Precision Proton Spectrometer project

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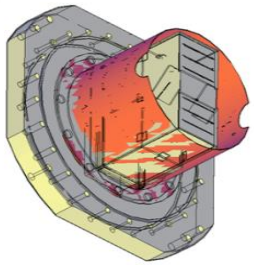
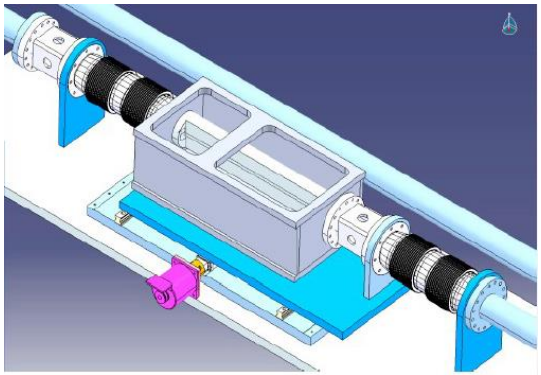
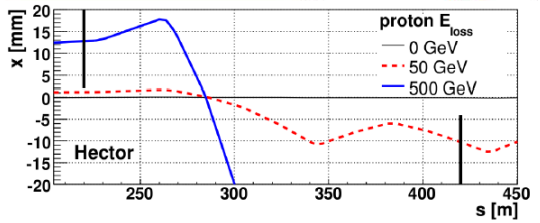
for the CMS and Totem Collaborations







How to continue?

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LHC PHYSICS

CMS sees first direct evidence for $\gamma\gamma \rightarrow WW$

In a small fraction of proton collisions at the LHC, the two colliding protons interact only electromagnetically, radiating high-energy photons that subsequently interact or "fuse" to produce a pair of heavy charged particles. Fully exclusive production of such pairs takes place when quasi-real photons are emitted coherently by the protons rather than by their quarks, which survive the interaction. The ability to select such events opens up the exciting possibility of transforming the LHC into a high-energy photon–photon collider and of performing complementary or unique studies of the Standard Model and its possible extensions.

The CMS collaboration has made use of this opportunity by employing a novel method to select "exclusive" events based only on tracking information. The selection is made by requesting that two – and only two – tracks originate from a candidate vertex for the exclusive two-photon production. The power of this method, which was first developed for the pioneering measurement of exclusive production of muon and electron pairs, lies in its effectiveness even in difficult high-luminosity conditions with large event pile-up at the LHC.

The collaboration has recently used this approach to analyse the full data sample collected at $\sqrt{s}$=7 TeV and to obtain the first direct evidence of the $\gamma\gamma \rightarrow WW$ process. Fully leptonic W-boson decays have been measured in final states characterized by opposite-sign and opposite-flavour lepton pairs where one W decays into an electron and a neutrino, the other into a muon and a neutrino (both neutrinos leave undetected). The leptons were required to have: transverse momenta p_T>20 GeV/c and pseudorapidity

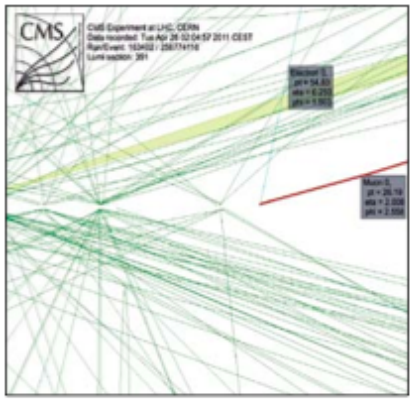


Fig. 1. Above: Proton–proton collisions recorded by CMS at $\sqrt{s}$=7 TeV, featuring candidates for the exclusive two-photon production of a W^+W^- pair, where one W boson has decayed into an electron and a neutrino, the other into a muon and a neutrino.

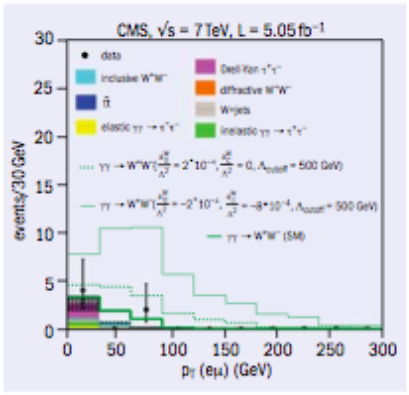


Fig. 2. Top right: The p_T distribution of eμ pairs in events with no extra tracks compared with the Standard Model expectation (thick green line) and predictions for anomalous quartic gauge couplings (dashed green histograms).

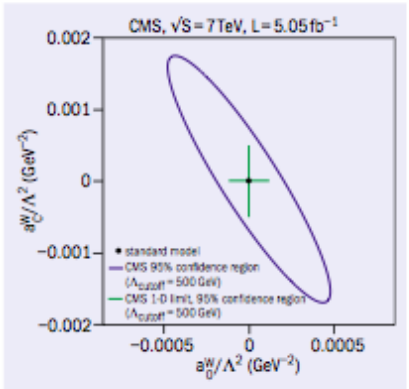


Fig. 3. Right: Limits on anomalous quartic $\gamma\gamma WW$ couplings.

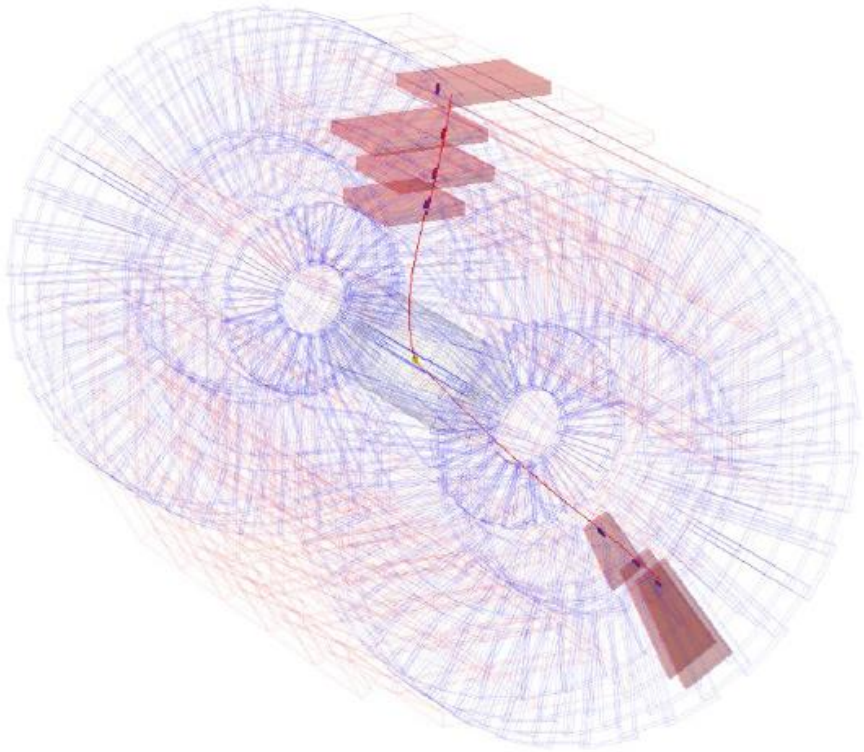
$|\eta| < 2.1$; no extra track associated with their vertex; and for the pair, a total p_T>30 GeV/c. After applying all selection criteria, only two events remained – compared with an expectation of 3.2 events: 2.2 from $\gamma\gamma \rightarrow WW$ and 1 from background (figure 2).

The lack of events observed at large values of transverse momentum for the pair, which would be expected within the Standard Model, allows stringent limits on anomalous quartic $\gamma\gamma WW$ couplings to be derived. These surpass the previous best limits, set at the Large Electron–Positron collider and at the Tevatron, by up to two orders of magnitude (figure 3).

Further reading

CMS collaboration 2013 arXiv:1305.5596 [hep-ex], submitted to *JHEP*.

Exclusivity conditions



In (very) low luminosity era:
2 muons and "nothing else"
in the tracker and calorimeters

In 2010, each event of interest accompanied by extra "PileUp" events within the same bunch crossing:
~ 2-3 pileup interactions

In 2011, roughly 7 PU and in 2012 about 15 PU per crossing

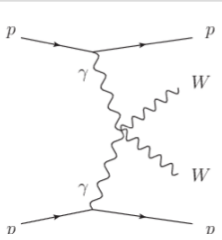
Restricting the analysis to single interaction events only would have reduced the data sample to < 0.1% of the total → **impose exclusivity using tracking only**

BUT it will not work at all beyond 2016 – exclusivity tagging is a MUST !

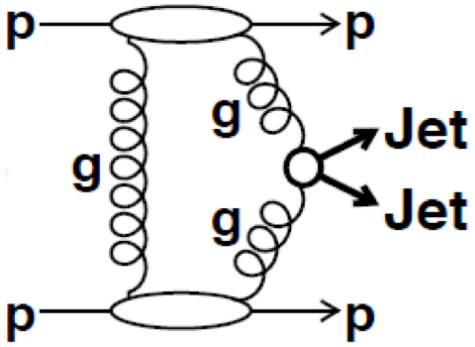
Physics motivations

EWK

- Measure $\gamma\gamma \rightarrow W^+W^-$
- **Quartic gauge boson coupling $WW\gamma\gamma$**
  sensitivity to anomalous couplings >> LEP, Tevatron
- Also search for SM forbidden $ZZ\gamma\gamma$, $\gamma\gamma\gamma\gamma$ couplings



LHC used as a "tagged" photon-photon collider $\sqrt{s_{\gamma\gamma}}$>> LEP



QCD

- Exclusive dijets, M(jj) up to ~ 750-1000 GeV.
- **Pure gluon-jets**, small component of b-bbar dijets
  - q-qbar dijets forbidden for massless quarks at t = 0.
- Test of pQCD mechanisms of exclusive production.

Gluon Jet Factory with very little quark jet contamination

WW production: extrapolations from data

arXiv.org > hep-ex > arXiv:1305.5596

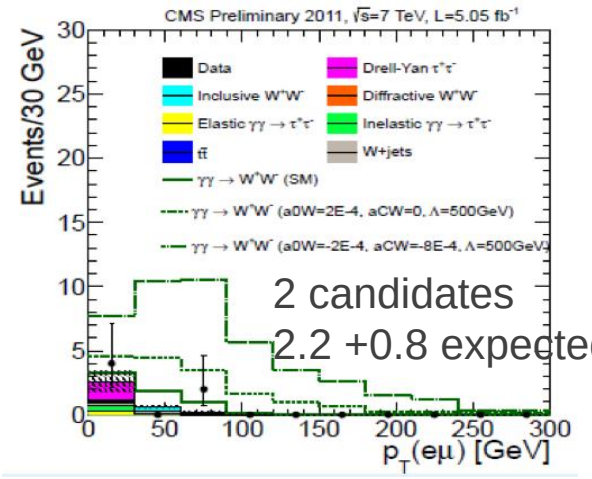
High Energy Physics – Experiment

Study of exclusive two-photon production of W(+)W(−) in pp collisions at sqrt(s)=7 TeV and constraints on anomalous quartic gauge couplings

CMS Collaboration

(Submitted on 24 May 2013)

More on Friday



Extrapolation from 2011 data:

- estimate that with 200 fb^{-1} PPS will collect about 200 fully leptonic
- and 1000 semi-leptonic WW events.

This statistics allows a sensitivity to anomalous parameters a_0^W/Λ^2 and a_C^W/Λ^2 close to 10^{-6} GeV^{-2} .

- **$10^{3\text{-}4}$ times** better than the limits established at LEP and Tevatron.
- **Two orders of magnitude** better than what is expected with the CMS central detectors only for the same luminosity.

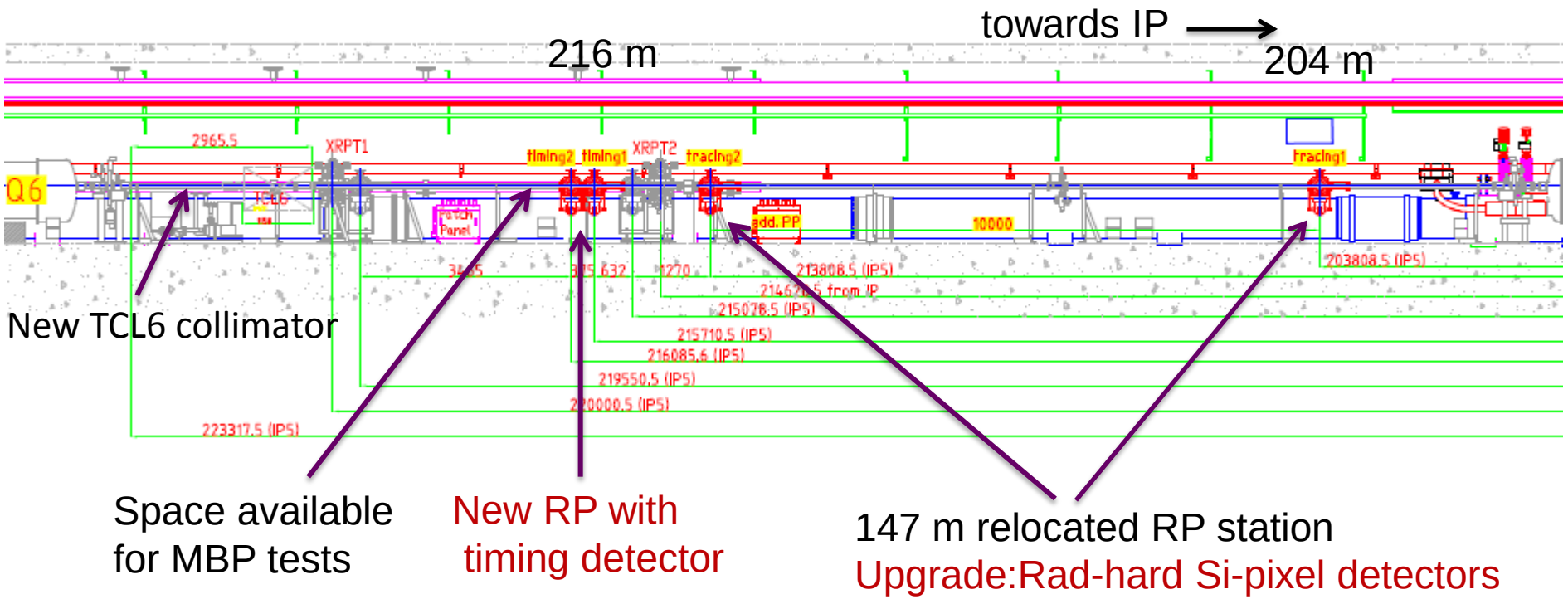
CT-PPS TDR

- The signature of the MoU between CERN CMS and TOTEM was already reported at last LHCC:
- Formed Management team of joint CT-PPS project
- Kick off meeting of Institution Board
- Organization to write the common project TDR (editorial board)

Marco BOZZO at LHCC meeting, June 4

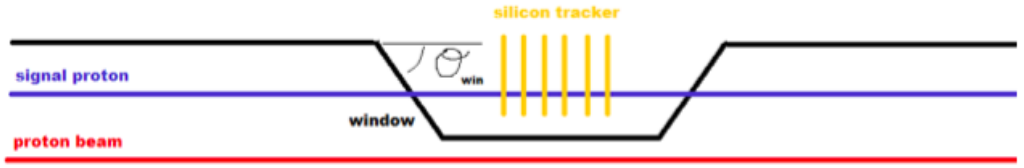
Detector concept: RP

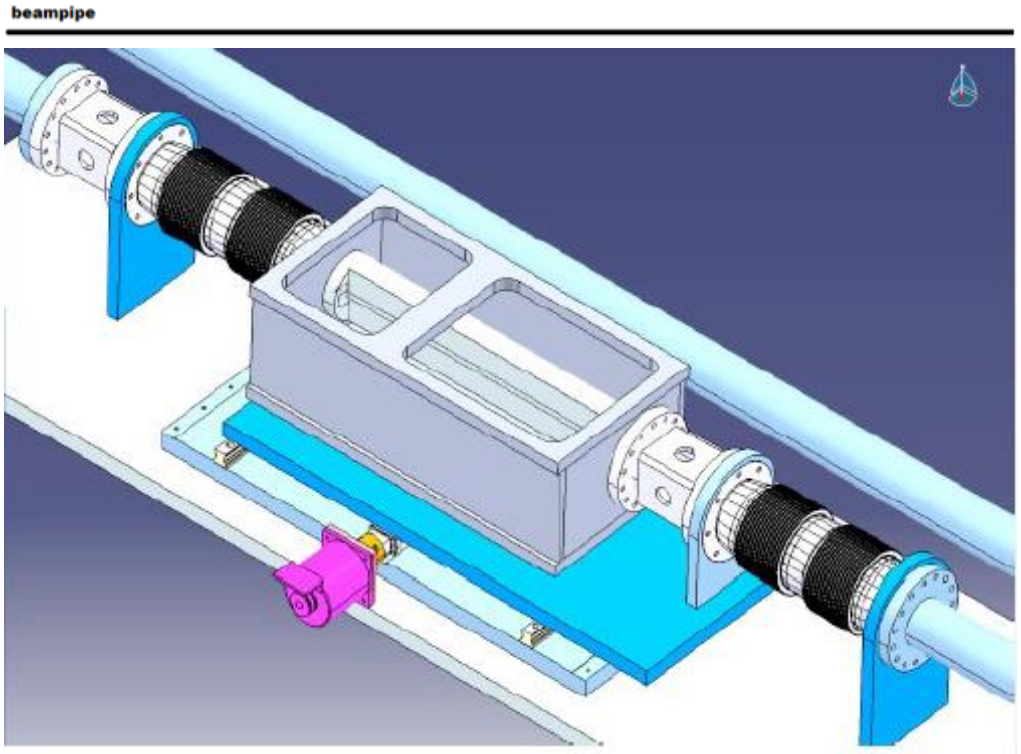
1) Two tracking stations, 10 meters apart instrumented with **rad-hard pixel detectors**:
   - Two RPs (or two short MBP)
2) Station for **timing detectors**
   - Two RPs (or one long MBP)
3) Proton spectrometer using **machine magnets**

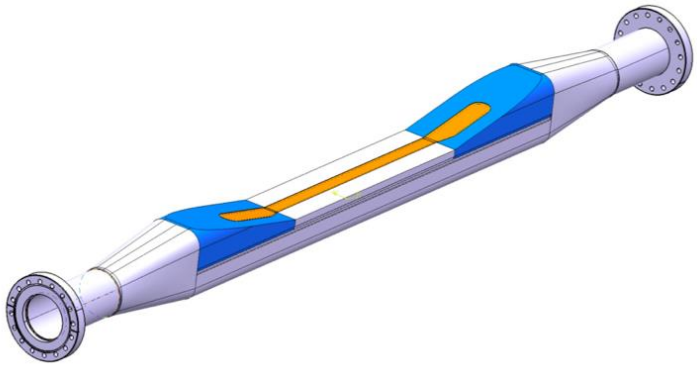


Movable Beam Pipe

- Stainless steel with copper coating
- Beam windows (300 μm) by electro-erosion
- Bellows to connect moving section to the normal beam pipe with lateral stroke of 25 mm under development





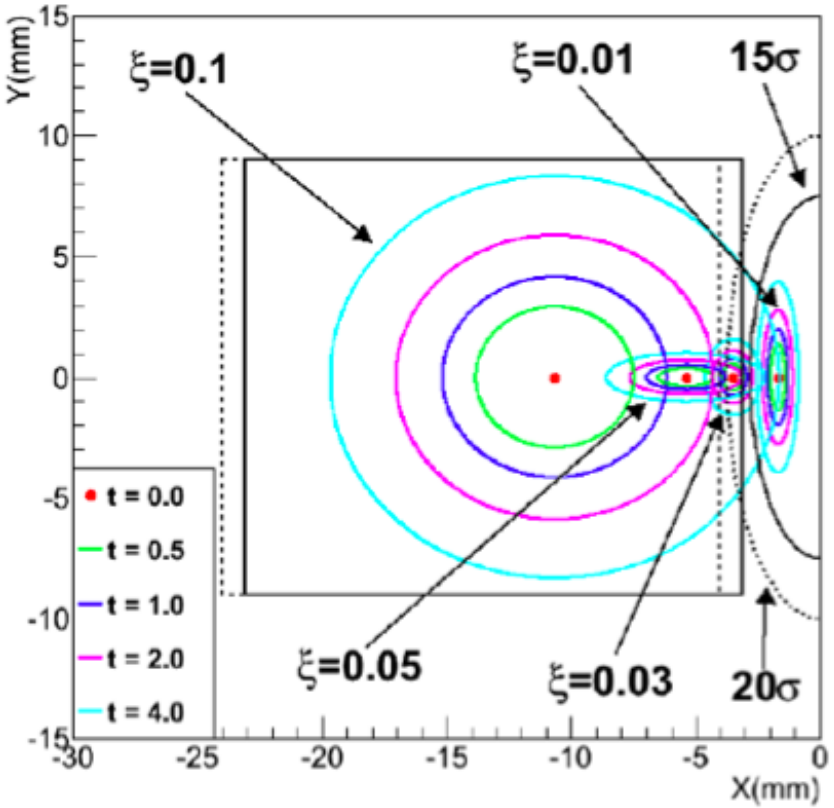


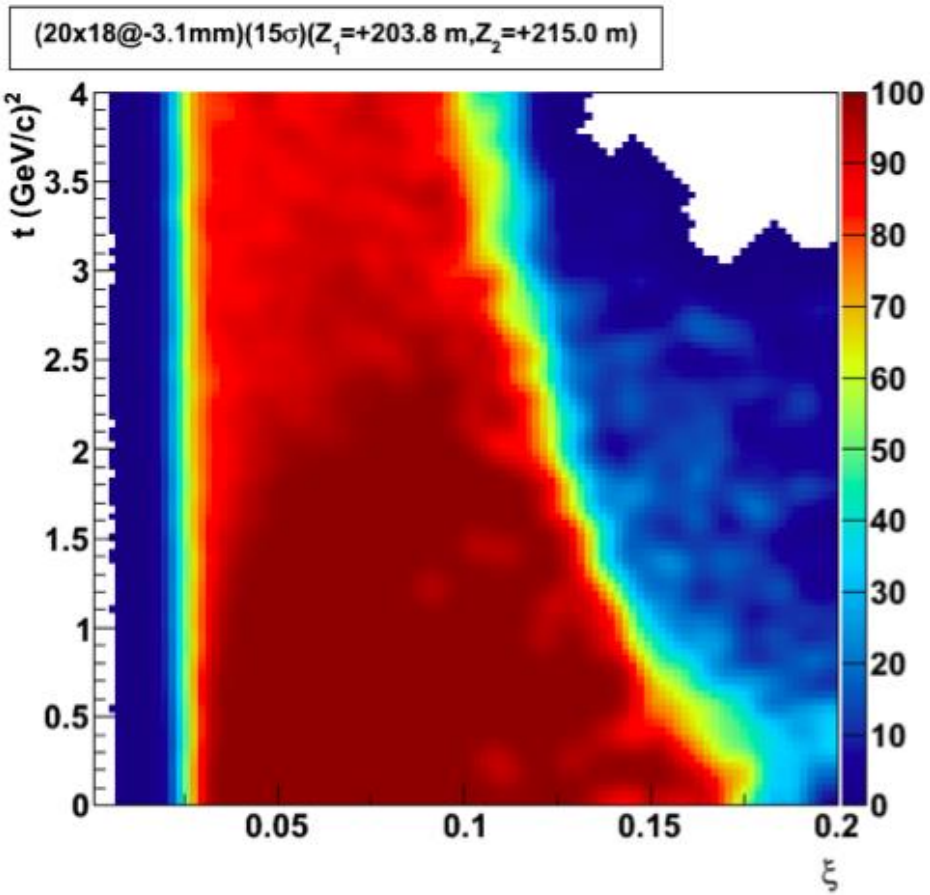
The latest MBP design includes 11 degree tapering structures to minimize the RF impedance.

Acceptance

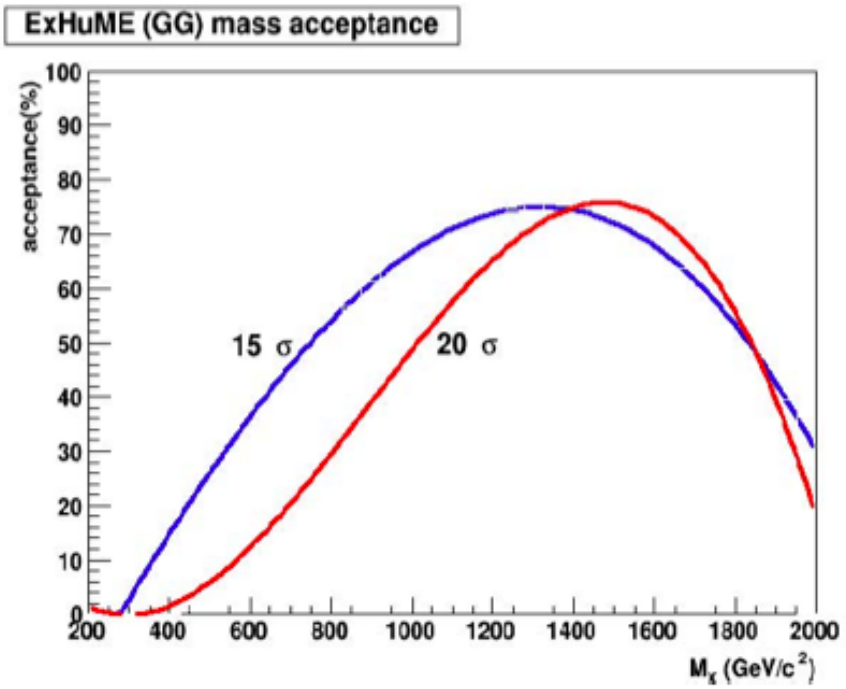
- Studies performed with the latest version of the LHC optics

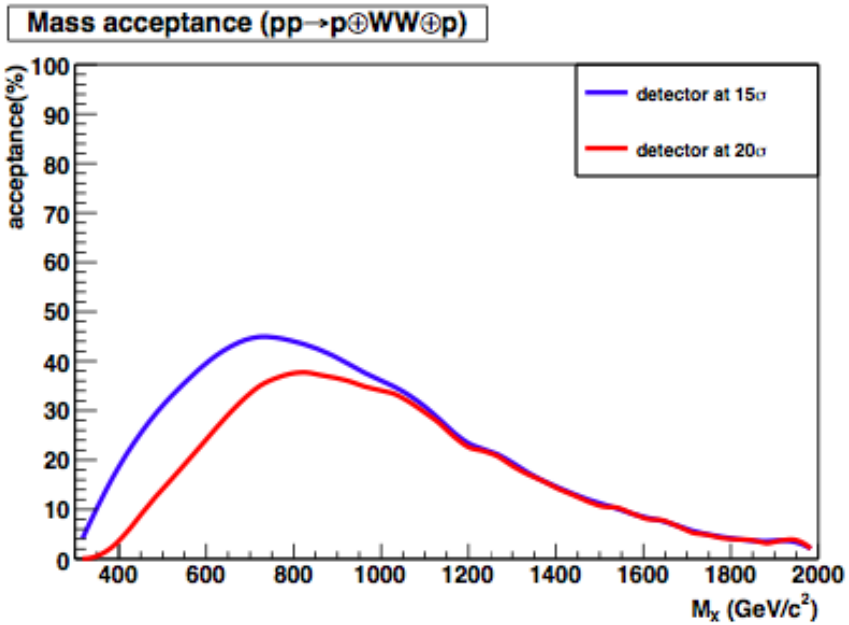
PRELIMINARY





Acceptance in M_{inv} for double tags

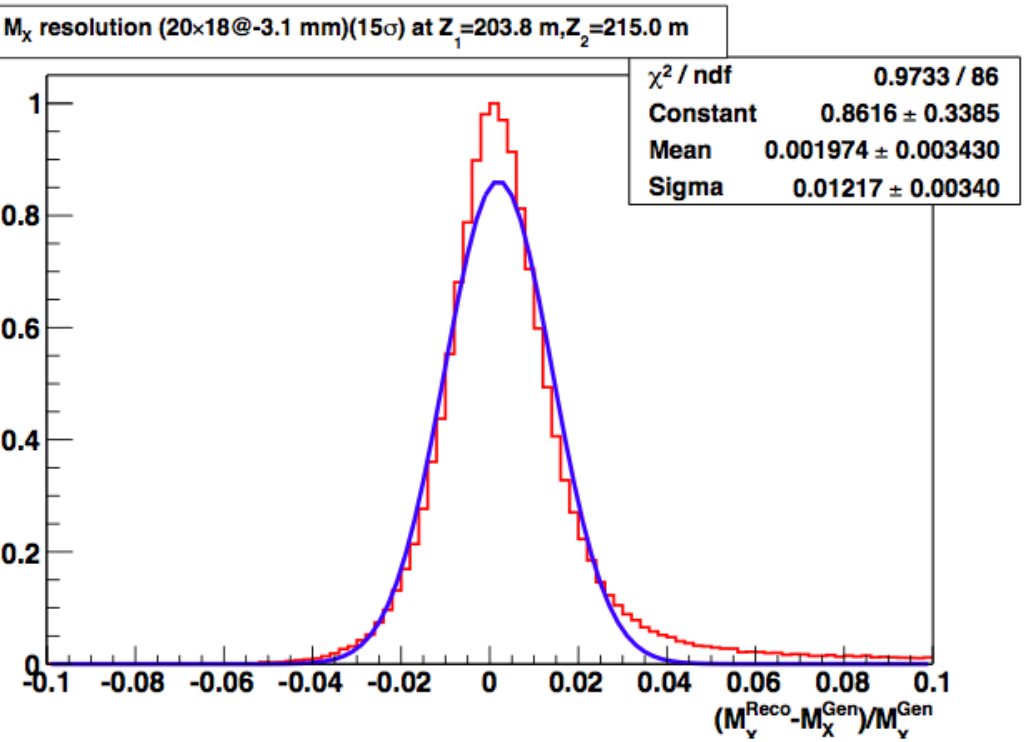


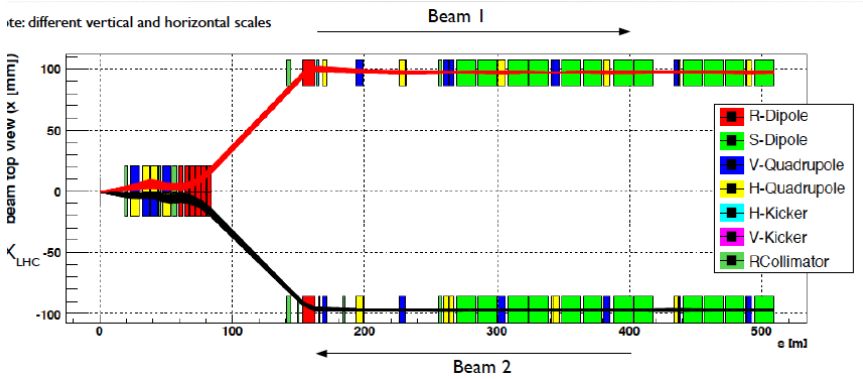


Very good for high masses – must fight for the closest approach to get it below 400 GeV
(esp. during initial lower intensity/luminosity running)

(Missing) Mass resolution

Includes vertex and hit smearing





- HECTOR, a fast simulator for the transport of particles in beam lines
  JINST, 2(2007)P09005
- Excellent agreement with MADx

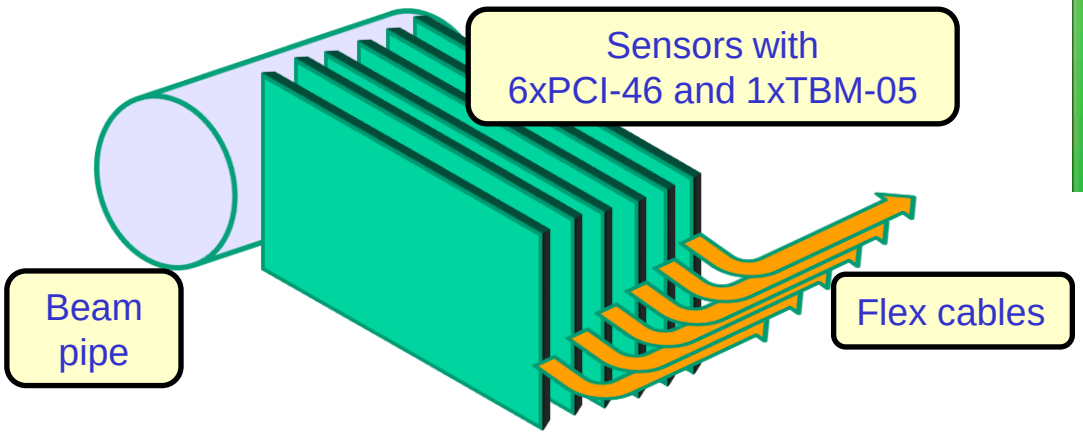
- **The relative mass resolution is improving with increasing mass, and is well below 1% at 1 TeV.**

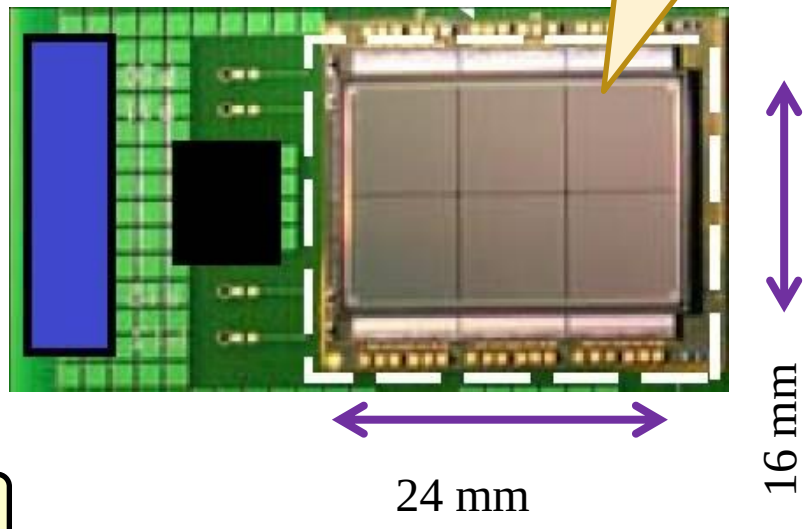
Tracking&Timing detectors

Sensor b-bonded to 6 PSI-46 chips

Tracking station: 6 pixel planes

3D or planar pixel sensors
synergy with stage2 Pixel R&D





Several detector options investigated for picosecond timing:

- Quartz Cerenkov detector with SiPMTs (QUARTIC)
- Gas Cerenkov detector with MCP-PMTs (GasToF)
- Silicon-based fast timing detectors
- OR, a mix of them?

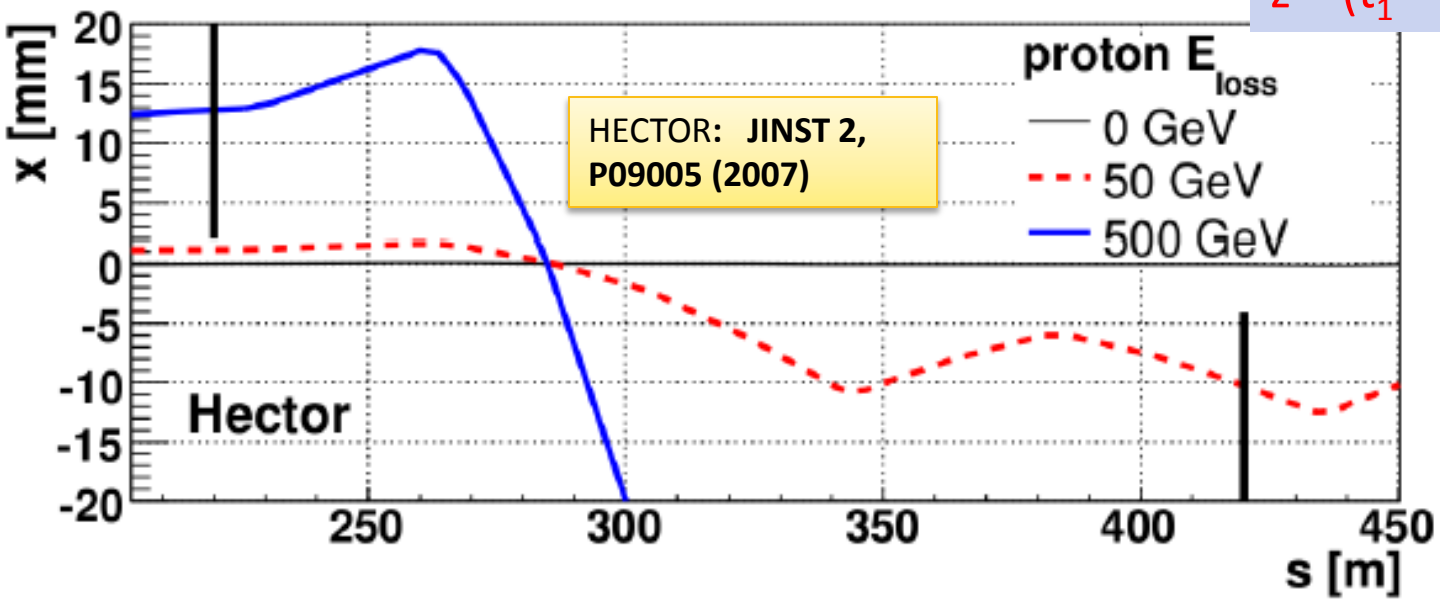
To be used to beat the major triple random coincidence background:

p ✚ X ✚ p

Picosecond ToF detectors @ LHC

Use very fast ToF detectors to measure *longitudinal vertex position* from *z-by-timing* from forward proton arrival time difference:

$z = (t_1 - t_2)/2c$



Path length differences are very small for forward protons at LHC, typically << 100 μm corresponding to sub-picosecond time differences.

Ultra fast timing detectors are essential for measuring the exclusive production at LHC, pp → pXp, JINST 4 (2009) T10001

CT-PPS program until LS2

Exploratory phase (2015-16) :

- Prove ability to operate detectors close to the beam line at high luminosity. In 2015, evaluate Roman Pots (RP) in the 205 – 215 m region. Evaluate Movable Beam Pipes (MBP) possibly in 2016 in the 240m region.
- Start tests with existing TOTEM silicon strip detectors and upgrade to pixel detectors as soon as possible.
- Demonstrate the timing performance and the pile-up rejection capabilities with the detector technologies that will be available.

Initial production phase (2016-17):

- Integrate the CT-PPS detectors in the CMS trigger/DAQ system. Finalize the CT-PPS detector commissioning.
- Aim at accumulating $\sim$100 fb^{-1} of data.