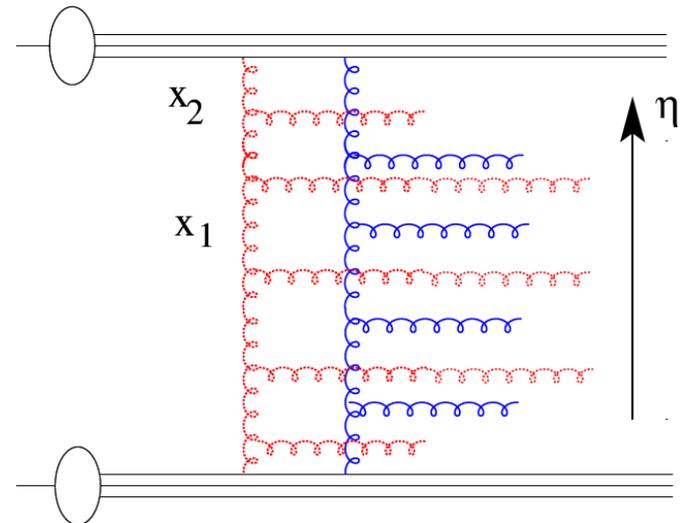


- Enhance the diffractive component by requiring $E(\text{HF}) < 8$ GeV to test MC modeling
- Phojet gives better agreement, especially at higher masses M_x
- Pythia 6 (D6T tune) generally shows a softer spectrum than data

Forward jets and energy flow

Energy flow

- Probe of the small-x proton content
 - Sensitive to large parton densities, multi-parton interactions
- Energy flow measurements performed at 0.9, 2.36, 7 TeV
 - Trigger on beam coincidence and BSC
 - Sum energy deposits above 4 GeV in HF
- Two event classes studied
 - Minimum Bias
 - Dijet events
 - Anti-kT algorithm
 - 2 jets with $|\eta| < 2.5$, $|\Delta\phi - \pi| < 1$
 - $p_T > 8$ (20) GeV at 0.9/2.36 (7) TeV

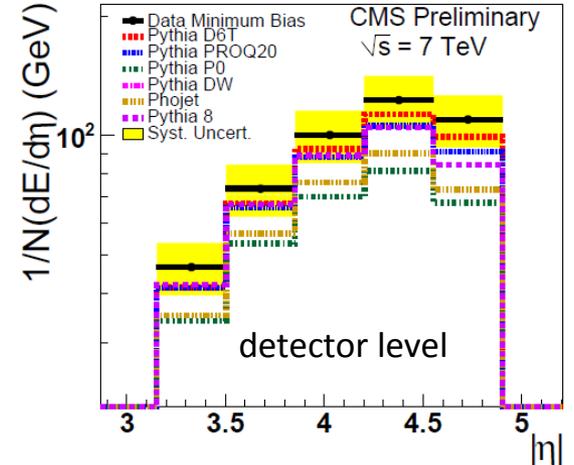
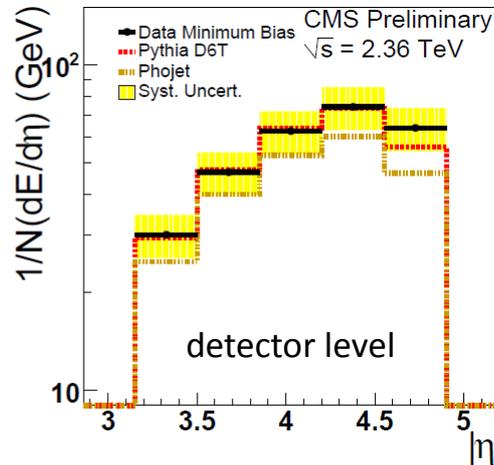
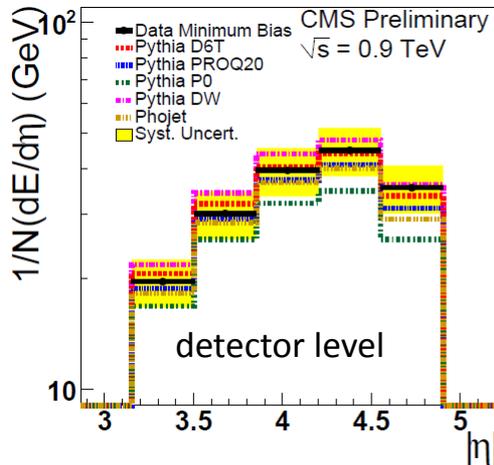


Energy flow – Minimum Bias

900 GeV

2.36 TeV

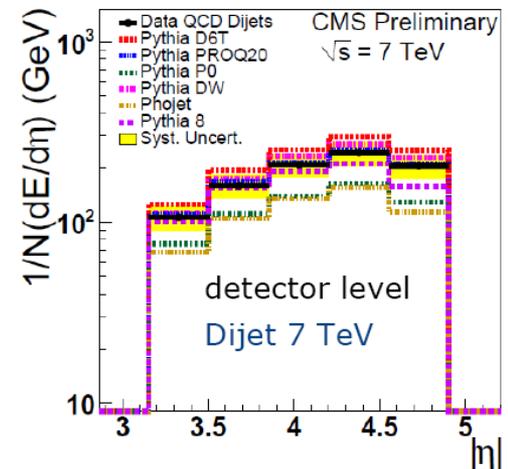
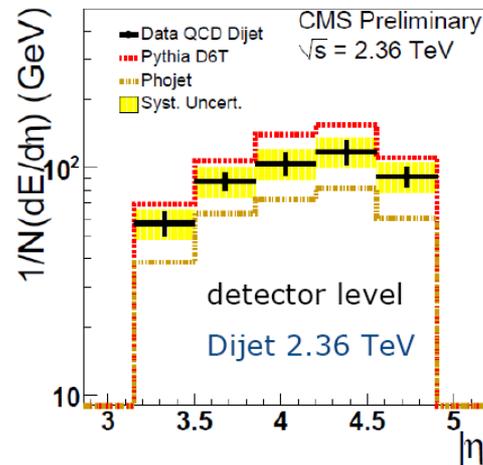
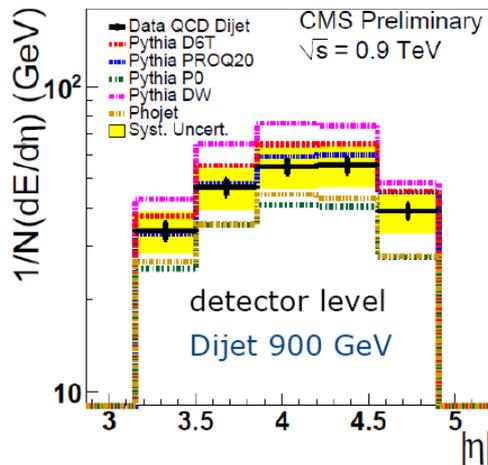
7 TeV



- 0.9/2.36 TeV: Best description by D6T tune of Pythia 6
- 7 TeV: Data above Pythia 8, Phojet, and all Pythia 6 tunes

Energy flow - Dijets

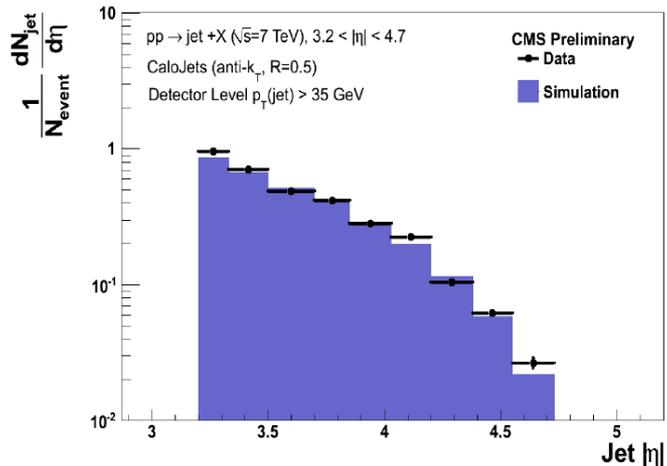
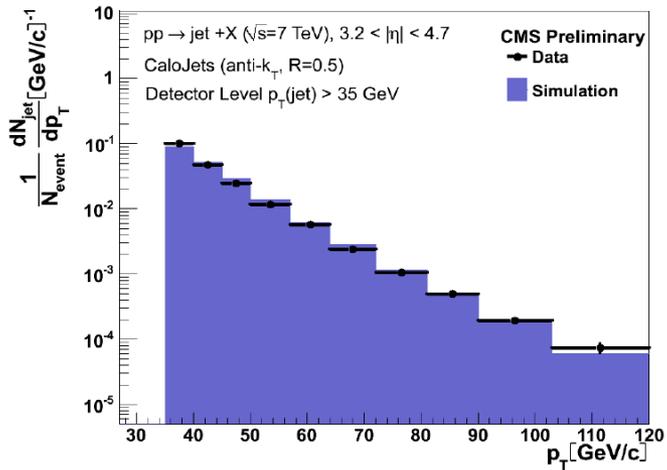
900 GeV → 2.36 TeV → 7 TeV



- 0.9 TeV: Best description by PROQ20 tune of Pythia 6
- 2.36 TeV: Pythia 6 D6T tune too high, Phojet too low
- 7 TeV: Reasonable description by PROQ20 Pythia 6 tune, Pythia 8

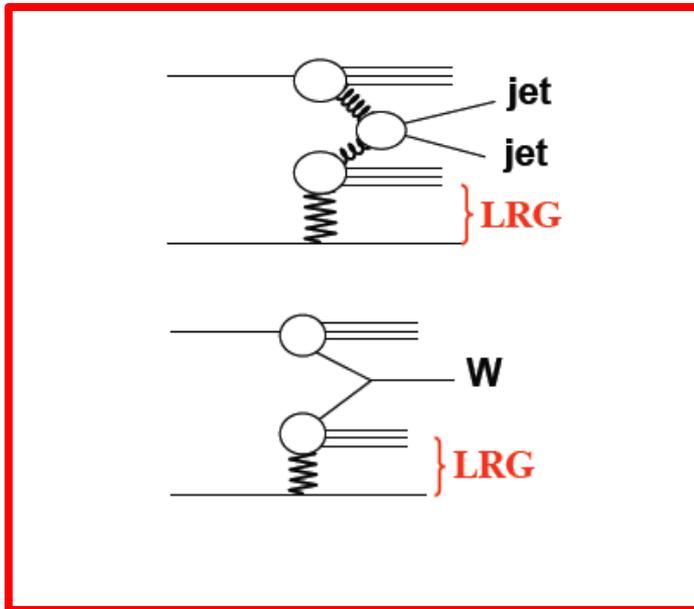
Towards higher luminosities

Forward jets



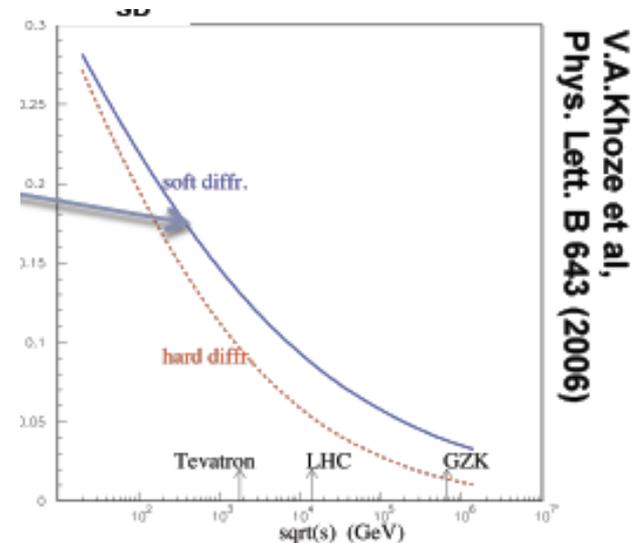
- First measurement in the forward region, using 10 nb^{-1} at 7 TeV
- Jet selection
 - $3.2 < |\eta| < 4.7$
 - $35 < E_T < 120$ GeV (corrected)
 - Anti- k_T algorithm ($R>0.5$)
- Reasonable agreement with MC (Pythia 6, D6T)
 - Detector-level distributions, no systematics, no unfolding
 - **Validation of forward jet reconstruction**
- Next steps: corrected and double differential distributions, forward-backward and forward-central correlations

Hard diffraction



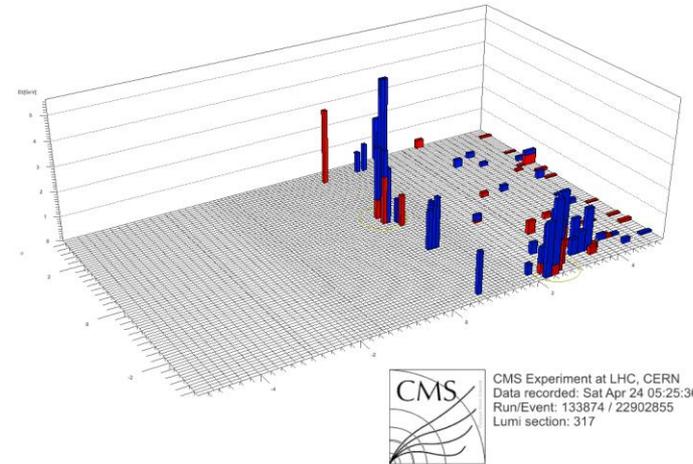
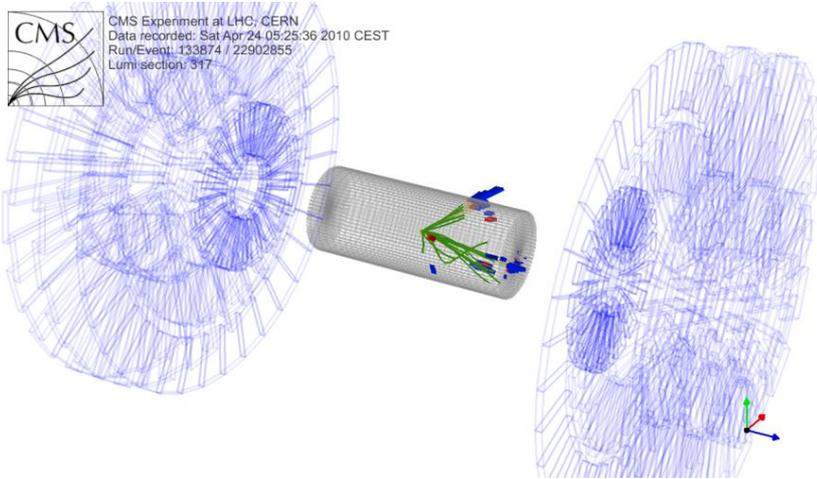
- Search for single-diffractive production with a hard scale involved
 - Dijets
 - W/Z

- Sensitive test of the gap survival probability $\langle S^2 \rangle$ at 7 TeV
 - Predictions typically of order $\sim 5\%$, but much larger/smaller values have been proposed



Diffractive dijet candidates

CMS
CMS Experiment at LHC, CERN
Data recorded: Sat Apr 24 05:25:36 2010 CEST
Run/Event: 133874 / 22902855
Lumi section: 317



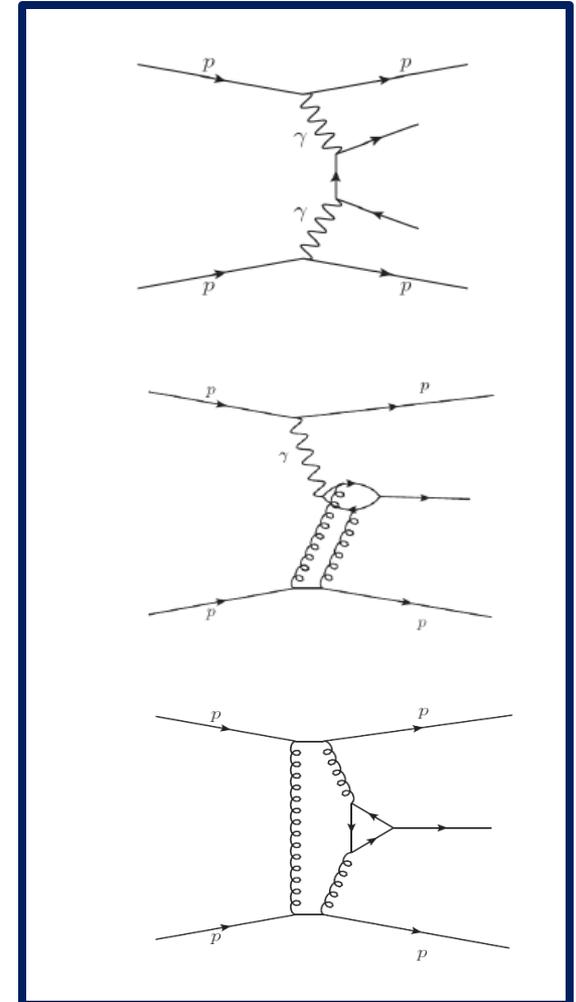
CMS
CMS Experiment at LHC, CERN
Data recorded: Sat Apr 24 05:25:36 2010 CEST
Run/Event: 133874 / 22902855
Lumi section: 317

$$p_T(\text{jet1}) = 43.5 \text{ GeV}, \quad p_T(\text{jet2}) = 36.9 \text{ GeV}$$
$$\eta(\text{jet1}) = 0.83, \quad \eta(\text{jet2}) = 2.55$$

- First diffractive dijet events observed in CMS, with
 - $p_T(\text{jet 1}) > 30 \text{ GeV}$, $p_T(\text{jet 2}) > 20 \text{ GeV}$
 - No HF energy deposition above 4 GeV

Exclusive processes

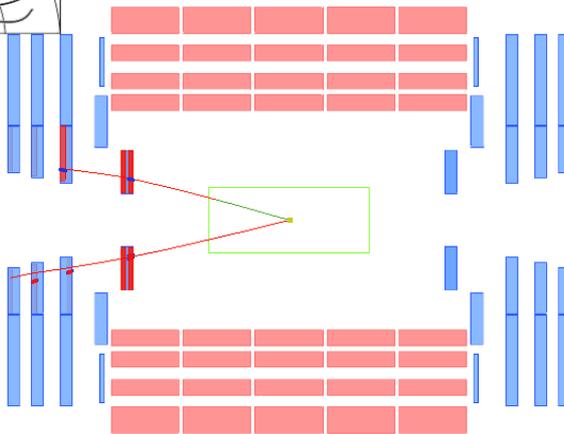
- For 2011-2012: rediscover exclusive processes at 7 TeV, begin exploring new territory beyond Tevatron/HERA
- $\gamma\gamma$ interactions
 - QED l^+l^- standard candle
 - BSM physics in high- p_T dilepton final states
- γp interactions
 - Extend J/ψ , Y photoproduction measurements beyond HERA energies
- Central exclusive production (dijets, $\gamma\gamma$, χ_b)
 - Test theoretical predictions at 7 TeV, as a prelude to exclusive Higgs searches



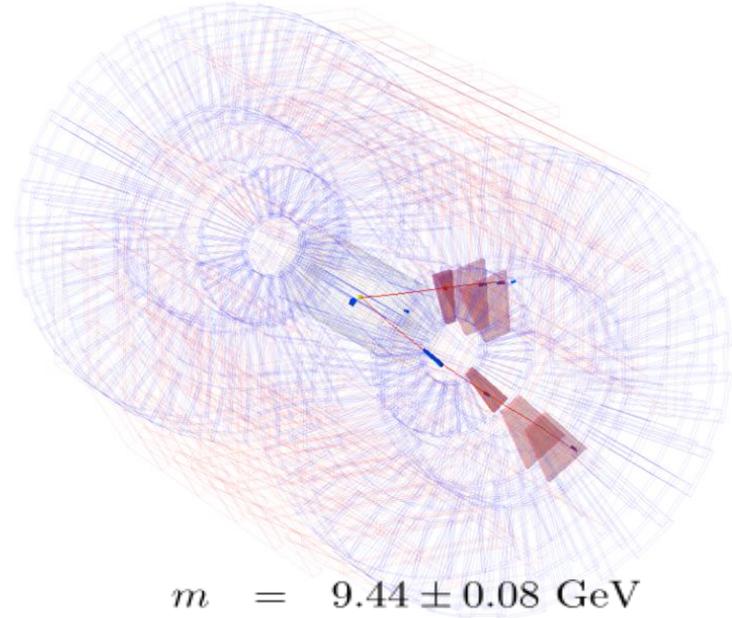
Exclusive quarkonia candidates



CMS Experiment at LHC, CERN
Data recorded: Sun Jul 4 07:53:17 2010 CEST
Run/Event: 139364 / 71476695
Lumi section: 70



$$\begin{aligned} m &= 3.05 \pm 0.03 \text{ GeV} \\ \frac{\Delta\phi}{\pi} &= 0.98 \\ \Delta p_T &= 0.05 \text{ GeV} \end{aligned}$$



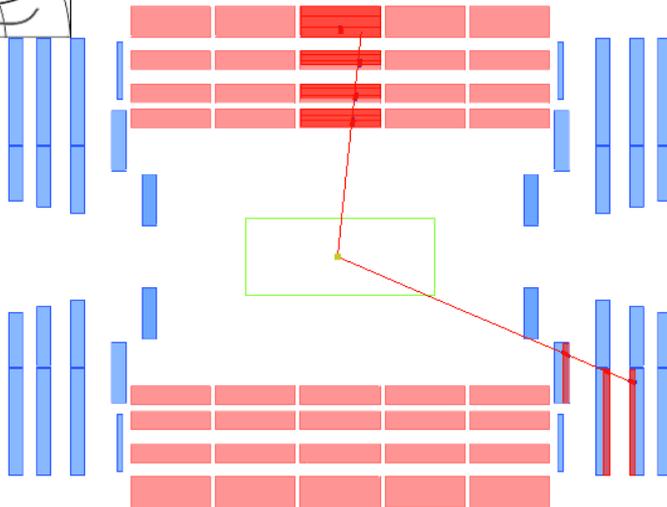
$$\begin{aligned} m &= 9.44 \pm 0.08 \text{ GeV} \\ \frac{\Delta\phi}{\pi} &= 0.99 \\ \Delta p_T &= 0.20 \text{ GeV} \end{aligned}$$

- First candidates for exclusive J/ψ and Y observed
 - $\Delta p_T \approx 0$, $\Delta\phi/\pi \approx 1$
 - No additional tracks, low calorimeter activity

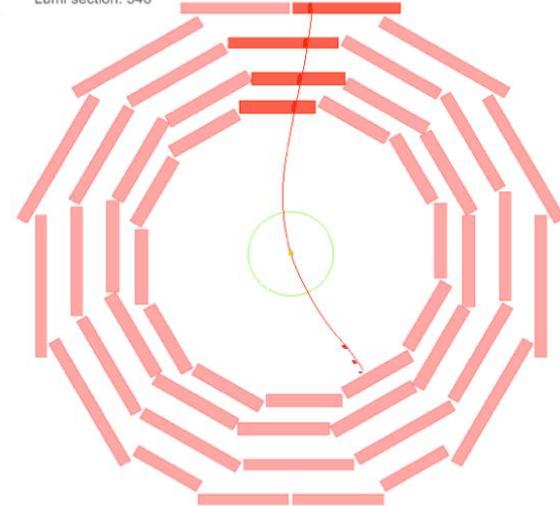
Exclusive $\gamma\gamma \rightarrow \mu\mu$ candidates



CMS Experiment at LHC, CERN
Data recorded: Fri Jul 30 01:43:39 2010 CEST
Run/Event: 141956 / 304737217
Lumi section: 546



CMS Experiment at LHC, CERN
Data recorded: Fri Jul 30 01:43:39 2010 CEST
Run/Event: 141956 / 304737217
Lumi section: 546



$$\begin{aligned} m &= 20.51 \pm 0.2 \text{ GeV} \\ \frac{\Delta\phi}{\pi} &= 0.98 \\ \Delta p_T &= 0.48 \end{aligned}$$

- Also higher mass QED ($\gamma\gamma \rightarrow \mu\mu$) candidates

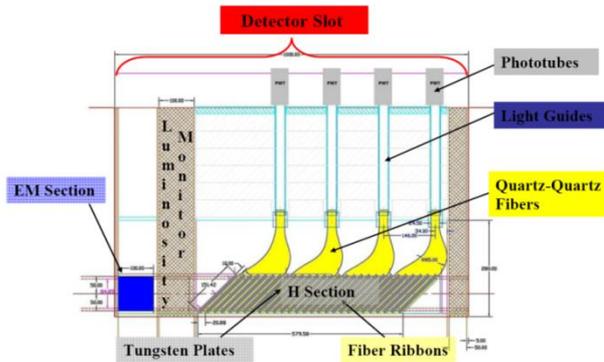
Conclusions

- CMS has a broad program of diffractive & forward physics
 - Designed to evolve with changing luminosity & pileup conditions
- Early analyses
 - Rediscovery of single diffraction at 0.9 and 2.36 TeV
 - First measurements of forward energy flow at 0.9, 2.36, 7 TeV
 - No MC predictions describe all measurements at all energies
- Towards higher-luminosity analyses
 - Validation of forward jet reconstruction, first candidates for exclusive $\mu\mu$, diffractive dijet production observed
 - Stay tuned for new results!

Extra

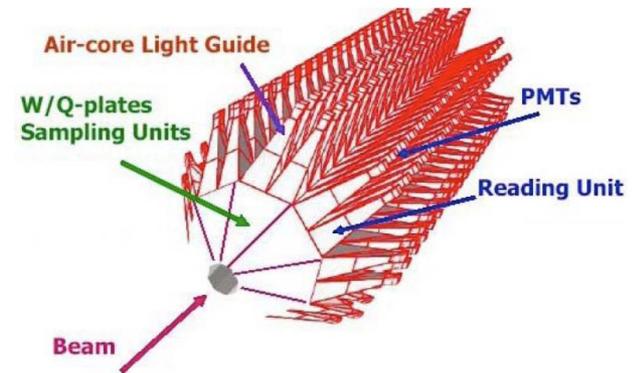
CMS forward detectors

ZDC



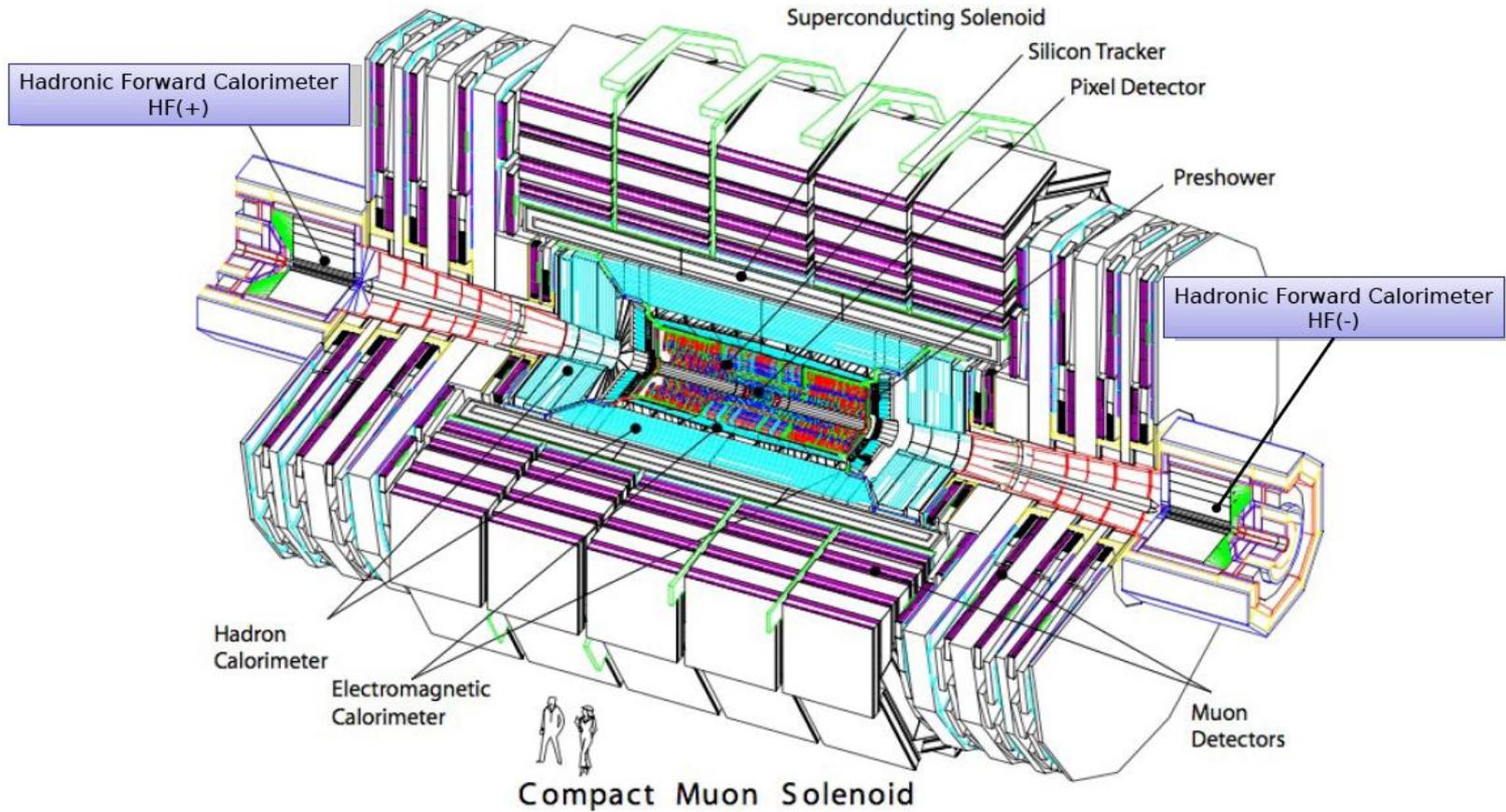
- Tungsten/quartz calorimeter 140m from IP5
- Acceptance for neutrals with $|\eta| > 8.1$

CASTOR

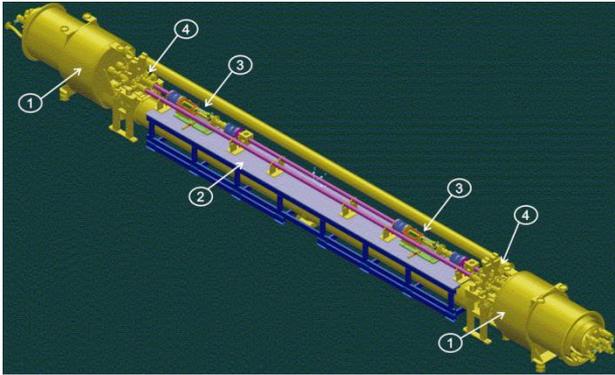


- Calorimeter 14m from IP5
- Acceptance for $-5.2 < \eta < 6.6$ (installed on one side only at startup)

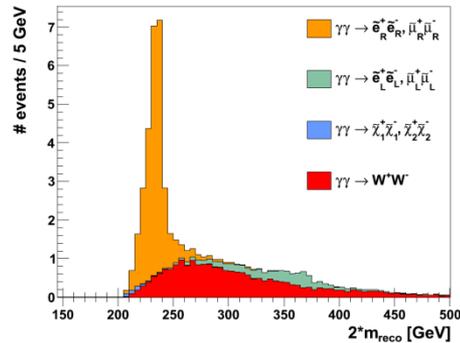
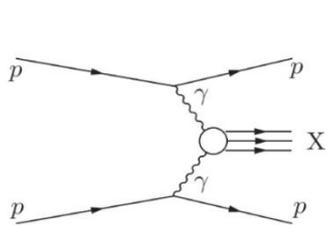
CMS central detector



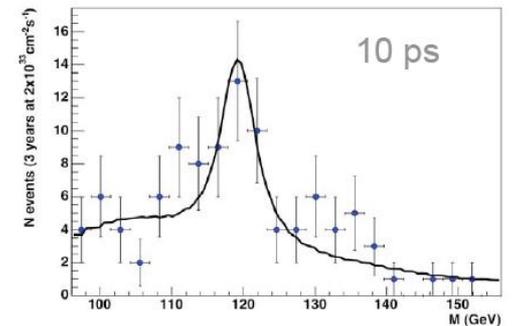
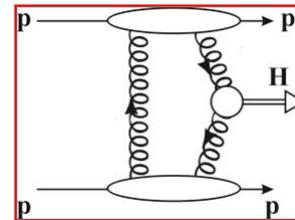
Physics at high luminosity



- Proposal to install forward proton tracking/timing detectors 240 & 420m from IP5, based on joint CMS/ATLAS FP420 R&D project
 - Exclusive $H \rightarrow bb$, $\gamma\gamma \rightarrow$ sleptons, and other BSM physics with tagged protons

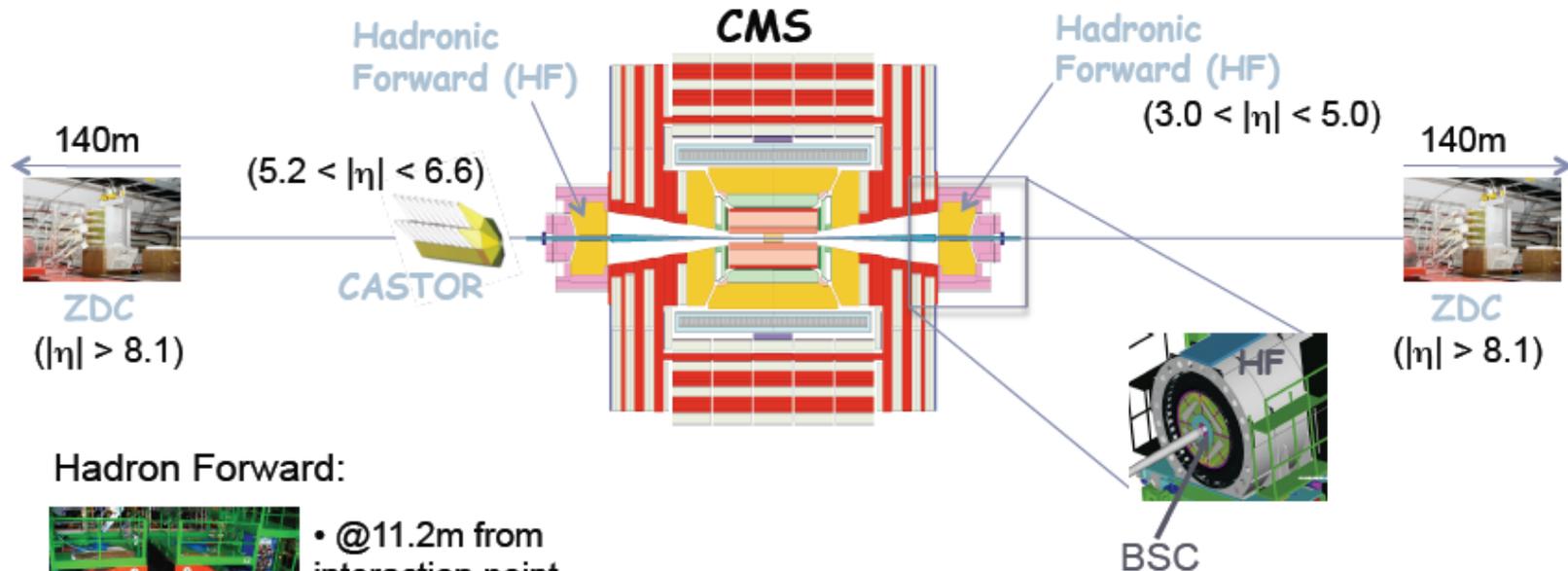


arXiv:0908.2020



JINST 4:T10001,2009

CMS

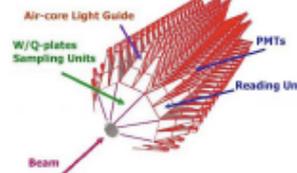


Hadron Forward:



- @11.2m from interaction point ($3 < |\eta| < 5$)
- Steel absorbers/quartz fibers (Long +short fibers)

CASTOR:



- W absorber/quartz plates ($5.2 < \eta < 6.6$)
- 16 segments in ϕ (EM/HAD) segments in z (no η segmentation)