CMS results on Hard Diffraction

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OUTLINE

W/Z with rapidity gaps

Eur.Phys.J.C72:1839,2012

Diffractive dijets

PRD 87 (2013) 012006

CMS-TOTEM – dijets with leading protons

CMS talks at this workshop:

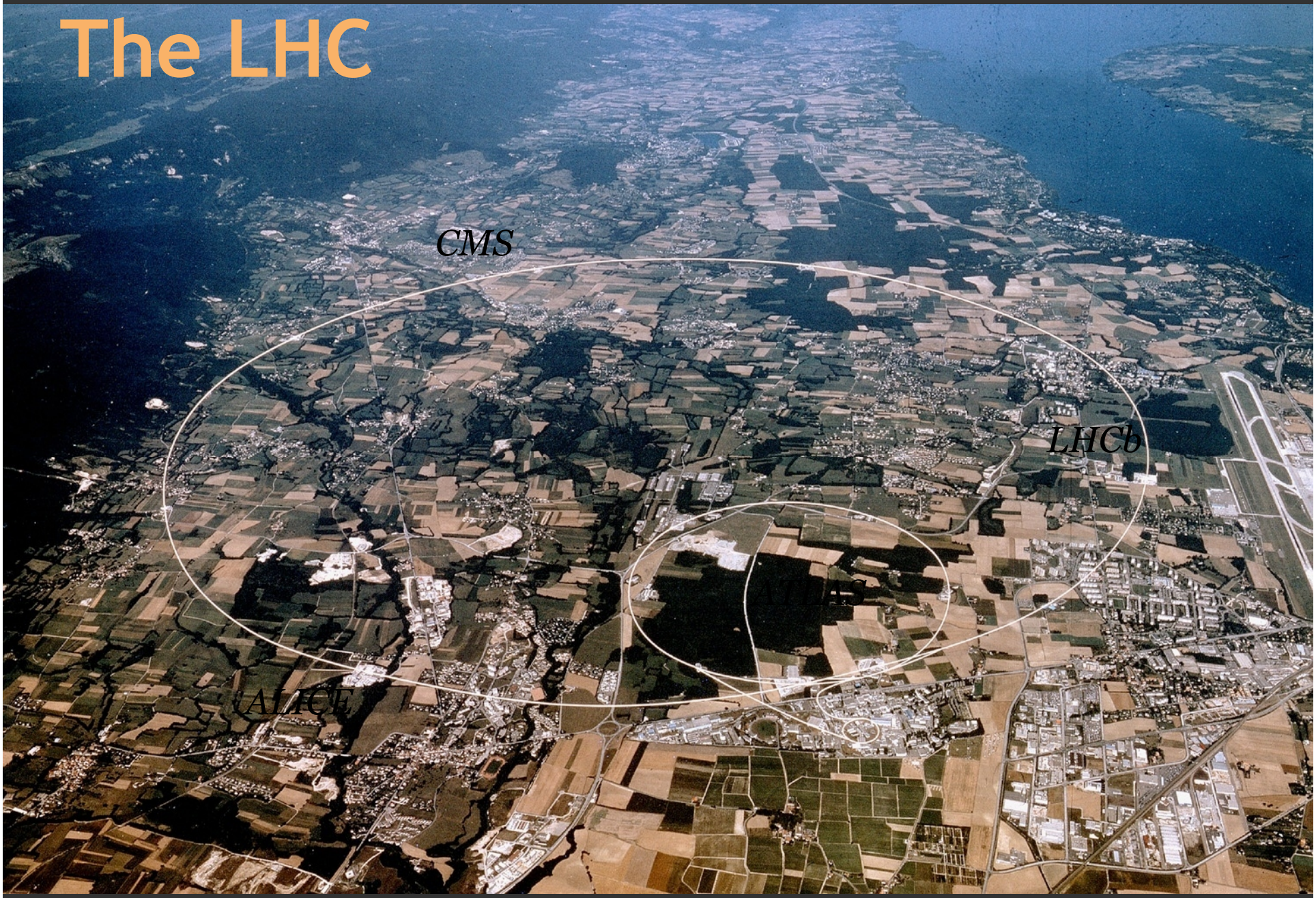
CMS results on soft diffraction — *Dino Goulianos*

Low x QCD results from CMS results — *Maciej Misiura*

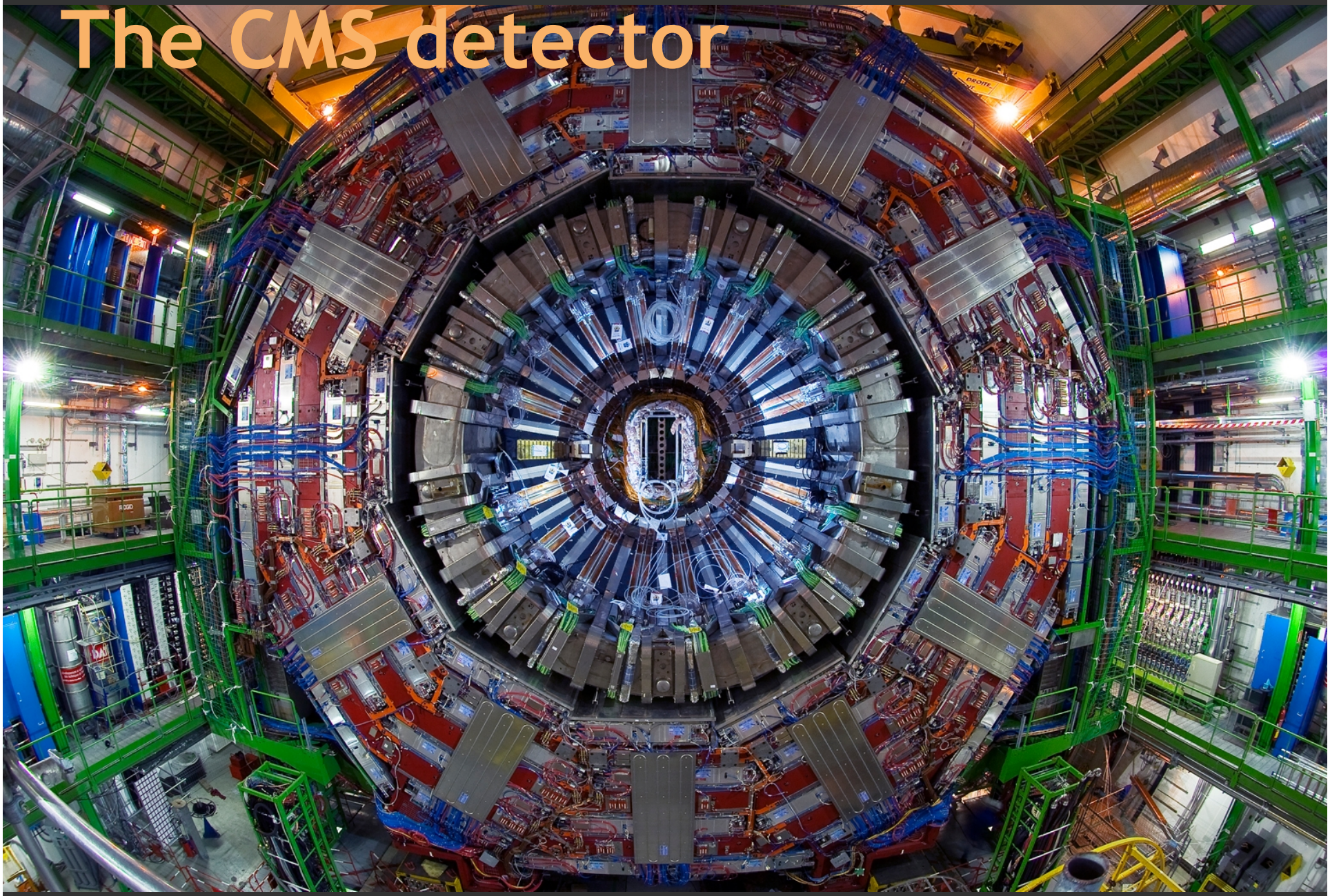
Many more results at:

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsFSQ

The LHC

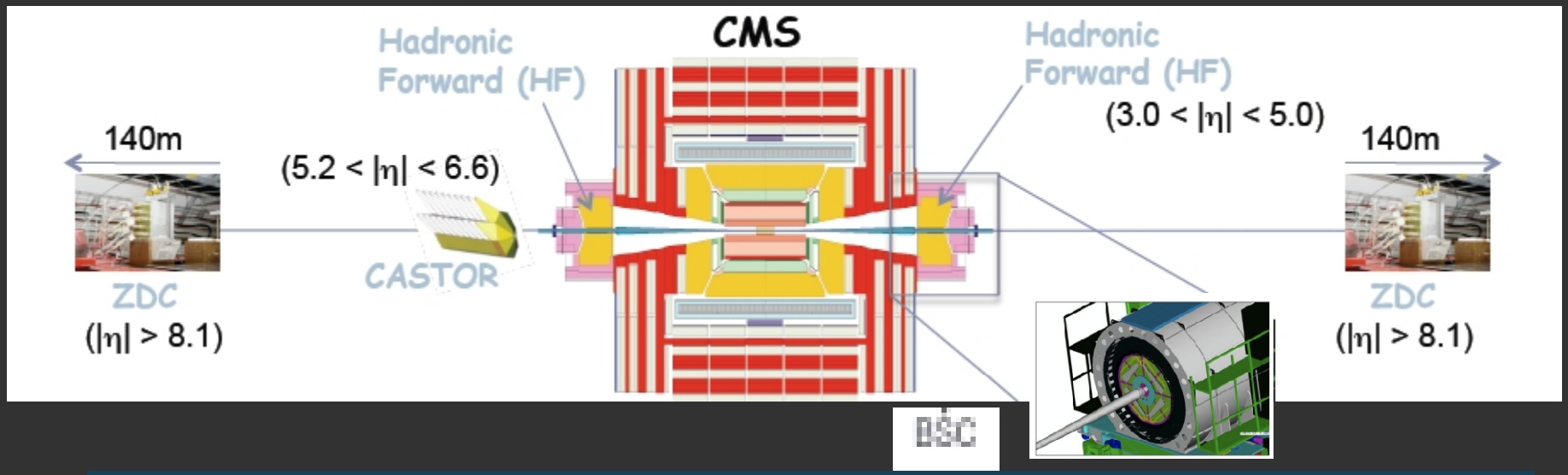


The CMS detector



CMS Detectors

N.B. only detectors highlighted in blue are used in these analyses



Calorimetry

Hadronic Forward (HF) $|\eta| < 5.2$
Electromagnetic calorimeter $|\eta| < 3.0$

Tracking

$|\eta| < 2.4$, p_T to ~100MeV

Muons

$|\eta| < 2.4$, $p_T > 3$GeV (barrel)

CMS Detectors

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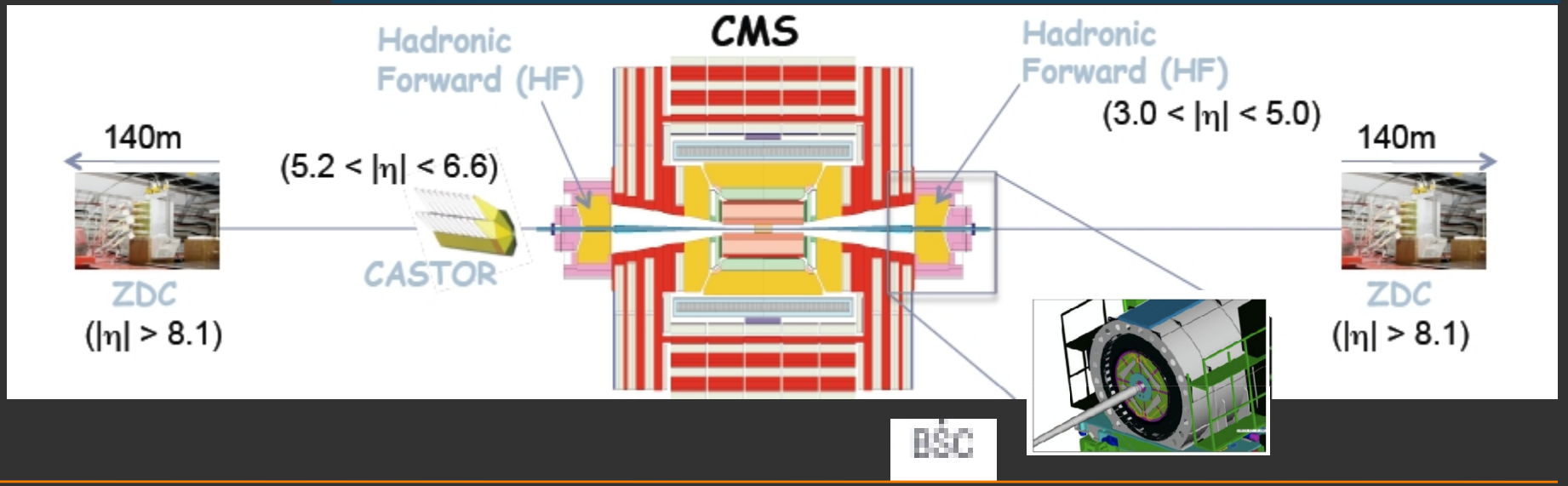
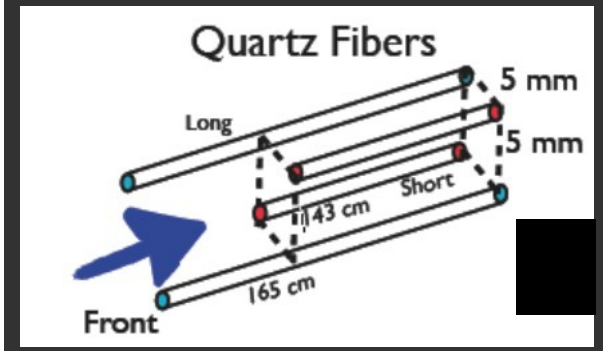




Hadron Forward (HF):

at 11.2m from interaction point

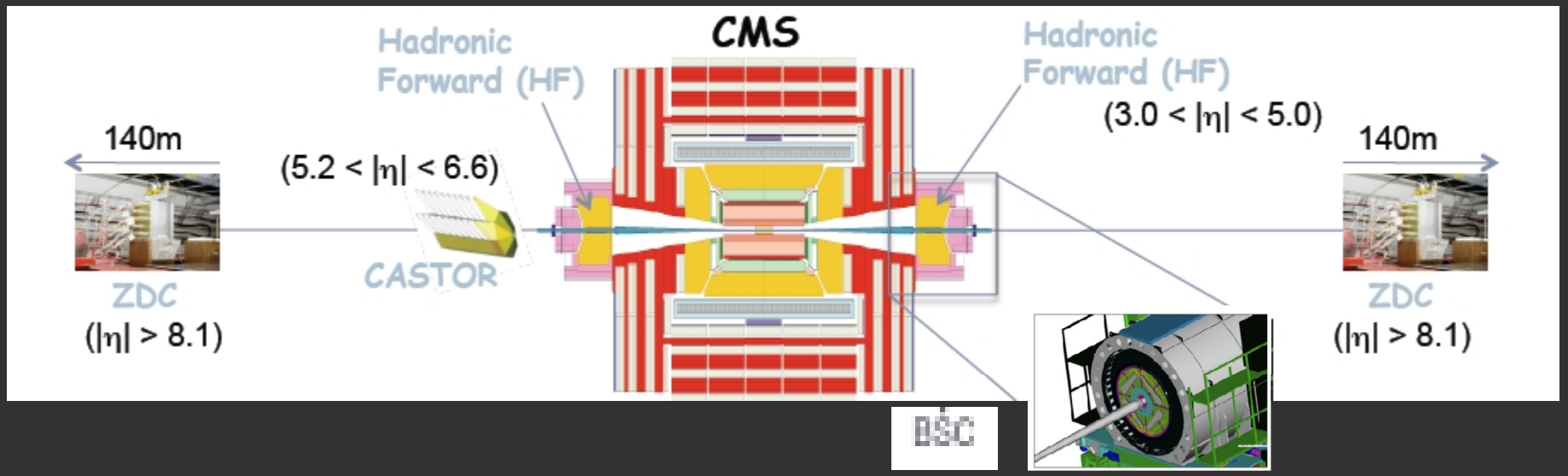
Rapidity coverage: $3 < |\eta| < 5$

Steel absorbers/quartz fibers (Long+short fibers)

0.175x0.175 η/φ segmentation

CMS Forward Detectors

N.B. only detectors highlighted in blue are used in these analyses



CASTOR: -5.2 > η > -6.6 (one side only)

Zero Degree Calorimeter (ZDC): |η|> 8.1

Beam Scinitillator Counters (BSC):
10.9 m from IP5, used for minimum bias triggers in 2010

Diffractive W/Z Production

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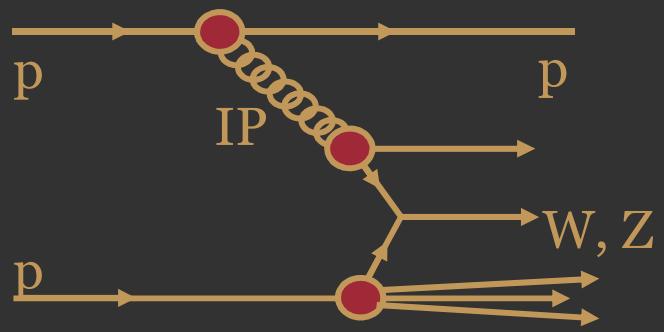
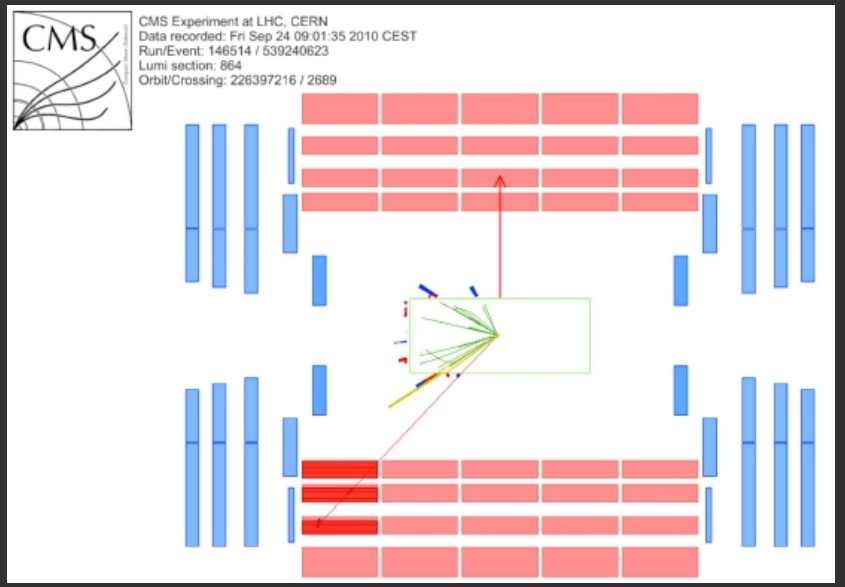
Analysis based on full 2010 dataset (36pb^{-1})



Events are selected
by triggering on
standard high-pT lepton triggers,
W/Z selection based on inclusive cross-section measurements

Require:
to suppress pile-up
only W/Z events with a single-vertex are used
Residual contamination from soft pileup events studied in MC, and in data as a function of average instantaneous luminosity

for diffractive selection:
no energy deposit in HF
LRG, Calo. Tower Energy > 4 GeV



W/Z events with rapidity gaps

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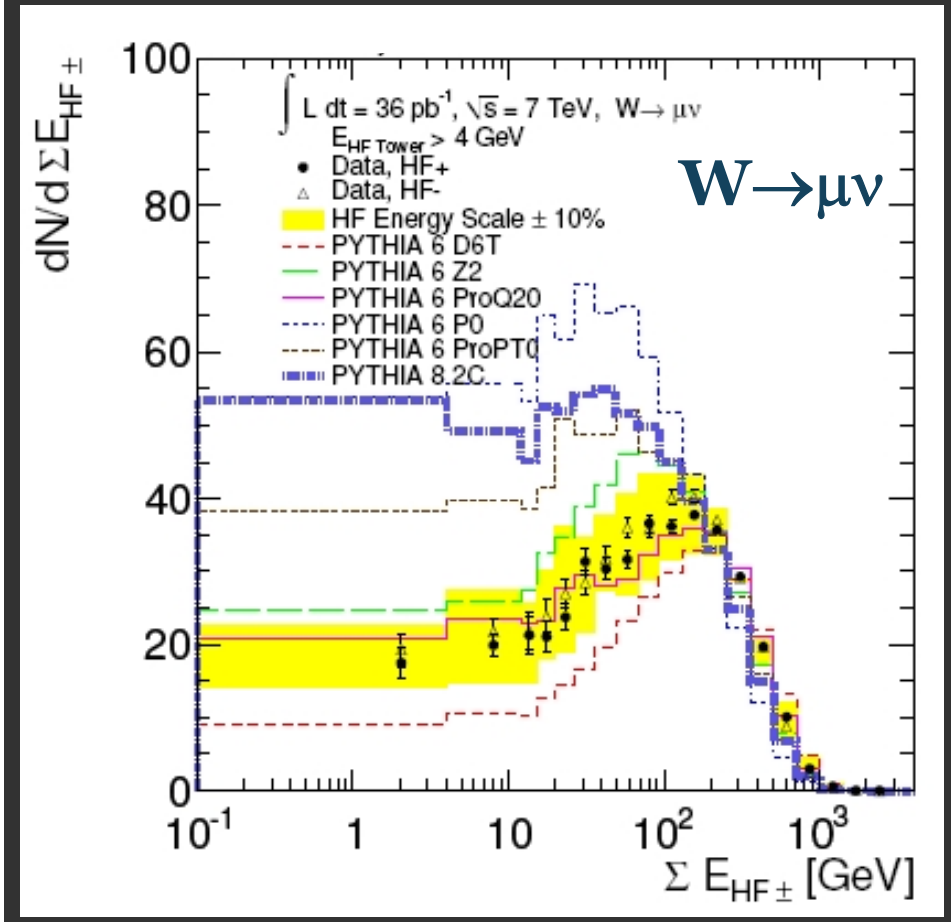

Measure the fraction of gap events, and compare to various models

- Wide range of predictions
- Excess of gap events compared to Pythia 6 D6T tune
- Deficit compared to Pythia 6 Z2, Pythia 8

Monte Carlo generators cannot describe the data

Fraction of W/Z events with a forward gap:

W→lν: ***1.46 ± 0.09(stat.) ± 0.38(syst.) %***

Z →ll: ***1.60 ± 0.25(stat.) ± 0.42(syst.) %***

W/Z events with rapidity gaps

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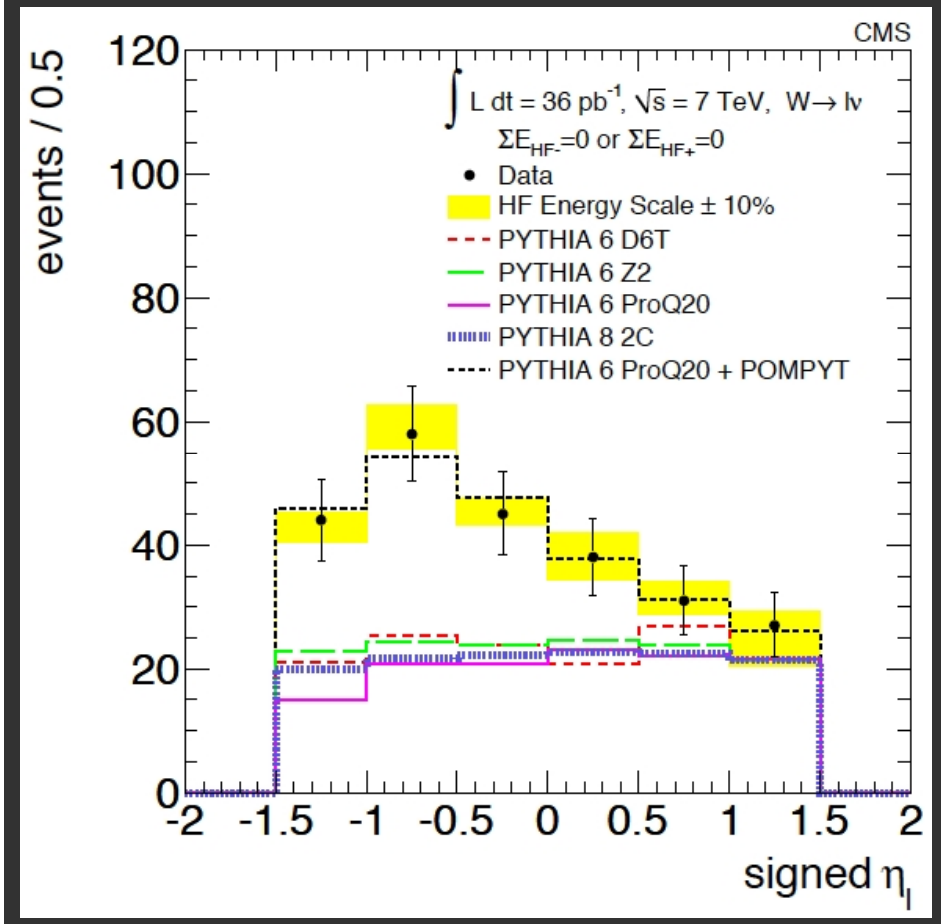


Alternative approach – exploit asymmetry between signed lepton and the gap side

Gap and lepton on **same side** → **η_l positive**

Gap and lepton on **opposite sides** → **η_l negative**

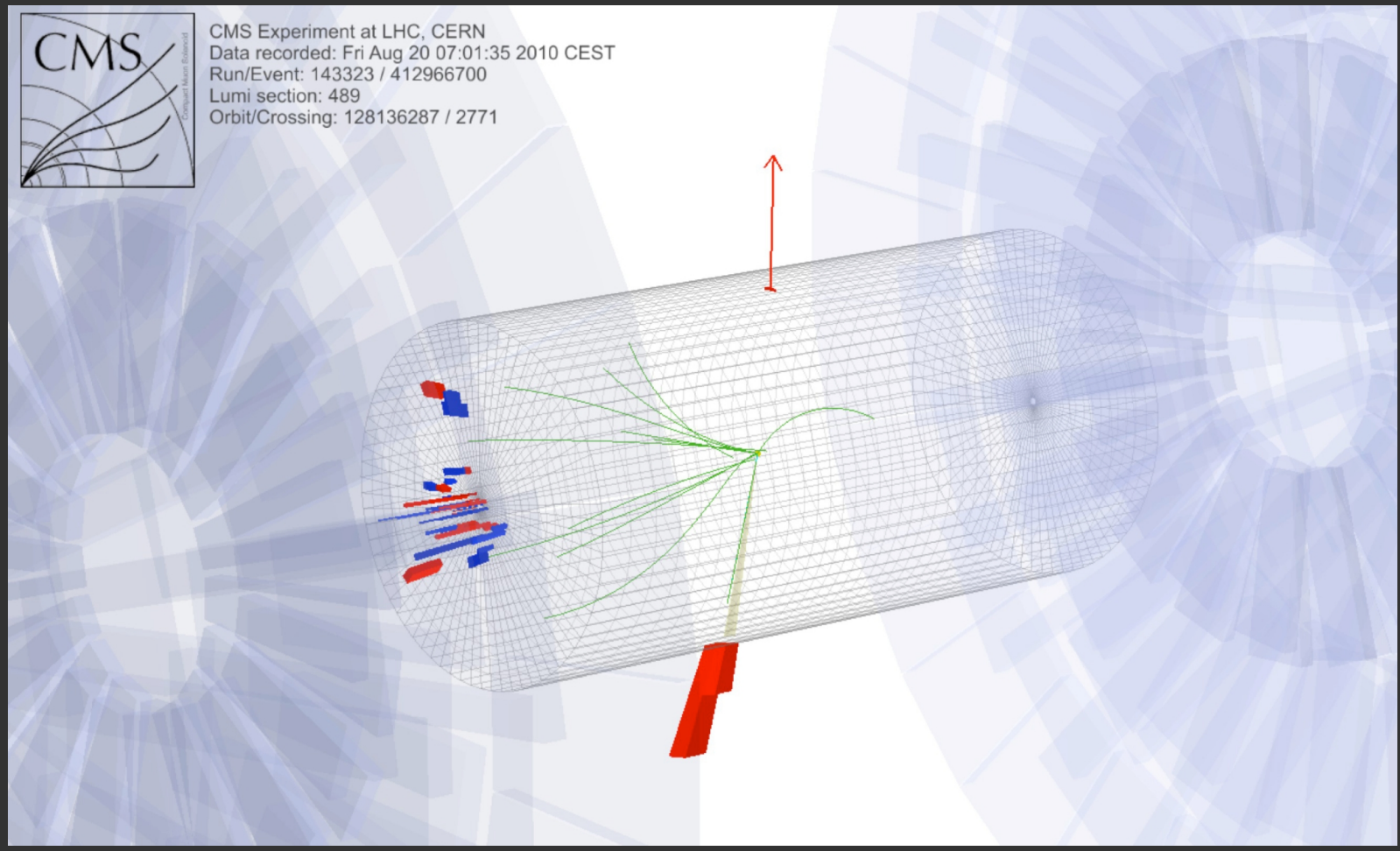
Large asymmetry in models including hard diffraction (POMPYT)

No significant asymmetry in non-diffractive PYTHIA W/Z samples ~independent of the tune

Diffractive component in LRG W/Z sample
50.0 ± 9.3(stat.) ± 5.2(syst.) %

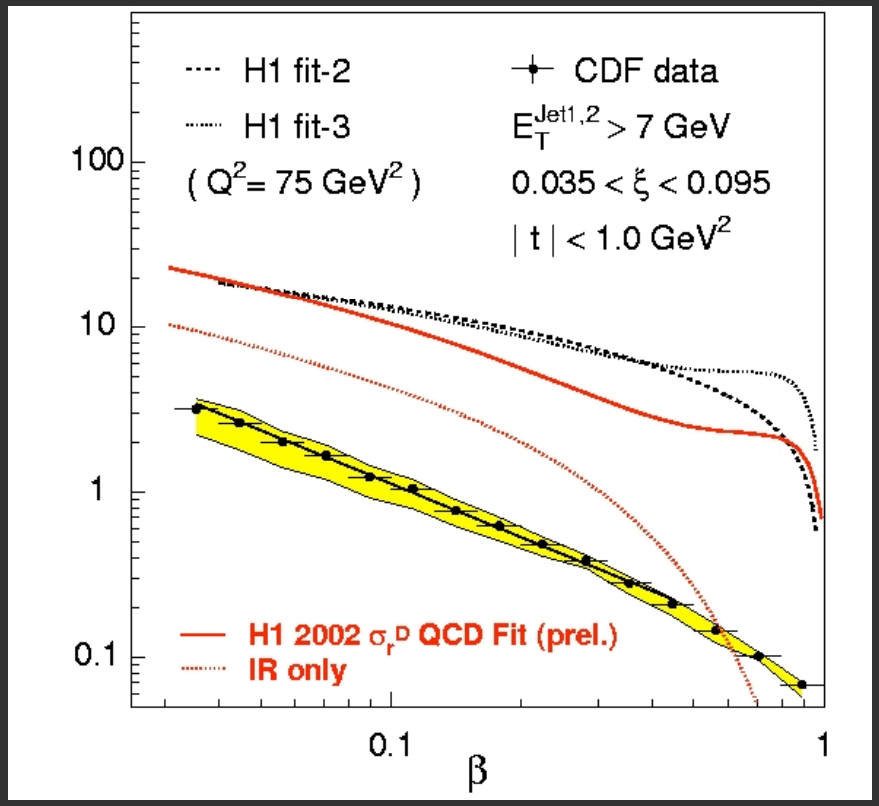
fitted value from MC mix of POMPYT and ND PYTHIA

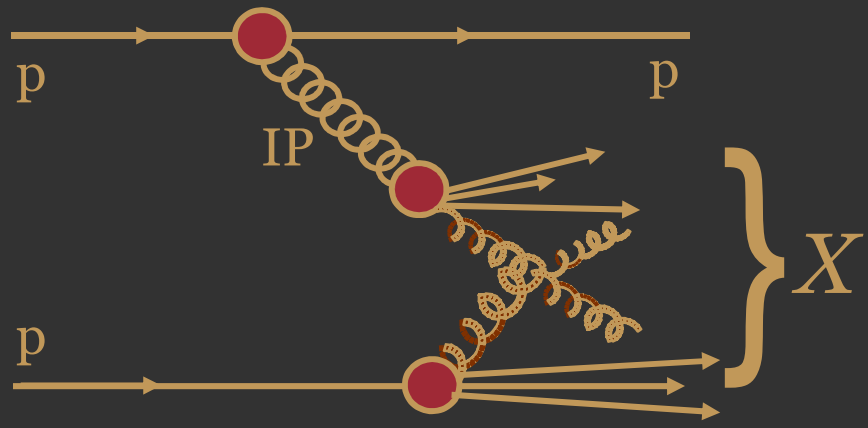
Diffractive W Event Candidate



Diffractive Dijet Production

Previous measurements of hard diffractive processes in pp (Tevatron), ep (HERA)





$\xi = M_X^2/s \sim$ fractional momentum loss of the scattered p

$$f_{diff}(\xi,t,x_1,\mu) = f(\xi,t)\, f_P(x_1,\mu)$$

dPDF — *Pomeron flux* — *Pomeron str.function*

$$d^2\sigma/d\xi dt = \sum x_1 x_2\, f(\xi,t)\, f_P(x_1,\mu)\, f_p(x_2,\mu)\, \hat{\sigma}$$

PDF

Diffractive Dijet Production

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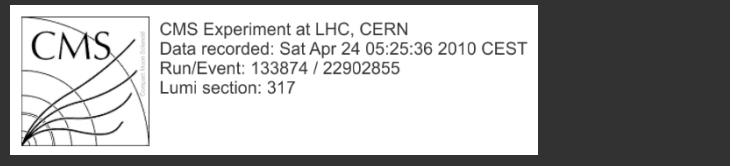
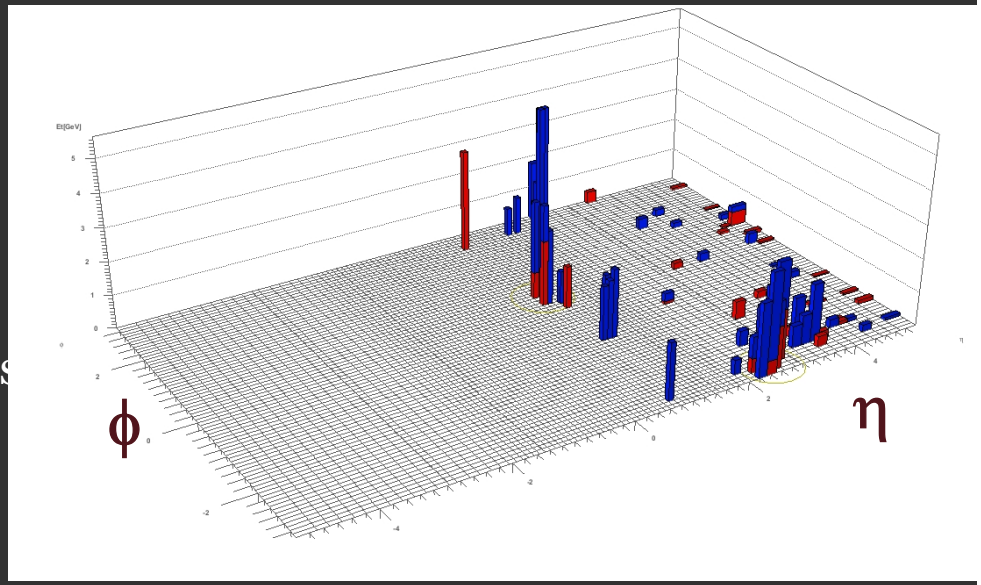
Analysis based on low pile-up 2010 data (2.7 nb^{-1})

Events are selected
by triggering on
single jets with p_T>6 GeV
anti-k_T algorithm R=0.5

Require:
off-line cuts
at least 2 jets with
E_T>20 GeV and $|\eta|$<4.4
Standard vertex and track quality selections

For ξ reconstruction:
Based on Particle Flow (PF) objects above noise threshold
global event reconstruction, combining charged tracking and calorimetry





p_T(jet1) = 43.5 GeV, p_T(jet2) = 36.9 GeV
η (jet1) = 0.83, η (jet2) = 2.55

Dijets: Kinematic distributions

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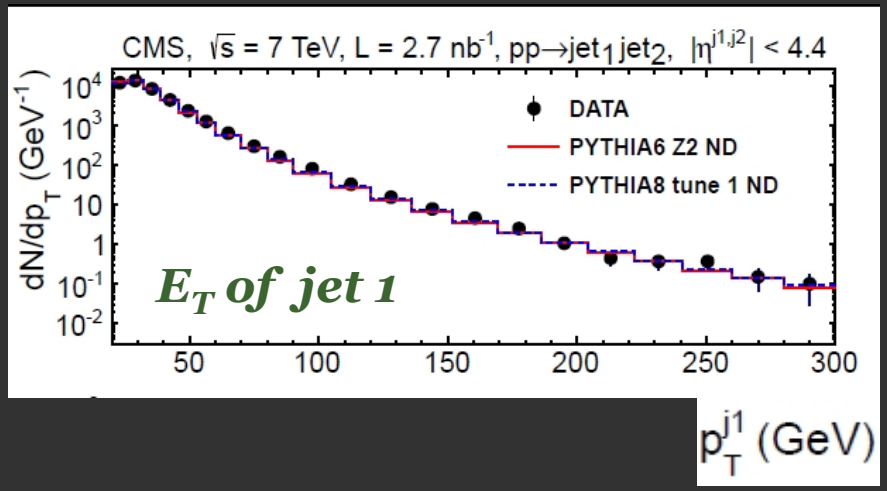

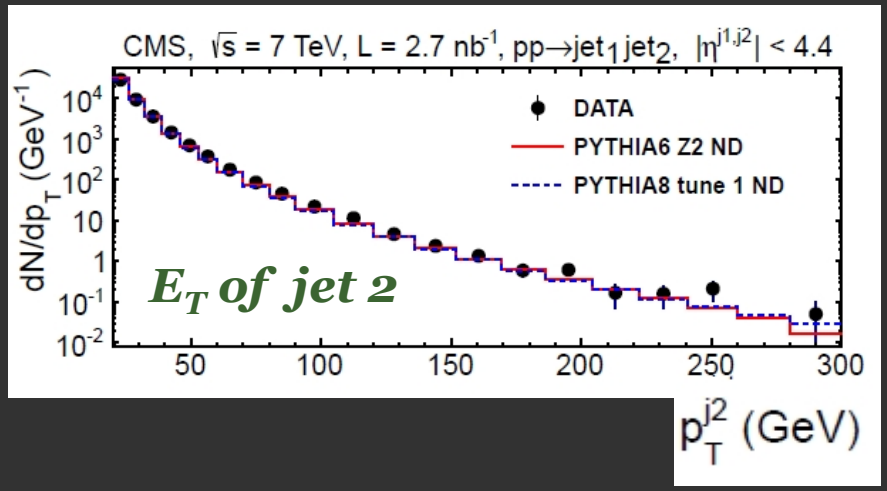

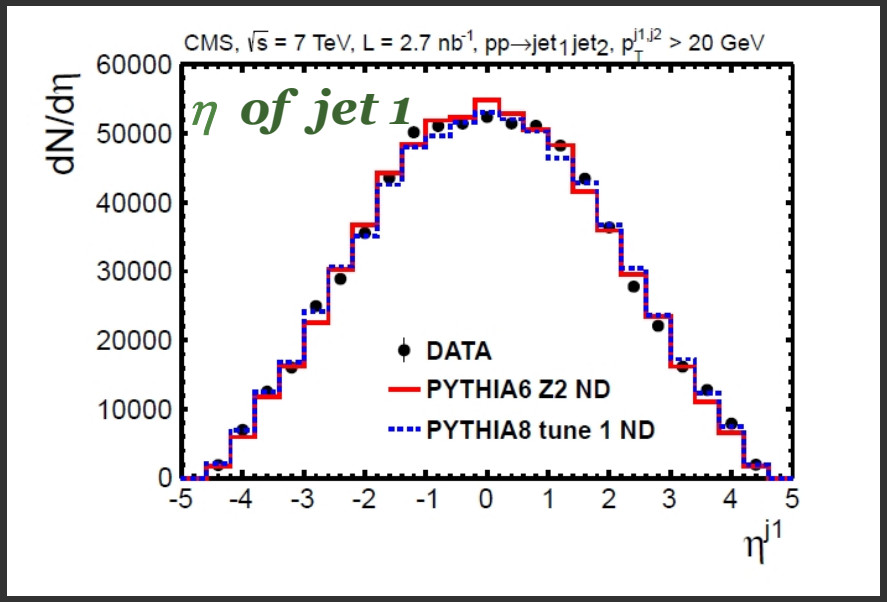

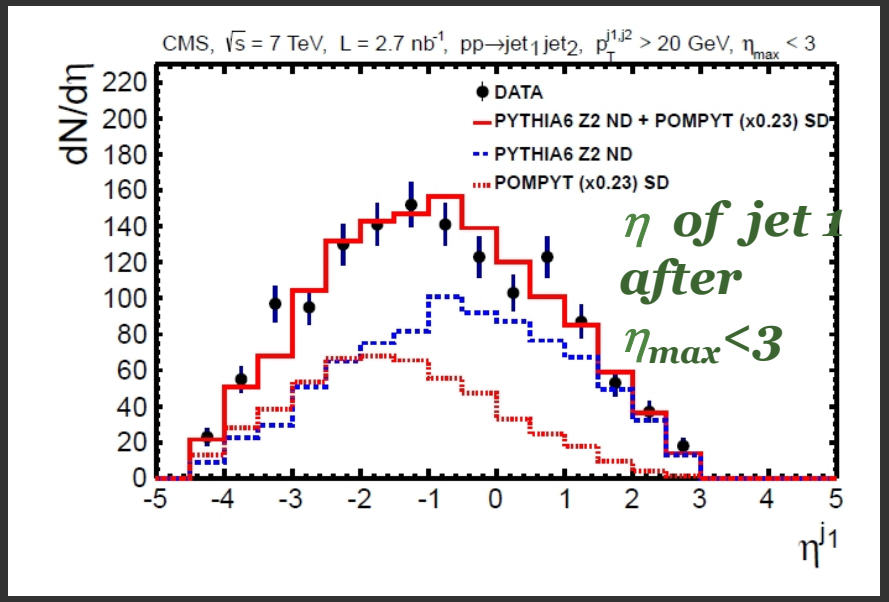

Diffractive Dijets

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To enhance diffractive contribution:

Require the most forward(backward) PF particle in the event satisfy $\eta_{max} < 3$ ($\eta_{min} > -3$)

Corresponds to a gap of 1.9 units
no Particle Flow objects in HF
with energy deposit > 4 GeV

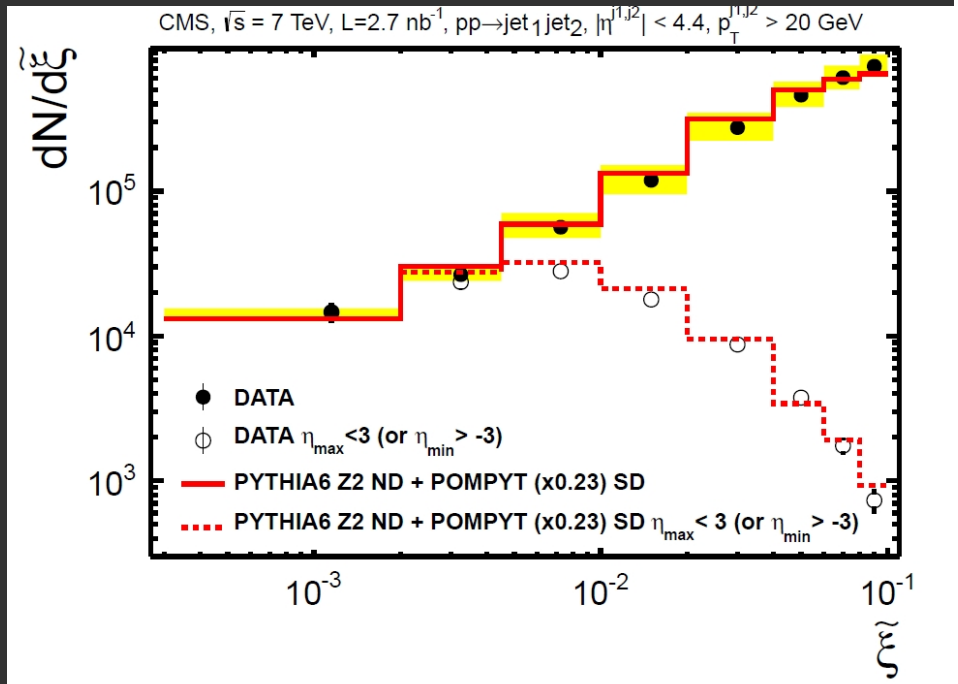
$$\tilde{\xi}^{\pm} = C\sum(E \pm p_Z)/\sqrt{s}$$

summed over all final state particles with $\eta < 4.9$ (ξ^+) or $\eta > -4.9$ (ξ^-):

C – correction factor determined from MC by comparing generated and reconstructed values of ξ

Definition converges to "true"

$\xi = M_X^2/s$ for SD events with low-ξ



Reconstructed ξ distributions in data and MC after η_{max}<3 (η_{min}>-3) cuts

Distributions are described by combination of POMPYT and PYTHIA6 Z2,
the relative contributions determined from the fit to ξ before $\eta_{max/min}$ cuts

Differential Cross Section for Dijet Production as a function of $\tilde{\xi}$

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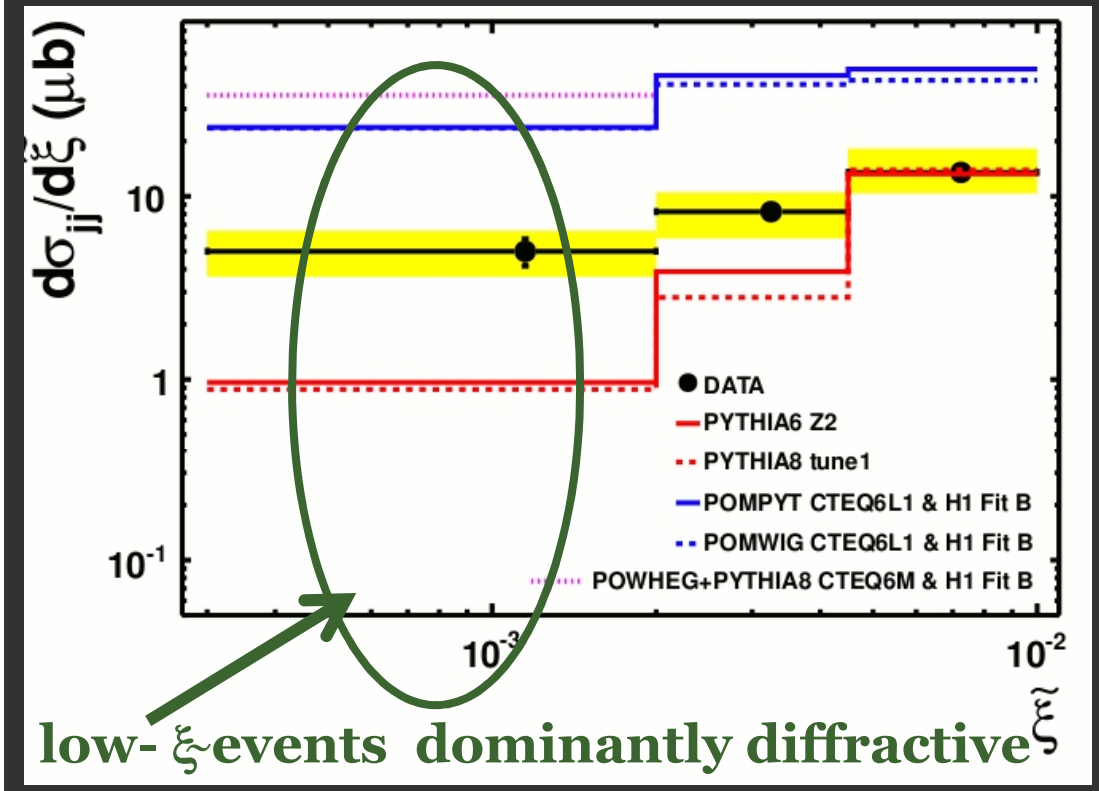

$$\frac{d\sigma_{JJ}}{d\tilde{\xi}} = \frac{N^i_{jj}}{L \cdot \epsilon \cdot A^i \cdot \Delta\tilde{\xi}^i}$$

Significant excess over PYTHIA6 D6T/PYTHIA8 at low ξ

Deficit compared to diffractive POMWIG/POMPYT MC's without gap survival effects

Interpret in terms of *"gap survival"* under different model assumptions

$\tilde{\xi}$ bin	$\Delta\sigma_{jj}/\Delta\tilde{\xi}$ (μb)
$0.0003 < \tilde{\xi} < 0.002$	$5.0 \pm 0.9(\text{stat.})^{+1.5}_{-1.4}(\text{syst.})$
$0.002 < \tilde{\xi} < 0.0045$	$8.2 \pm 0.9(\text{stat.})^{+2.3}_{-2.3}(\text{syst.})$
$0.0045 < \tilde{\xi} < 0.01$	$13.5 \pm 0.9(\text{stat.})^{+4.7}_{-3.1}(\text{syst.})$

upper limit

$S^2_{\text{data/MC}} = 0.21 \pm 0.07$ (LO MC)
$S^2_{\text{data/MC}} = 0.14 \pm 0.05$ (NLO MC)

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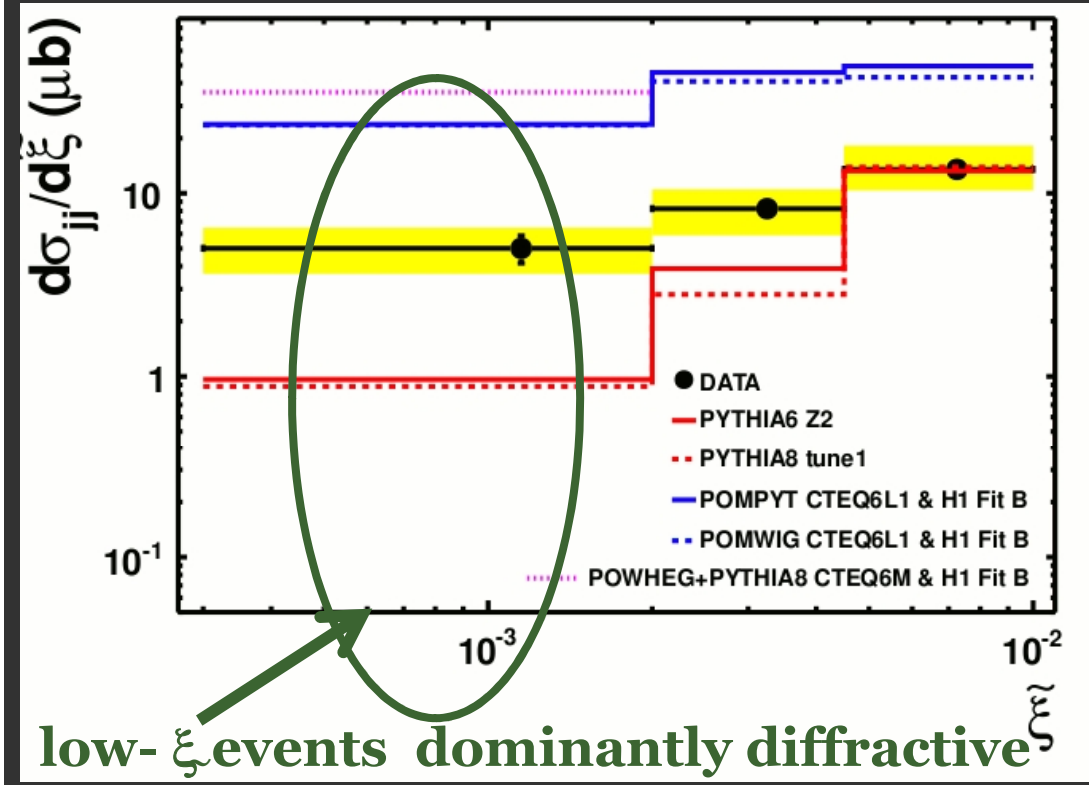

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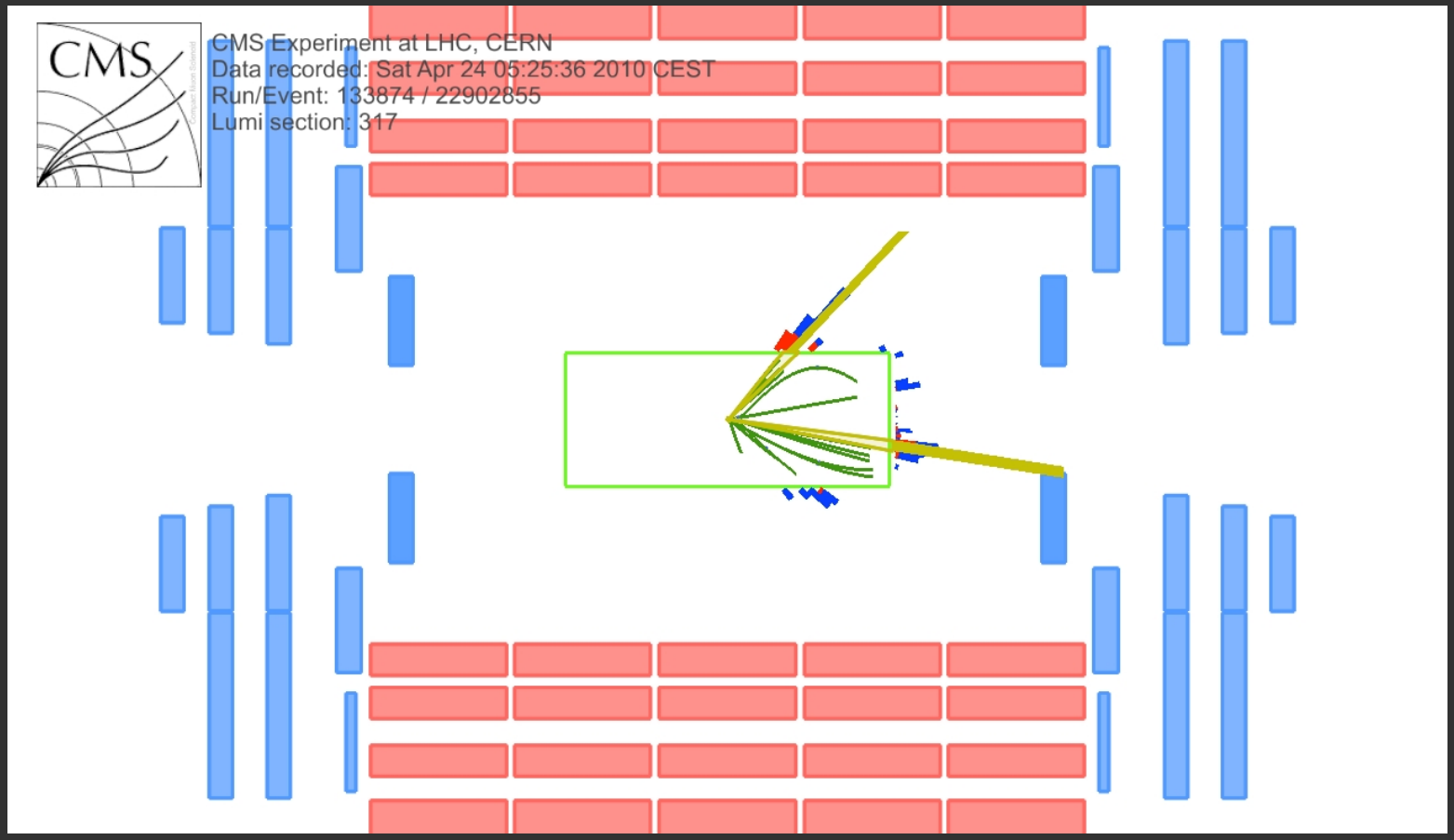
$0.0045 < \tilde{\xi} < 0.01$	$13.5 \pm 0.9(\text{stat.})^{+4.7}_{-3.1}(\text{syst.})$

after taking into account proton dissociation

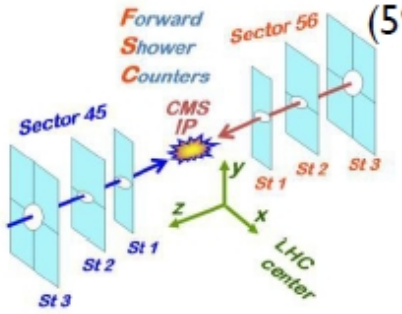
$S^2_{\text{data/MC}} = 0.12 \pm 0.05$ (LO MC)
$S^2_{\text{data/MC}} = 0.08 \pm 0.04$ (NLO MC)

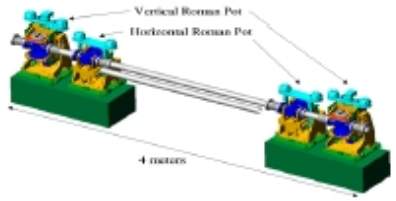
Diffractive Dijet Event Candidate



CMS-TOTEM detectors

Forward Shower Counters
(59-114m)





TOTEM RPs
(147, 220m)

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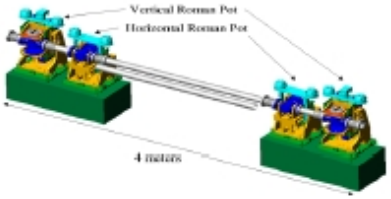
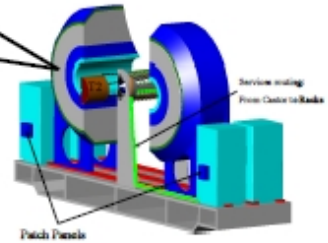
(147, 220m)



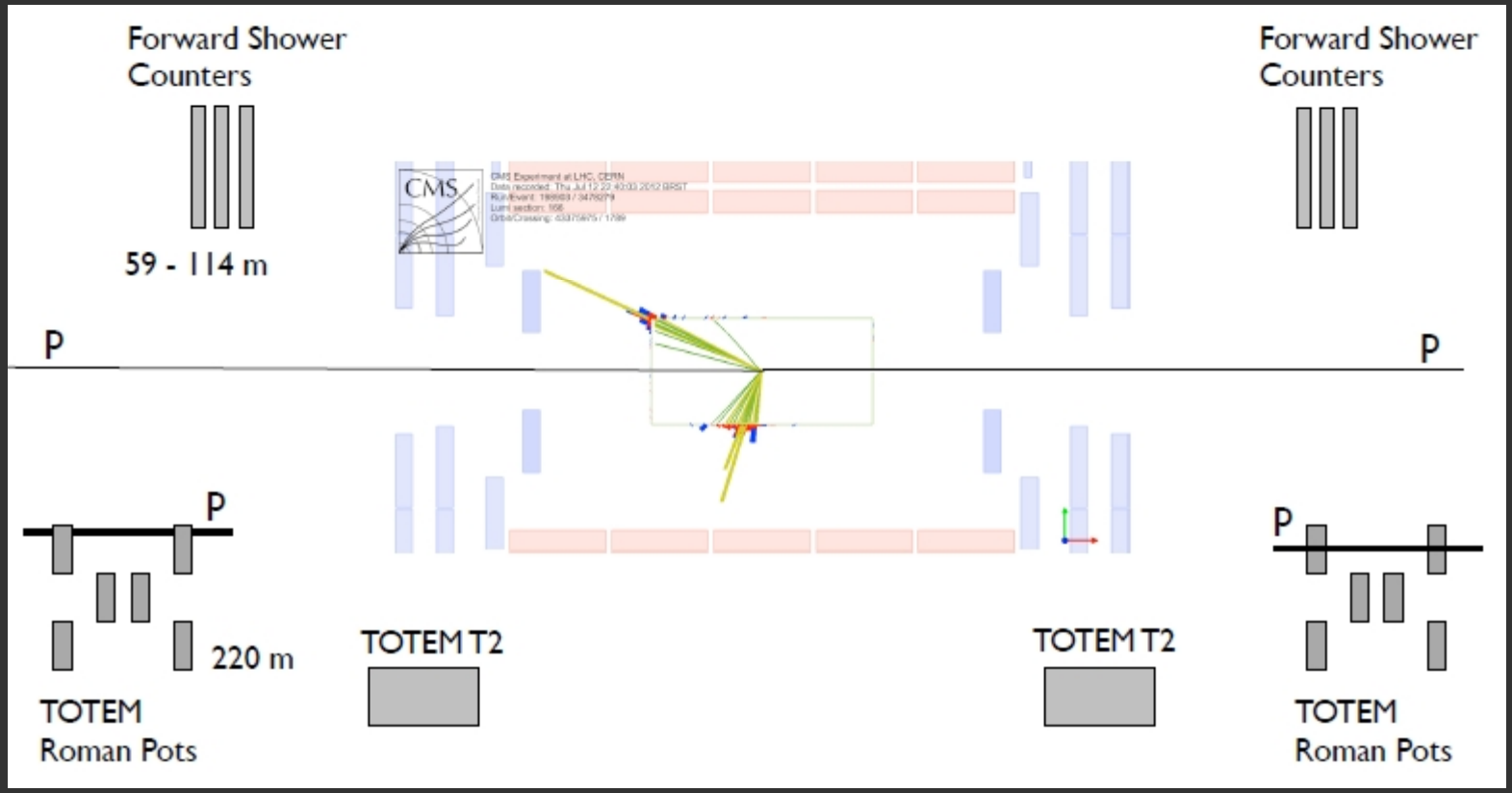


TOTEM T2
(In front of
CASTOR position)

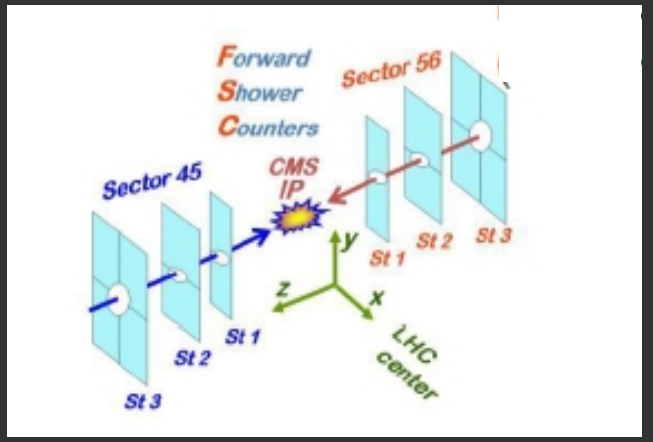
Common data taking during low-PU runs in 2012

CMS-TOTEM : High p_T jets with two leading protons

EVENT TOPOLOGY



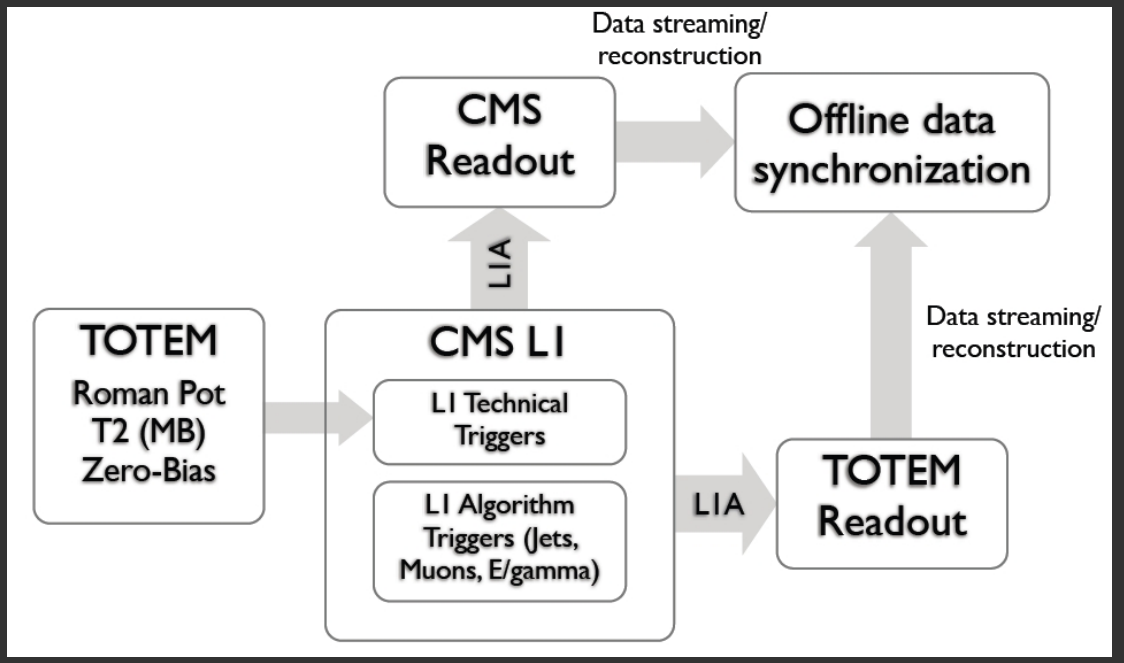
CMS-TOTEM detectors



Events are selected
from low-PU β*=90m run
common CMS-TOTEM trigger

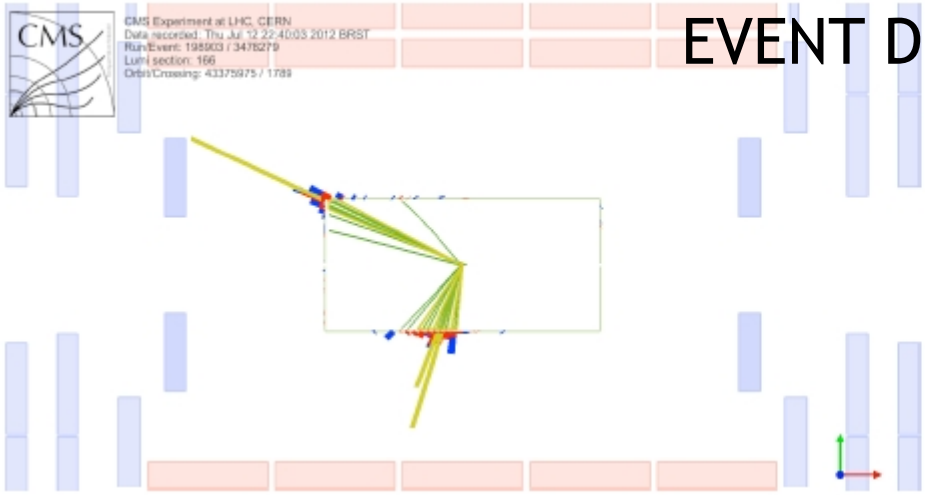
Require:

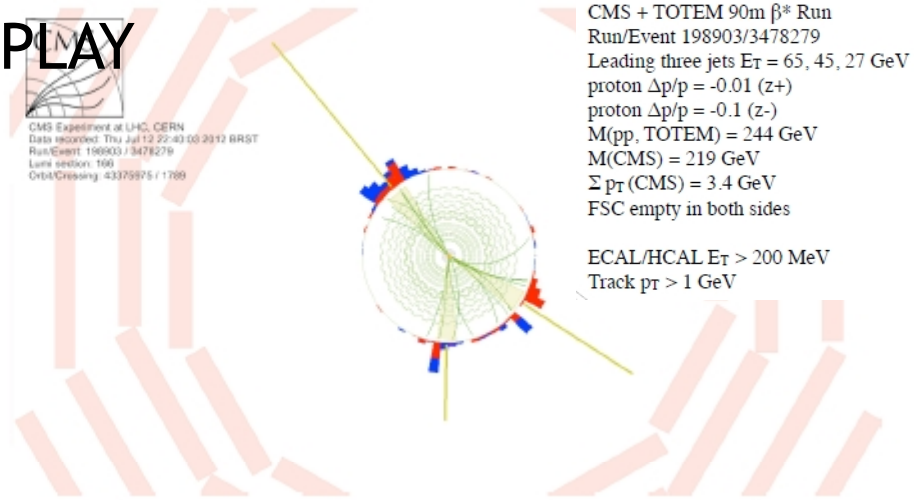
-at least 2 jets with p_T>20 GeV
-Forward Shower Counters empty
-Reconstructed proton tracks
(TOTEM Roman Pots)
on both sides of IP

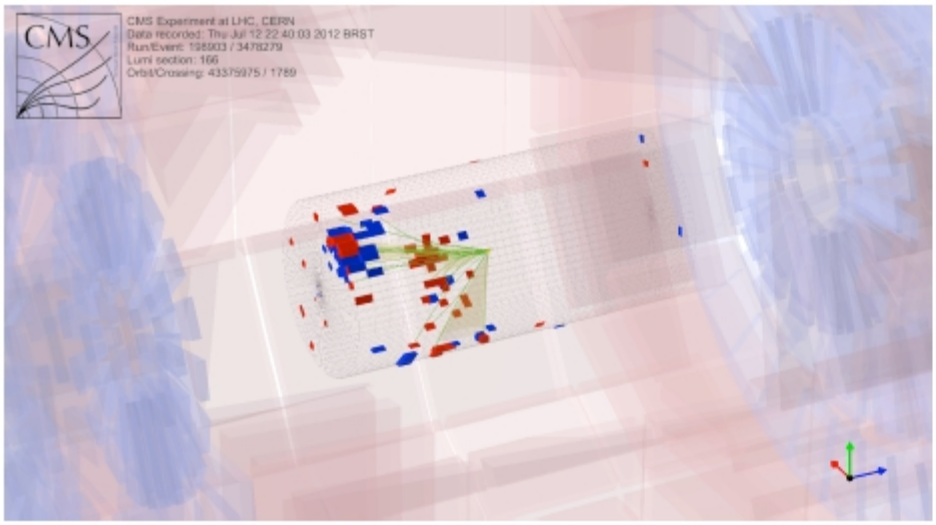


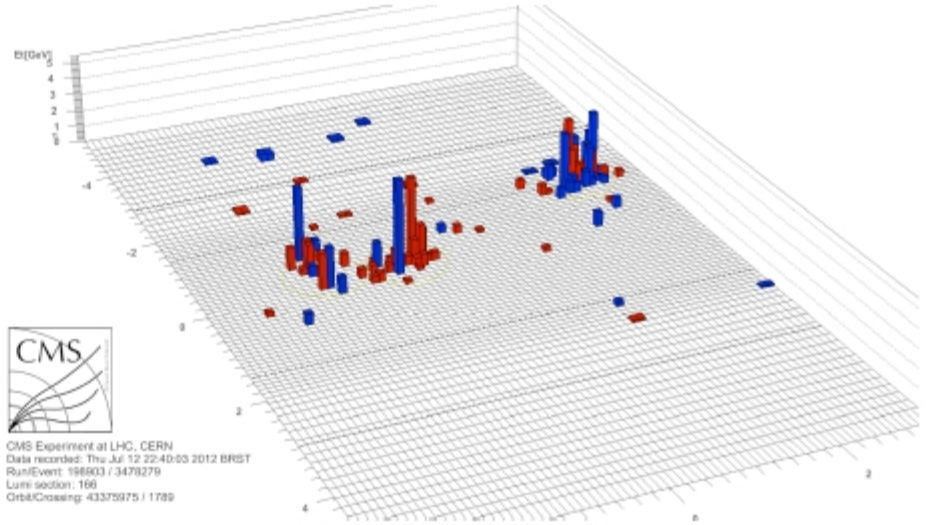
CMS-TOTEM: High p_T jets with two leading protons

EVENT DISPLAY





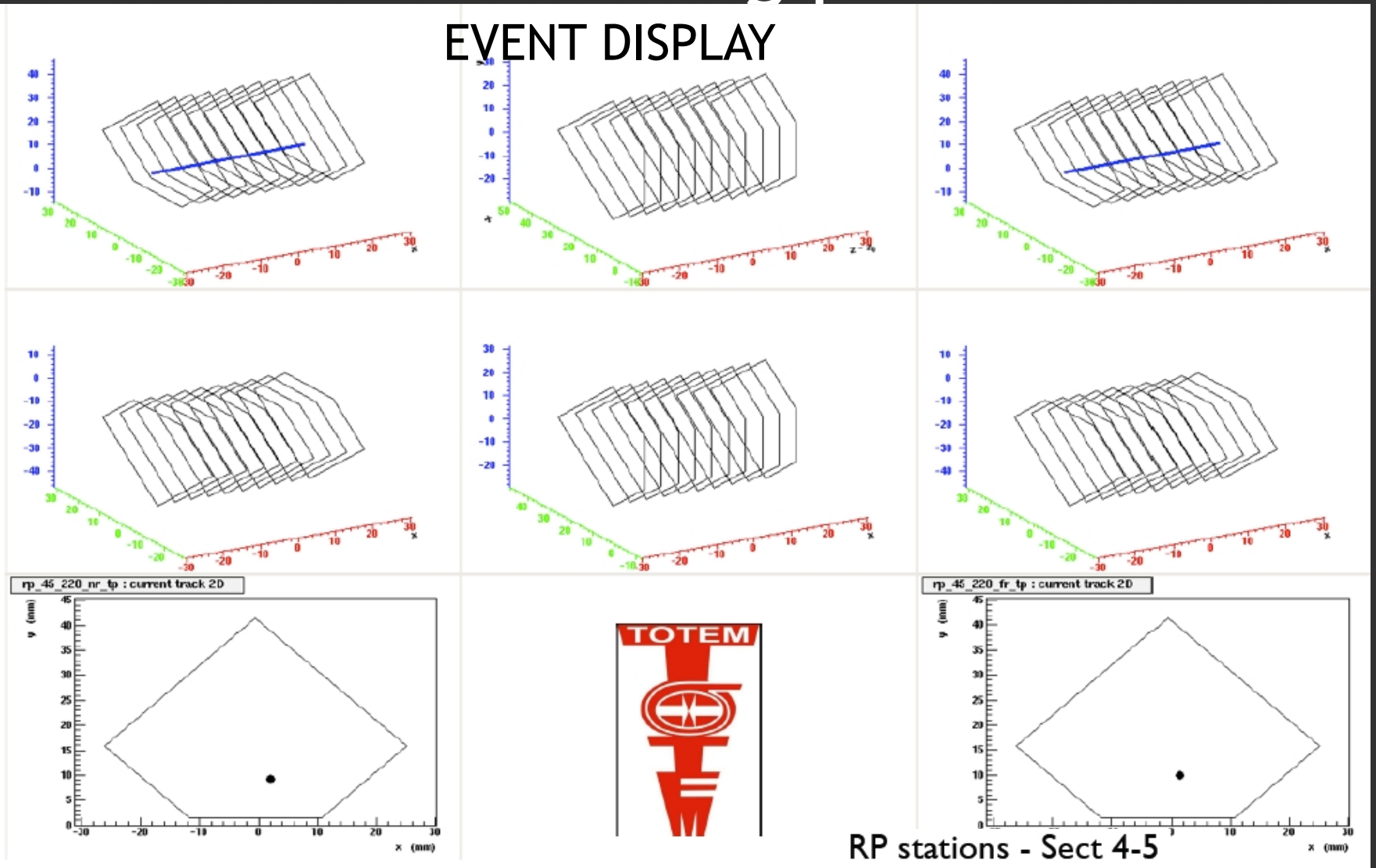




CMS-TOTEM : High p_T jets with two leading protons

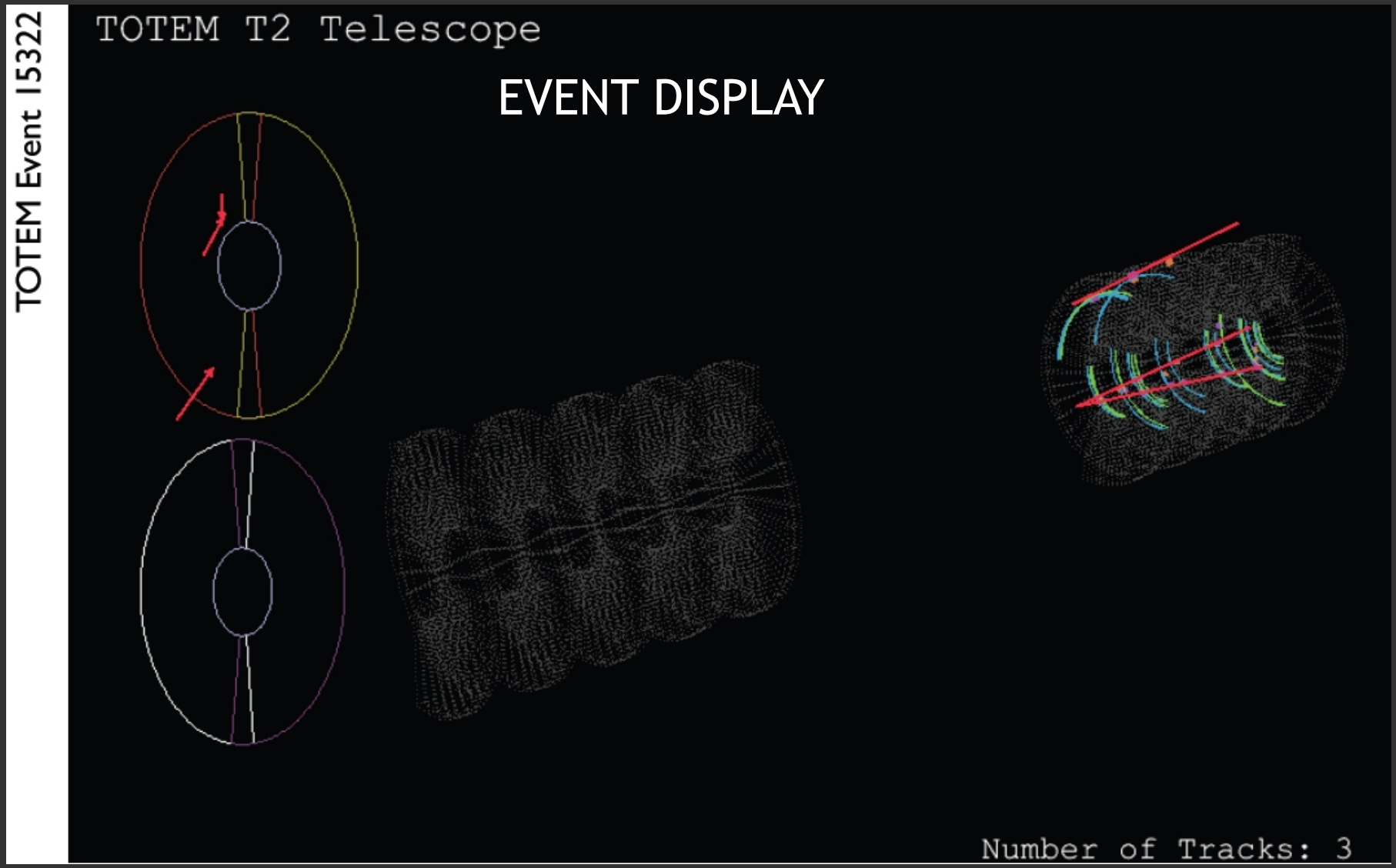
TOTEM Event 15322

EVENT DISPLAY



RP stations - Sect 4-5

CMS-TOTEM : High p_T jets with two leading protons



Conclusions

First measurements of hard diffraction at the LHC, associated with high-p_T jets and W/Z bosons

No models reproduce all aspects of forward energy flow/multiplicities in inclusive diffraction or *W/Z analyses*

Constraints on survival probabilities at 7 TeV from diffractive dijet cross-section

Prospects

Many analyses still to be done with 2010/early 2011 data
Low-pileup runs in 2012

Only beginning to exploit the potential of forward detectors (CASTOR, ZDC, FSC, CMS+TOTEM combination) for physics analysis

Stay tuned !