TOTEM status report
LHCC 04/12/2013

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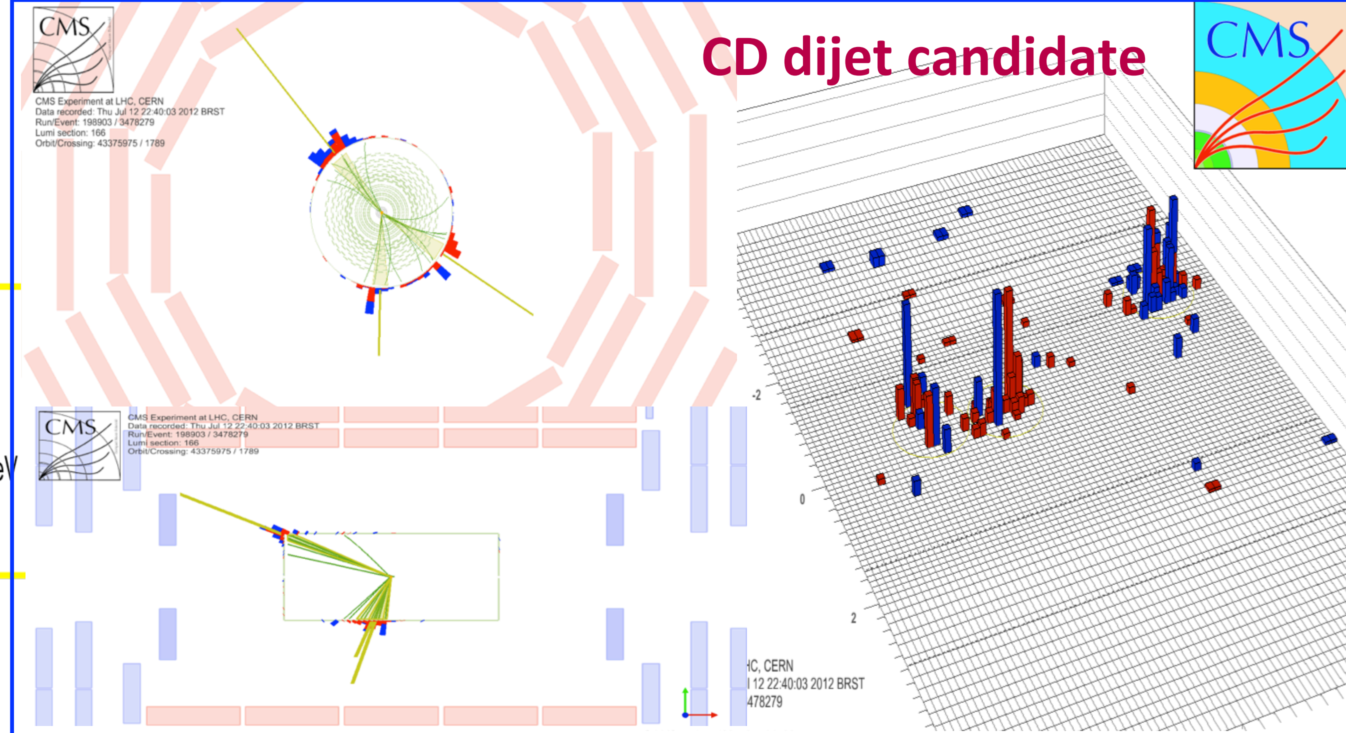
Outline

- consolidation and upgrades conceived in the view of
  - past experience
  - future measurements
- analysis highlights

what we have learned

- The experiment has performed beautifully, and in trying to extend its reach we have discovered what should be made better
- during special runs, difficult-to-obtain conditions lead to limited statistics
  - **non-standard optics are challenging and higher are the chances of losing the beam**
  - **close distance of approach and delicate RP alignment procedures**
- pile-up and halo backgrounds are the main limiting factor to
  - **lowering t (at a given β^*) in elastic scattering measurements**
  - **achievable integrated luminosity in any configuration (standalone and w/CMS)**
- The RPs performed as expected w.r.t. RF impedance, but this is not enough if we want to collect larger samples.
- Off-line association of TOTEM and CMS events works nicely but
  - **time consuming**
  - **does not allow to exploit the CMS 2nd level trigger**

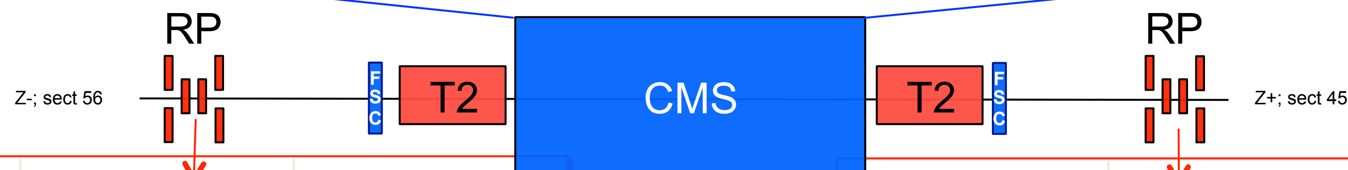
CD dijet candidate

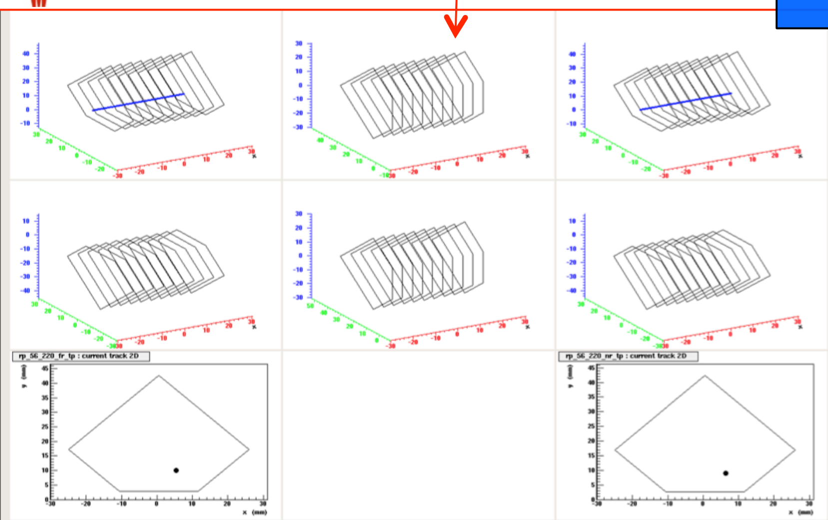


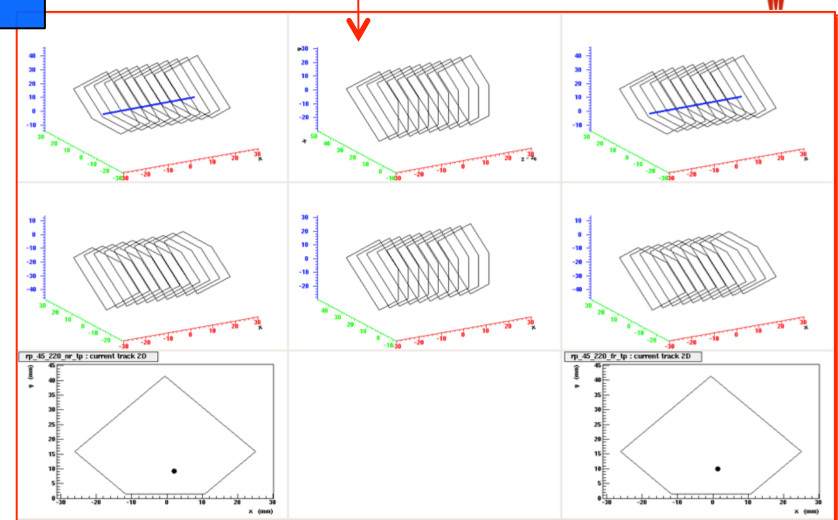
CMS + TOTEM 90m β*
Run/Event 198903/3478279
Jets E_T = 65,45,27 GeV

MM(pp) = 244 GeV; M(CMS) = 219 GeV
Σp_T(CMS) = 3.4 GeV
FSC empty both sides

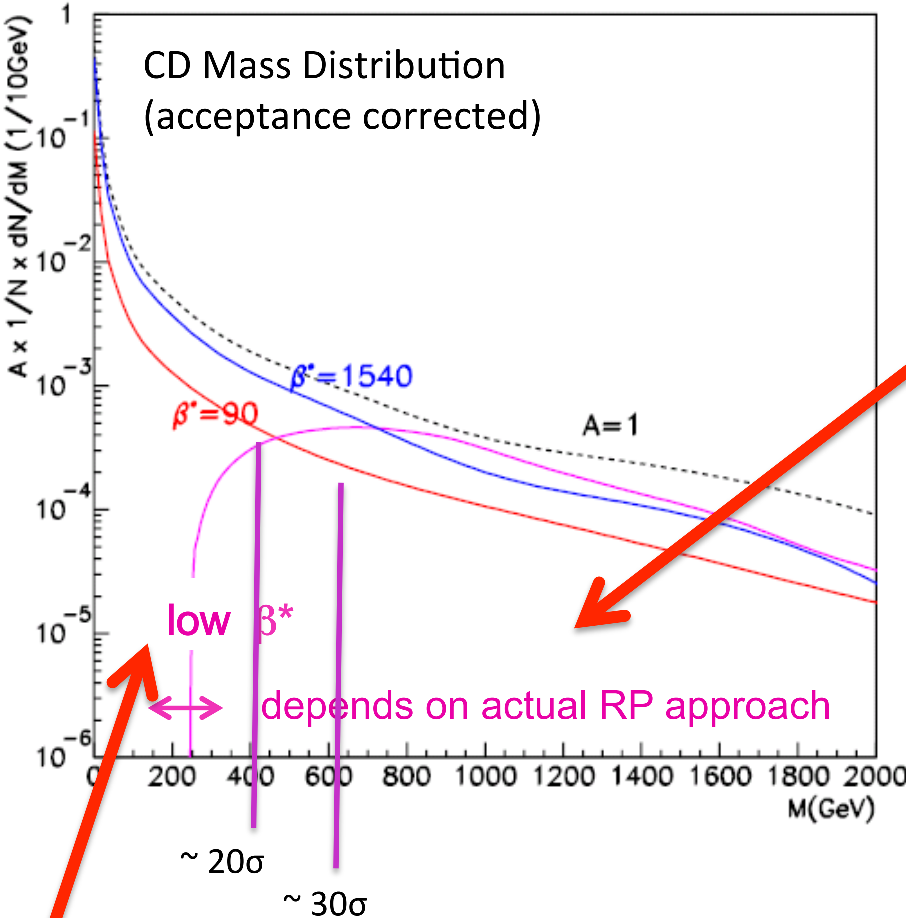
M(pp) = 244 GeV
≈ M(central)
$\xi_1 = 0.1 \quad \xi_2 = 0.01$





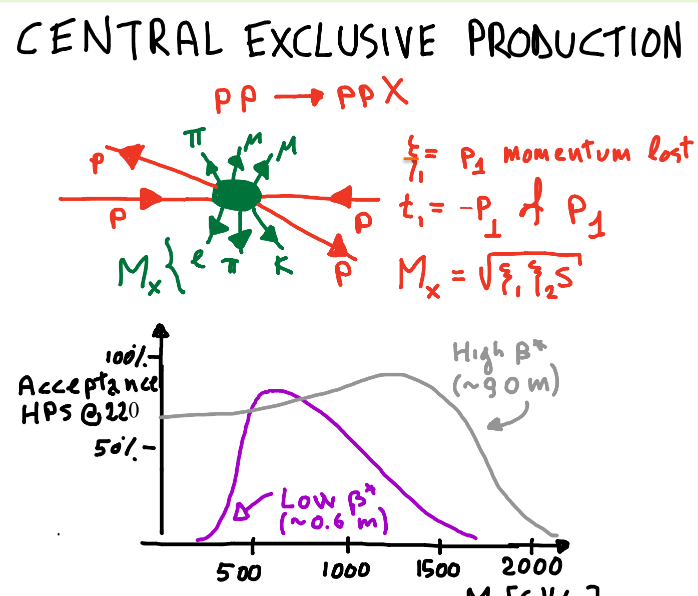


CD and the low/high β* perspective



- β*=0.5m and high luminosity is the ideal condition to explore
  - higher M, above ~400GeV/c
  - low-cross section processes

Physics aide-memoires

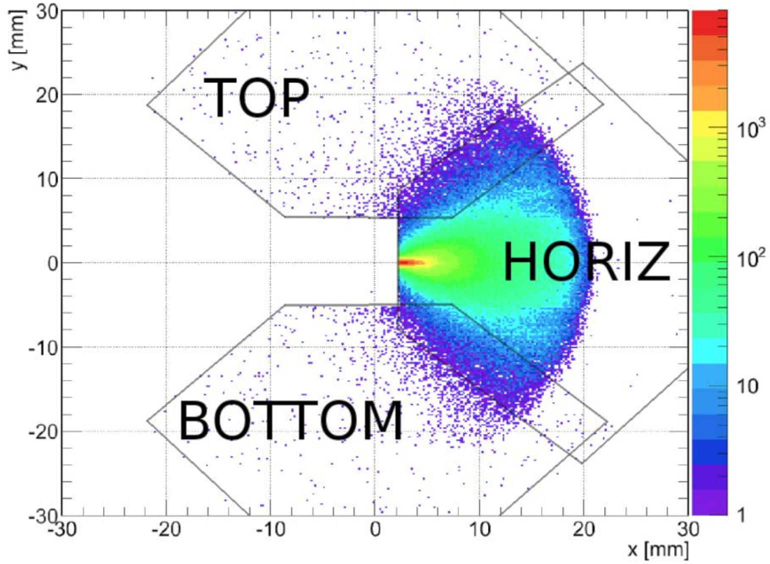


- Low(er) M region and high cross-section channels can be explored with β^*=90m @ intermediate luminosity
- Actual acceptance region strongly depends how the RPs approach the beam
- A realistic approach is 20σ

Different LHC Optics

Hit maps of simulated diffractive events for 2 optics configurations

Standard low β* runs:



diffractive protons in **horizontal** RP

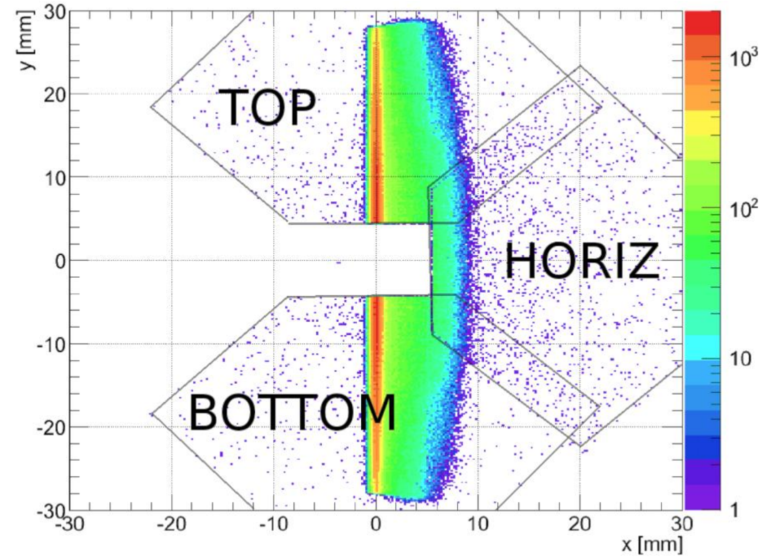
μ = 25 – 50 (~5 with reduced N_p/bunch)

low cross-section processes (hard diffraction) – continuous running (with reduced N_p/bunch?)

~ 10^{34} cm^{-2} s^{-1}

$$\mathcal{L} \propto \frac{1}{\beta^*}$$

Special high β* runs:



diffractive protons in **vertical** RP

μ = 0.05 – 0.5

high cross-section processes – dedicated short runs with optimized conditions

~$10^{30\text{-}32}$ cm^{-2} s^{-1}

TOTEM

Running scenarios

β^* [m]	cr. angle [μrad]	ε_N [μm rad]	N [10^{11} p/b.]	k bunches	μ	Luminosity [$\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$]	
2500	0	2	$0.7 \div 1.5$	2	$0.004 \div 0.02$	$(1.2 \div 5.6) \times 10^{27}$	$= (0.1 \div 0.5)\,\mathrm{nb}^{-1}/24\mathrm{h}$
90	0	2	$0.5 \div 1.5$	156	$0.06 \div 0.5$	$(1.3 \div 12) \times 10^{30}$	$= (0.1 \div 1)\,\mathrm{pb}^{-1}/24\mathrm{h}$
90	100	2	$0.5 \div 1.5$	1000	$0.06 \div 0.5$	$(0.9 \div 7.7) \times 10^{31}$	$= (0.8 \div 7)\,\mathrm{pb}^{-1}/24\mathrm{h}$
11	$310 \div 390$	$1.9 \div 3.75$	1.15	$2520 \div 2760$ ($\Delta t = 25\,\mathrm{ns}$)	$1.3 \div 2.5$	$(5.3 \div 9.5) \times 10^{32}$	$= (46 \div 82)\,\mathrm{pb}^{-1}/24\mathrm{h}$
0.5	$310 \div 390$	$1.9 \div 3.75$	1.15	$2520 \div 2760$ ($\Delta t = 25\,\mathrm{ns}$)	$19 \div 34$	$(0.8 \div 1.3) \times 10^{34}$	$= (0.7 \div 1.1)\,\mathrm{fb}^{-1}/24\mathrm{h}$

- Strategy for the future
  - consolidate the detectors with the goal of resolving pileup in low- to medium-lumi running
    - multiple tracks and halo background
    - multiple events
  - consolidate the RP enclosures
    - better RF behavior
  - upgrade the apparatus
    - with rad-hard tracking devices
    - with high-performance timing detectors
  - Operate at higher luminosities during special runs and later run in standard LHC fills.

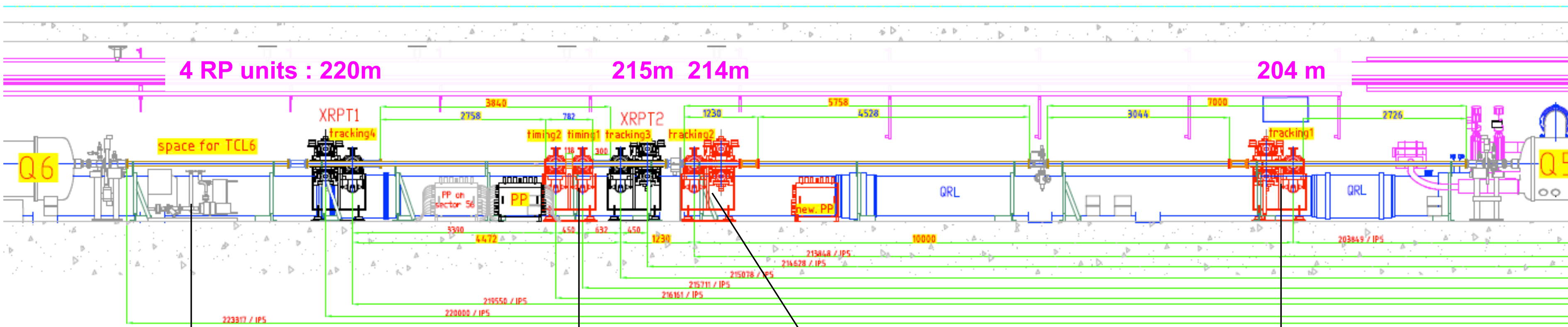
challenges in 3 different running modes

1. $\beta^* \geq 0.5$km
   - setting-up challenges and very limited running time
   - inefficiencies due to track pile-up (halo) increase with closer approach
2. β^*=90m, intermediate luminosity ($10^{28} \div 10^{30}$)
   - wish for moderate pile-up (μ=0.5÷5) and 1000 bunches to overcome statistics limitations (short running periods)
3. $\beta^* \cong$ 0.5m, high luminosity ($10^{33} \div 10^{34}$)
   - high ($\mu \geq 20$) pile-up
   - radiation damage

interventions (in a logical order)

- Consolidate by
  - equipping the present tracking strips with stereo-views (for any β^*)
  - reduce RF impedance and its consequences
  - removing bottlenecks in the standalone DAQ
  - providing intermediate-performance timing information in vertical pots (β^*=90m)
  - and in addition sending data directly to the CMS DAQ.
- Upgrade (with CMS) by
  - adding specific new RPs for high-performance timing
  - installing radiation-hard pixels for tracking
  - RP enclosures ready by end of LS1, detectors later

Relocation and new configuration



Install collimator to protect Q6

Allow insertion of (horizontal) RPs closer to beam in high intensity scenario
→ **improved ξ acceptance**

Infrastructure to install 2 new horizontal pots

Cylindrical pots to host **timing detectors**

RP147 (fully equipped) relocated at 203-213 m 1 unit rotated by 8 degrees

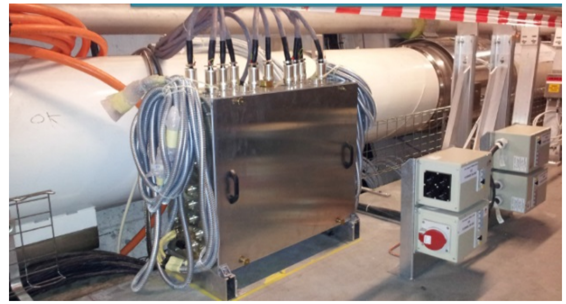
Long lever arm (~15m) **improves angular resolution** (until beam divergence limit)

Si-strip detectors rotated to improve multitrack event reconstruction (beam halo pileup, background)

- RP system will consist of 4 RP units/arm, each with 2 vertical + 1 horizontal pots equipped with 10 planes Si-strip detectors, with full trigger capability
- Extreme flexibility in using 4 units according to running scenario; possibility to dedicate pots to new **Si-pixel detectors** as well as to timing detectors with low material budget

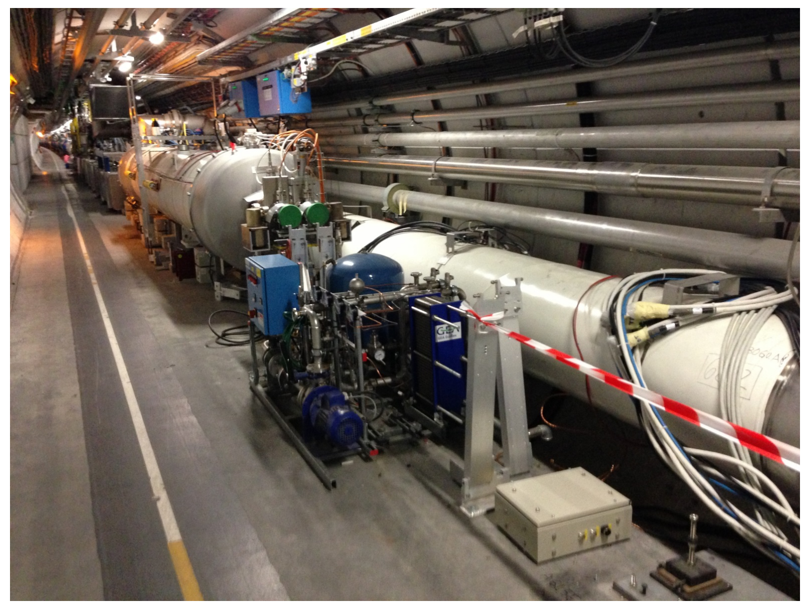
tunnel work (4/5 & 5/6)

Relocated patch panels
and cablings



210-220m region

TCL6 region

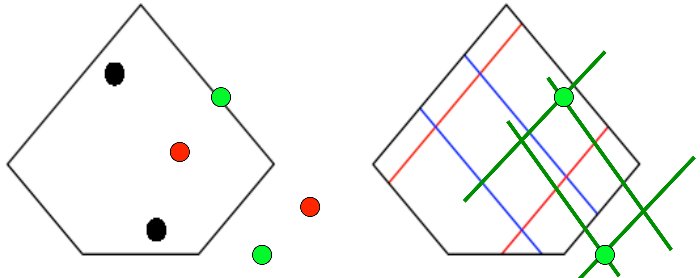


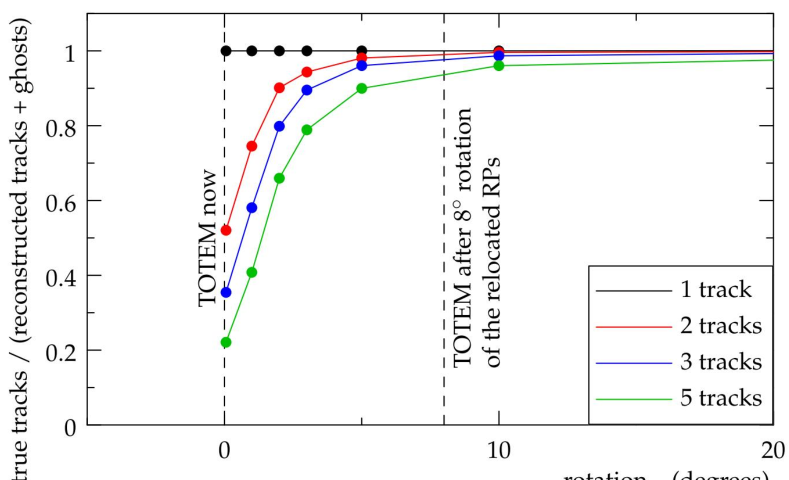
All service cables laid 147 – 220
All patch panels are relocated

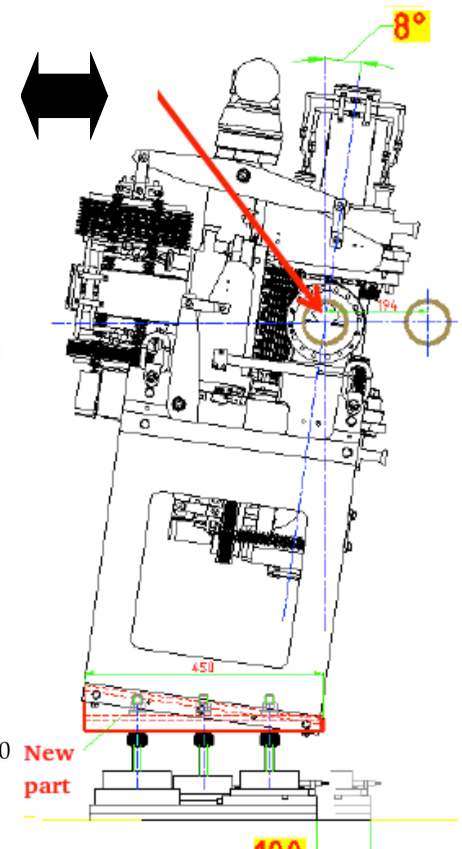
Stereo angles

Current limitation: not able to reconstruct events with ≥ 2 tracks in same pot

Solution: tilt by ~8° FAR RP station at 210m (ghost tracks suppression)

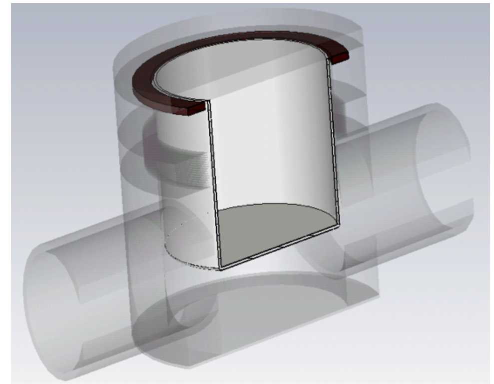


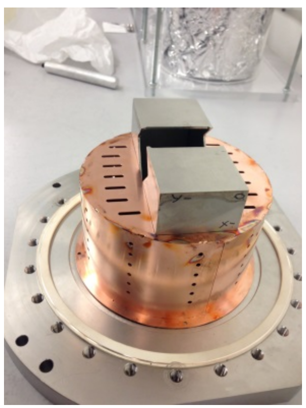


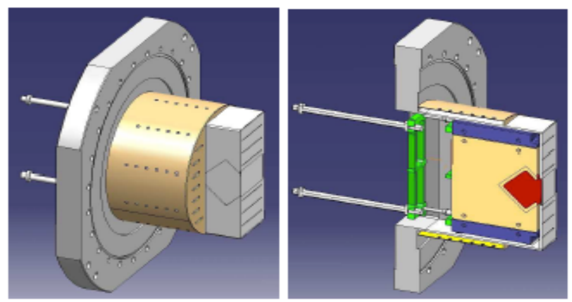


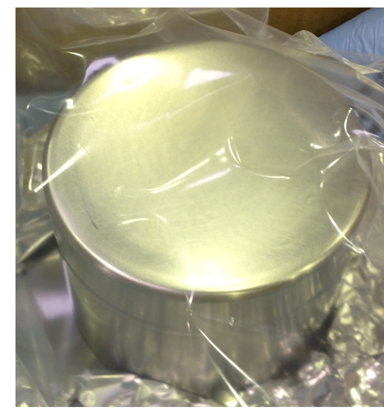
RF impedance

- new cylindrical RPs
- cylindrical RF shields for "box" RPs
- prototypes ready









- + new ferrites for all RPs. Much higher
  - bakeout temperature: 1000 °C
  - and Curie temperature: 375 °C

Main Timeline for RP service work & re installation in tunnel

Possible critical path-> determines the earliest possible installation in the tunnel

Ferrite delivery & control → Ferrite bake out → Ferrite removal & mounting of new ferrite → Roman Pot anti collision switch & calibration → Roman Pot Vacuum test TE-VSC-LBV →

All tunnel and RP work is on schedule, all work packages defined, orders placed and no criticalities identified

Laser alignment ~ 1 month
Commissioning ~ 1 month

Date of bake out needs to be re discussed !!

At latest
5/6 2.6.2014
4/5 23.6.2014

5/6 16.6.2014
4/5 7.7.2014

Installation of detector packages cables connection & RP Laser calibration !!!

August 2014
Week 34
4/5
Week 31
5/6

Return of stations to H4- kept under vacuum → Re transfer to LHC tunnel- installation in tunnel → Connection to beam pipe elements & motor connection → Bake out of beam line 4-5 & 5-6 → RP commissioning → END of access line 4-5 & 5-6

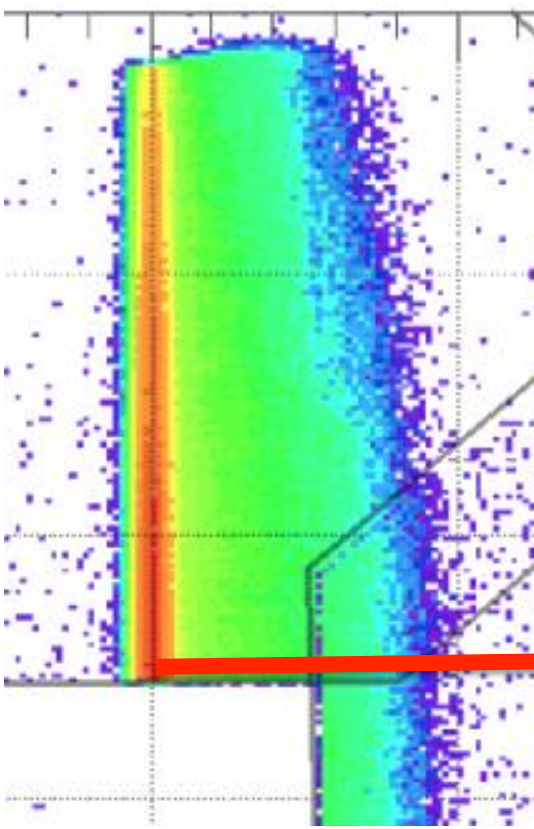
Consolidation: Timing in V-RPs. Design constraints

- Scattered protons seen in vertical RPs when $\beta^*=90m$
- Long collision region (50cm) and a worst-case scenario of $\mu \leq 5$
  - Resolution in the range 50÷100 ps
- Optimize the number of TDC channels keeping into account that
  - the hit distribution is anisotropic
  - cell size can be chosen to minimize inefficiency
- “box” enclosures must not be modified

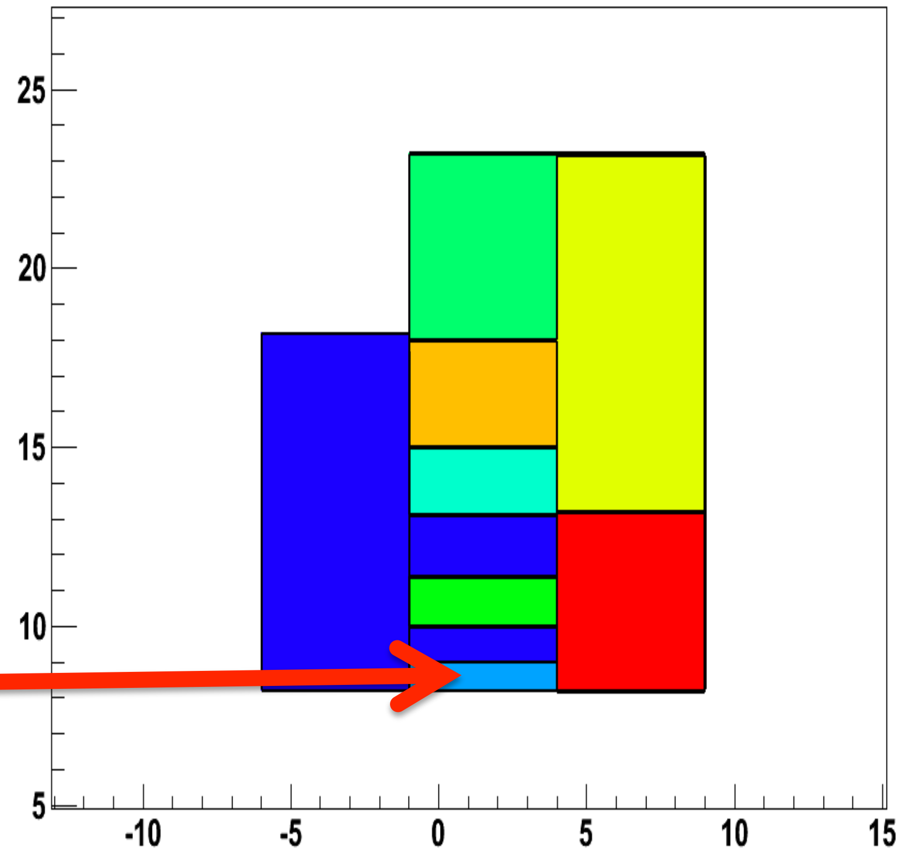
- The best candidate is a diamond detector
  - same form factor as present strip detectors → can fit in existing enclosure
  - cell size and shape can be freely obtained by design of the metallization mask
  - credible option for <100ps resolution
- A fast silicon detector option is also being evaluated

Timing in V-RPs: cell design

Hit map



10 channels: cell size and efficiency



Cell size and shape designed in order to minimize double-hit inefficiency and limit number of channels

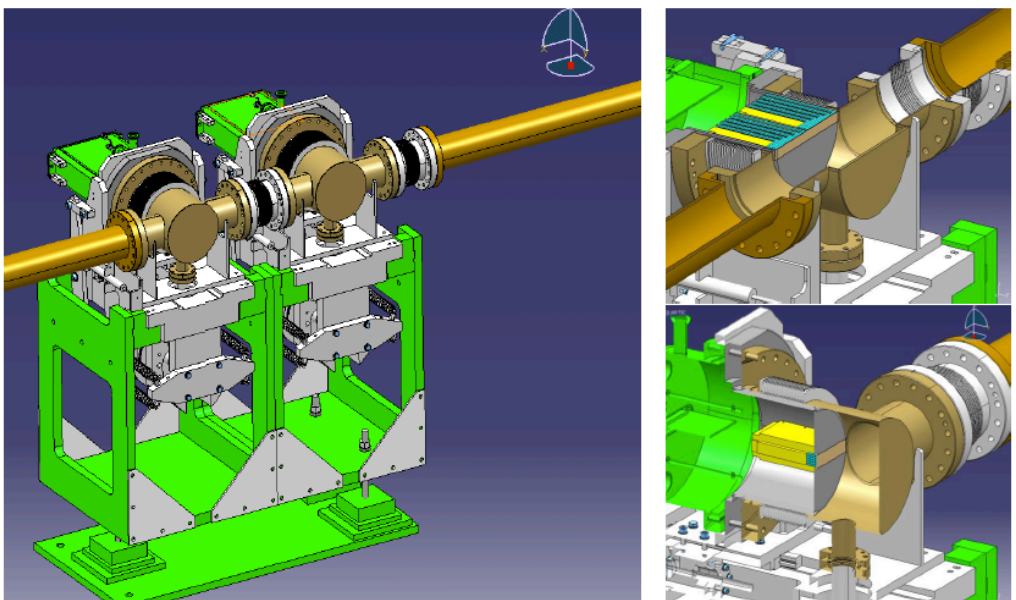
Cell DPE inefficiency < 8% @ μ=5

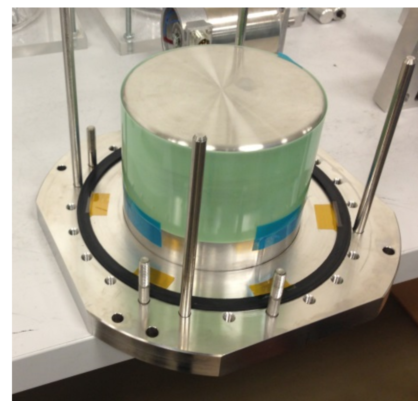
Upgrade: new cylindrical RPs

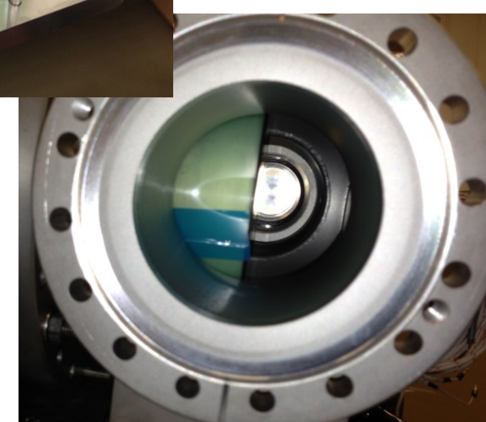
- Installation of additional horizontal RP to host timing detectors
  - operation at low β* → best possible impedance characteristics
  - enough volume in the enclosure to host long Cherenkov detectors

→ cylindrical shape

new RP design with cylindrical head





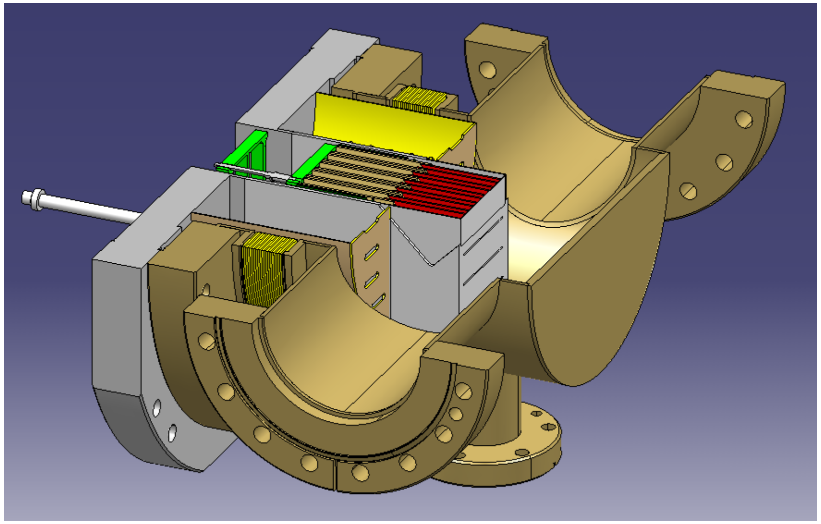


Movement test of the prototype

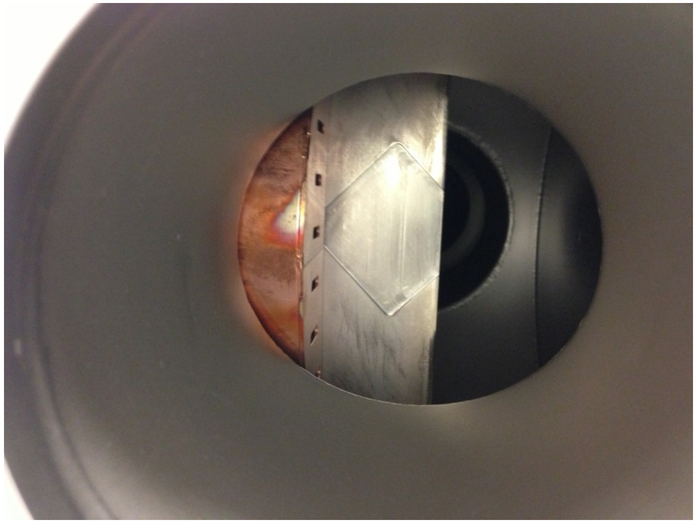
Upgrade: new RF shields for H-RPs

- Modification of an existing RP with the addition of a cylindrical RF shield and new ferrites
  - "box" enclosure still suitable for silicon trackers
  - ready for testing/running 3D-pixels with high granularity and radiation tolerance

RF shield and detector box



Movement test of the prototype



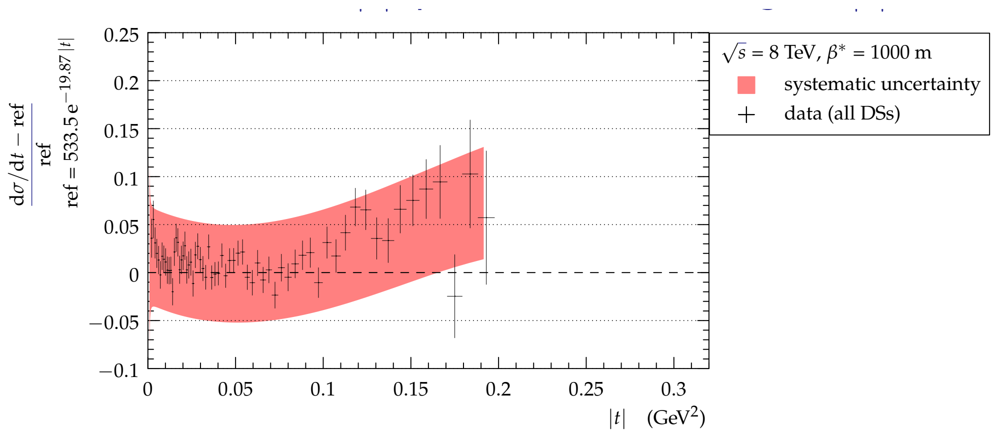
Analysis highlights

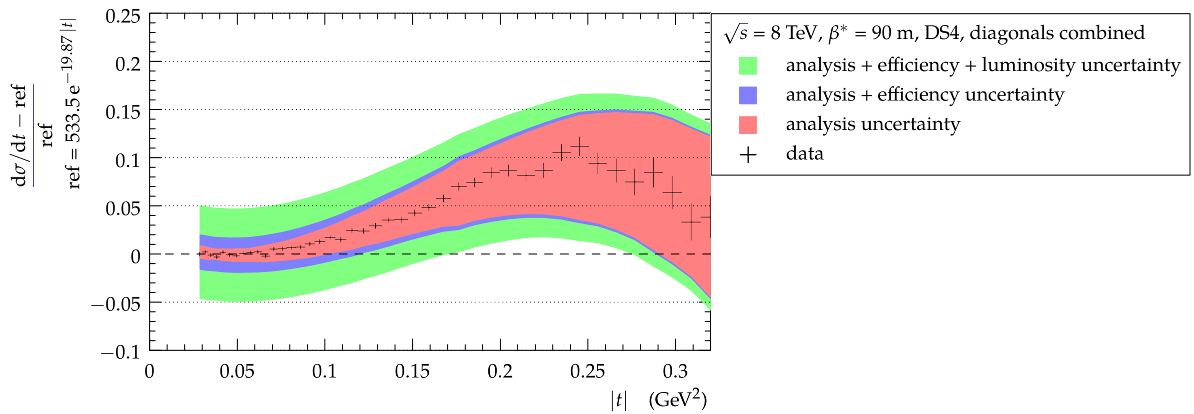
- A total of 8 physics and 3 technical papers.
- Analyses published since last LHCC:
  - soft DD @ √s = 7 TeV (β* = 90 m); accepted for publication in PRL
- Analyses with high priority:
  - $dN_{charged}/d\eta$ @ √s = 8 TeV with T2 & CMS tracker (β* = 90 m);

    Status: CMS & TOTEM collaboration wide review
  - hadronic-Coulomb interference @ √s = 8 TeV (β* = 90 and 1000 m)
  - low mass DPE @√s = 8 TeV (β* = 90 m); with CMS
- Analyses in advanced stage:
  - SD dijets @ √s = 8 TeV (β* = 90 m); with CMS
  - soft SD @ √s = 7 TeV (β* = 90 m)
  - σ_{inel} @√s=2.76TeV with T1+T2(β*=11m)
  - large-t elastics with low β*
- + a host of ongoing analyses both standalone and w/CMS

hadronic-Coulomb interference @ √s = 8 TeV

- Exploit 2 data sets to pin down the effects of the hadronic phase in different |t| regions
  - **β*=90m for good statistics at high |t|**
  - **β*=1000m for access to low |t|**





Conclusions

- TOTEM has devised a comprehensive list of interventions for consolidation and upgrade
- A clear distinction between [large β*,low lumi] and [small β*, high lumi] allows complementary approaches to hardware interventions
- Consolidation operations are proceeding smoothly according to schedule
- Services in view of upgrades will be ready by end of LS1
- Analysis of 2012/2013 data sets proceed steadily, with a first milestone paper together with CMS in its final review process.