TOTEM

Stato dell'esperimento

Attività di Pisa/Siena

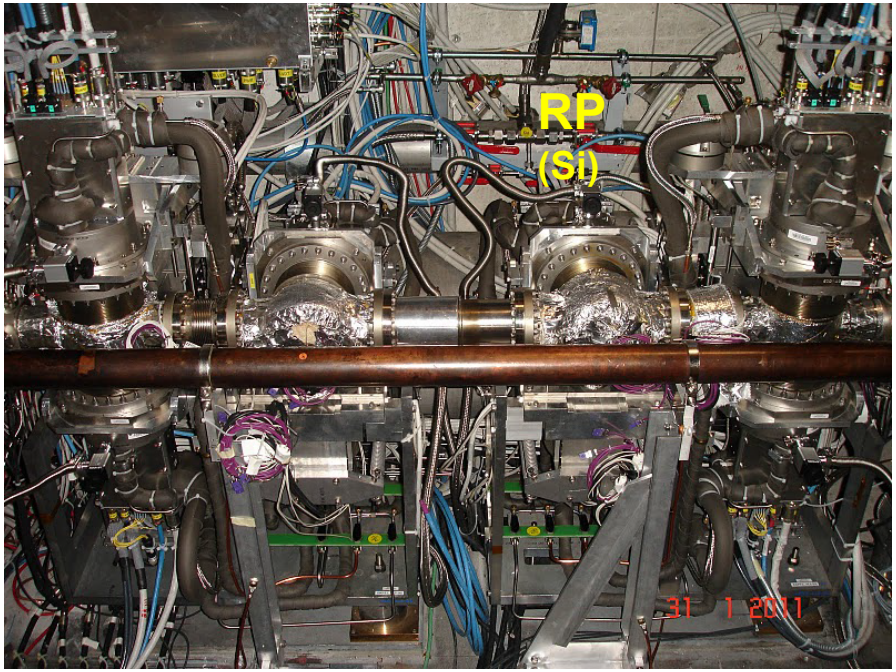
Composizione Gruppo

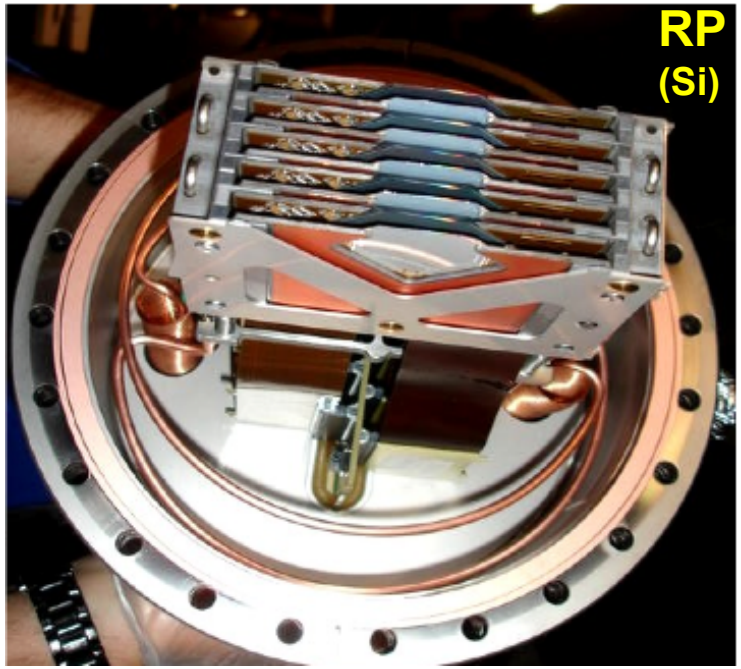
Richieste 2015

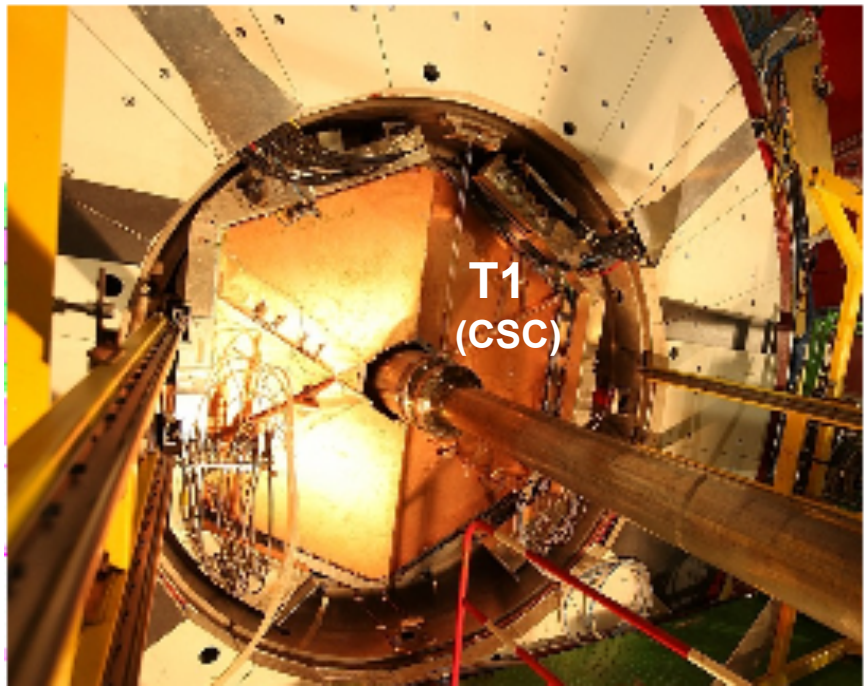
Nicola Turini

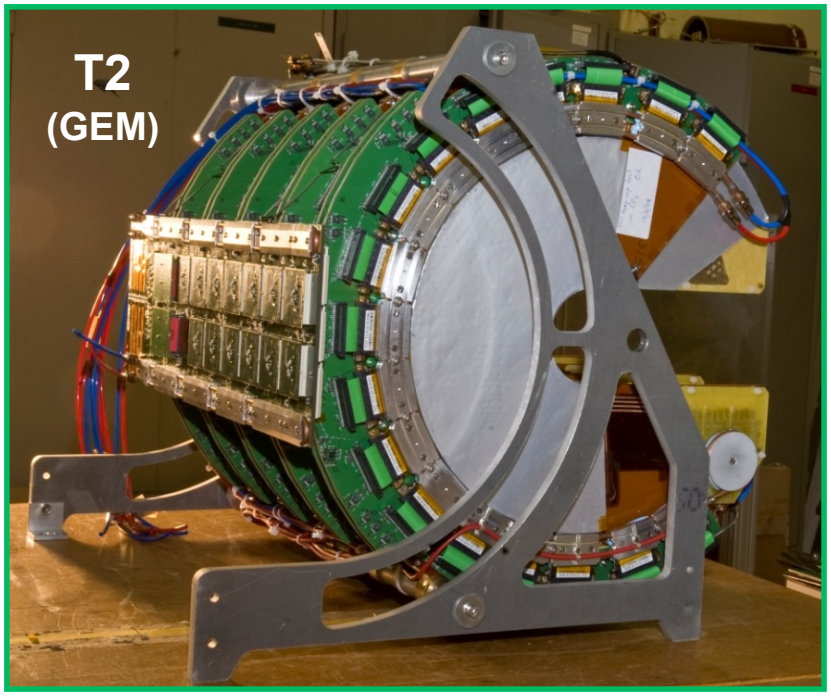
on behalf of the
TOTEM PISA/SIENA Group

TOTEM Detectors

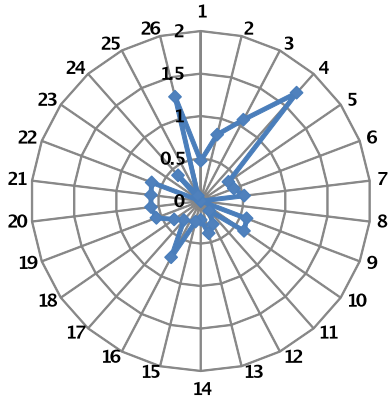








LHC Optics: RP sensitivity

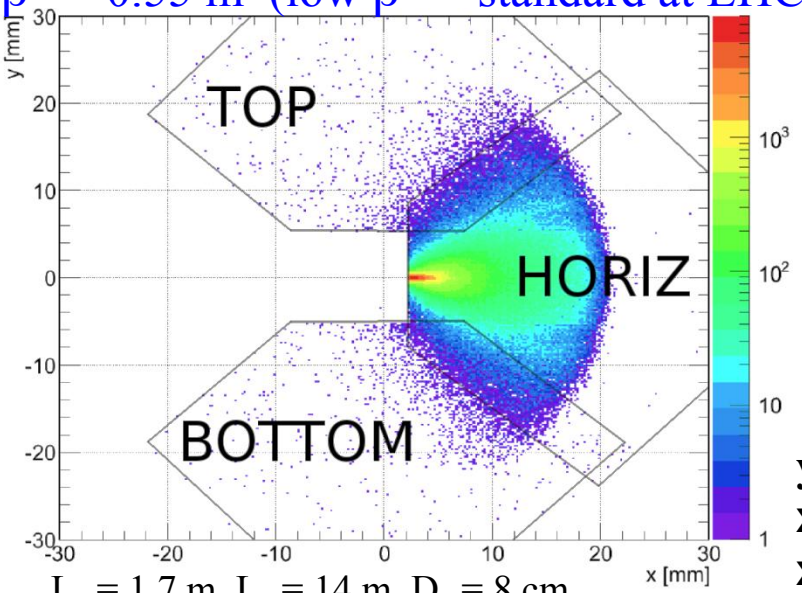


Optics parameters: data full non-linear fit, harmonics, displacements,…

Hit maps of simulated diffractive events for 2 optics configurations

(β* = betatron function at the interaction point)

β* = 0.55 m (low β* = standard at LHC)

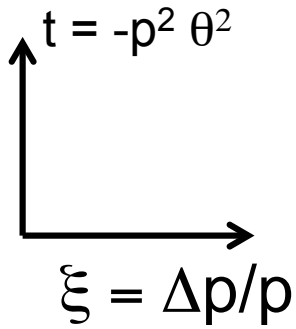


L_x = 1.7 m, L_y = 14 m, D_x = 8 cm

diffractive protons: mainly in **horizontal** RP

elastic protons: in vertical RP near x ~ 0

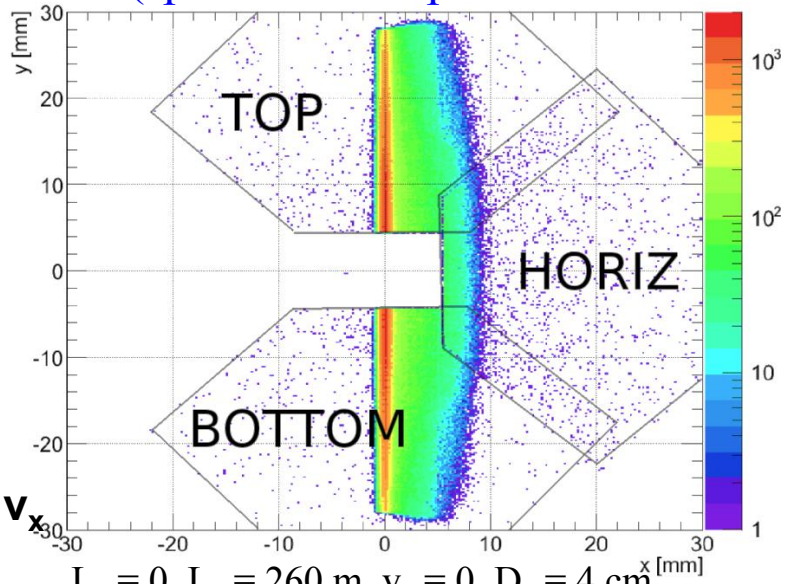
sensitivity only for large scattering angles



$y = L_y \Theta_y + v_y y^*$

$x = L_x \Theta_x + \xi D + v_x x^*$

β* = 90 m (special development for RP runs)



L_x = 0, L_y = 260 m, v_y = 0, D_x = 4 cm

diffractive protons: mainly in **vertical** RP

elastic protons: in narrow band at x ≅ 0,

sensitivity for small vertical scattering angles

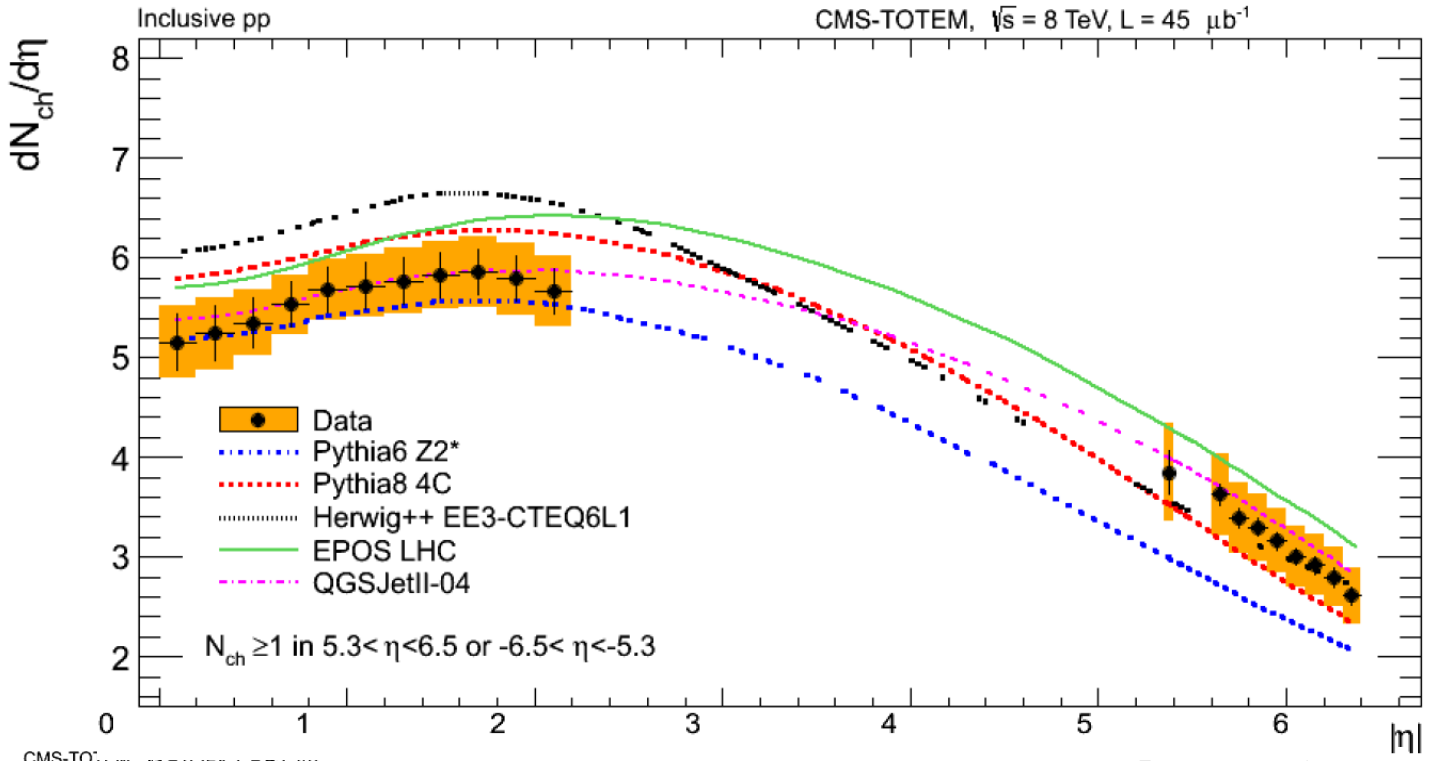
	Beam width @ vertex	Angular beam divergence	Min. reachable |t|
β* ~ 0.5-3.5 m	$\sigma^*_{x,y} = \sqrt{\frac{\varepsilon_n \beta^*}{\gamma}}$ small	$\sigma(\Theta^*_{x,y}) = \sqrt{\frac{\varepsilon_n}{\beta^* \gamma}}$ large	$\lvert t_{\min}\rvert = \frac{n_\sigma^2 p \varepsilon_n m_p}{\beta^*}$ ~ 0.3–1 GeV²
β* = 90 m	large	small	~ 10^{-2} GeV²

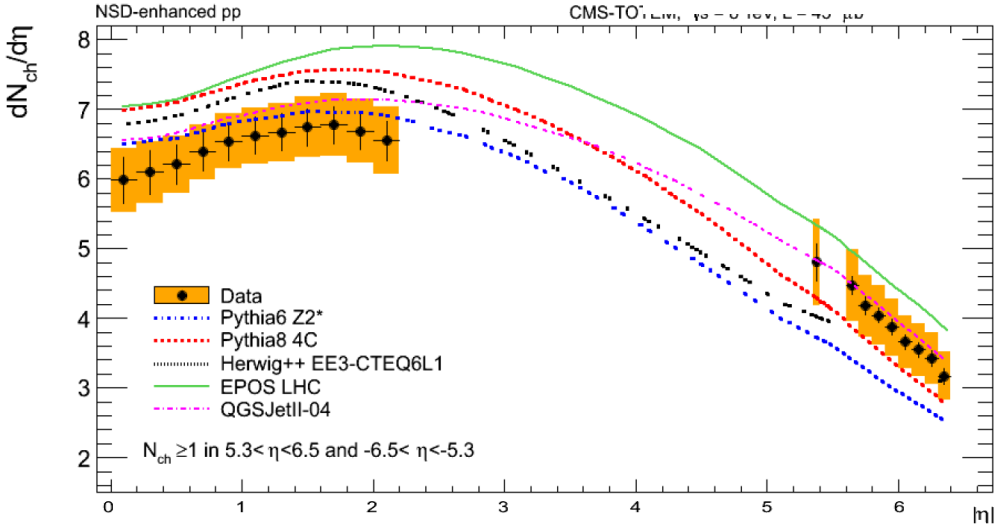
CMS-TOTEM Forward Charged Multiplicity

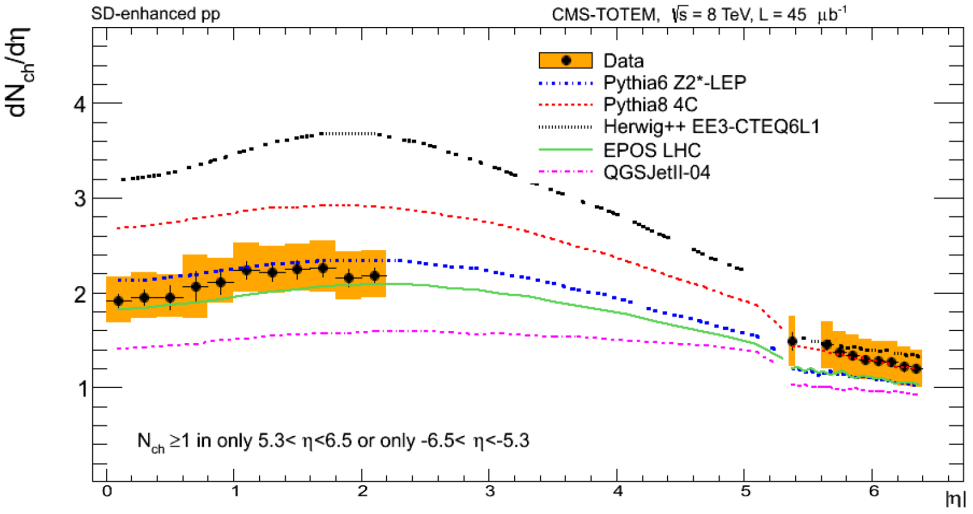
Mirko Berretti

Joint CMS-TOTEM
data taking / trigger

1st common paper
CMS-TOTEM
[EPJ]

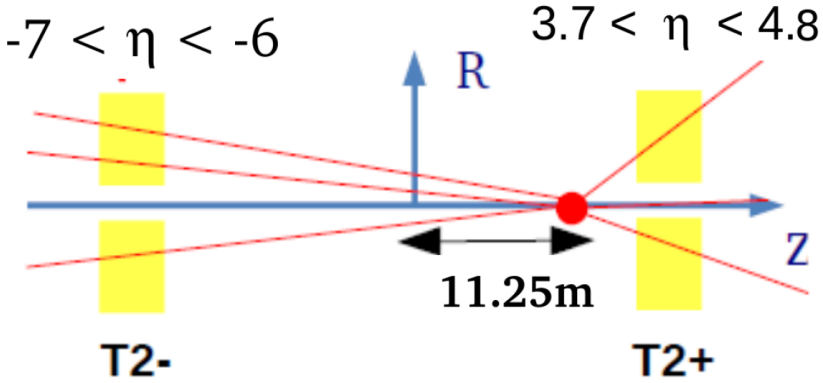


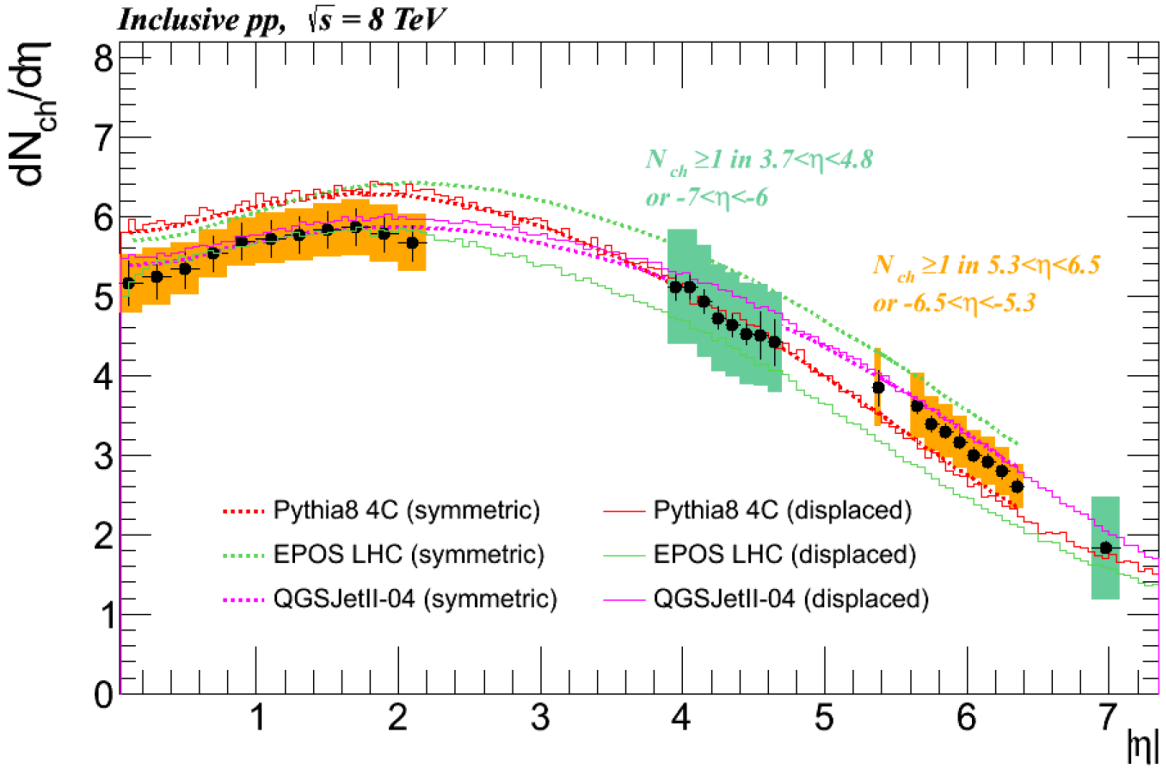




Extended-η Forward Charged Multiplicity

Mirko Berretti



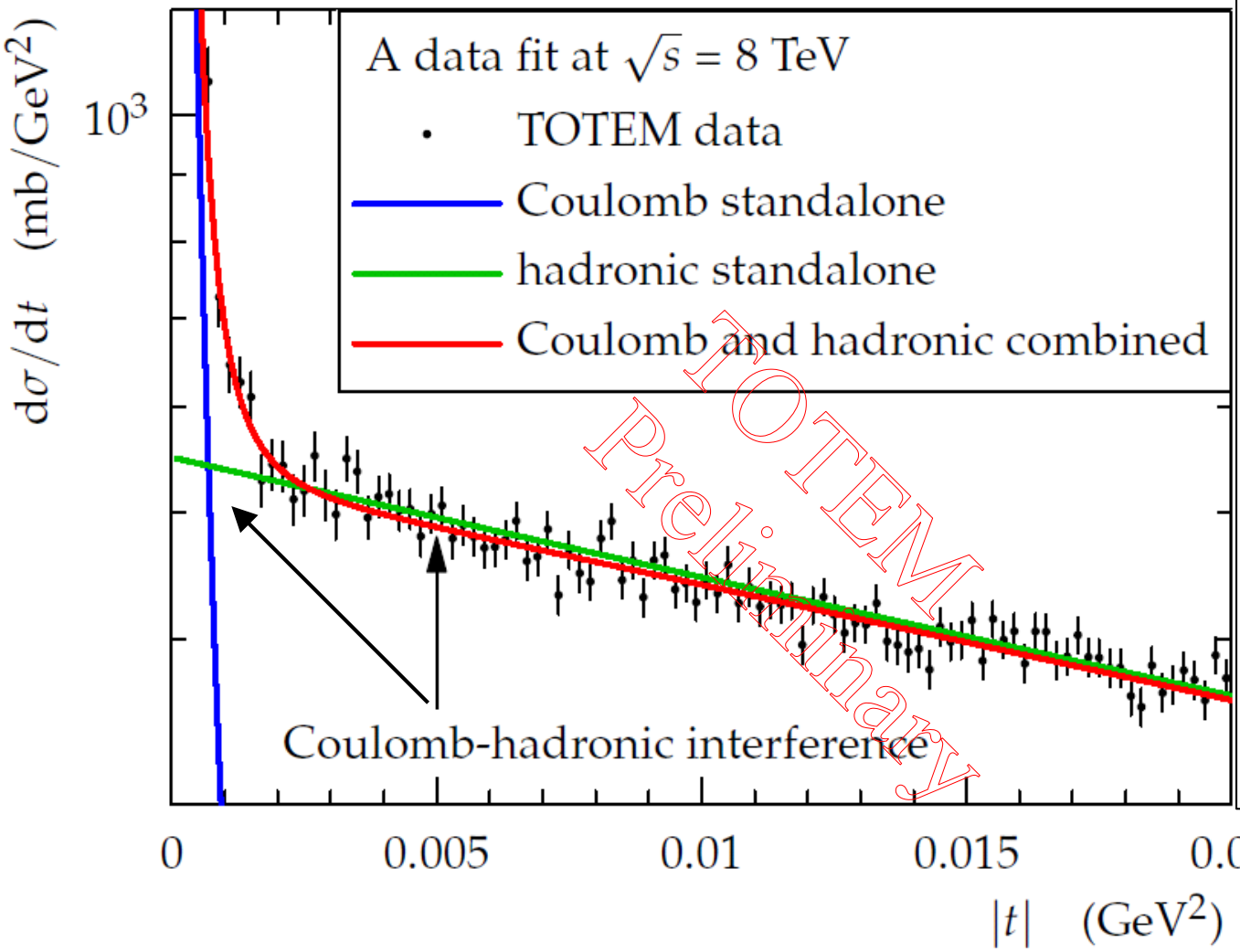


Coulomb-Nuclear Interference

Measure elastic scattering at **|t|** as low as **6 x 10^{-4} GeV^2**:

- $\beta^* = 1000$ m optics
- RP approach to 3 σ from the beam centre

$d\sigma / dt \propto |F^{C+h}|^2$ = Coulomb + interference + hadronic



Preliminary Results:

- First observation of not constant hadronic slope B in pp elastic scattering
- Simplified West-Yennie (SWY) interference formula ruled out by data
- Evidence of Coulomb-hadronic interference at $\sqrt{s}$ = 8 TeV
- TOTEM data exclude centrality of elastic scattering in the form it was derived via SWY formalism

MoU

CT-PPS

CMS-TOTEM : full diffractive physics programme and related new physics searches O(fb) at standard high LHC luminosity.

CMS-TOTEM joint-upgrade MoU signed
Institution Board & Management Team
Tracking detectors Si pixels in RPs
Timing detectors in new horizontal RPs
10 ps requirement for high pile-up LHC
TDR

Management Team

-Project Manager	Joao Varela
-Deputy PM	Nicola Turini
-Tech Coord	Joachim Baechler
-Deputy TC	Johnatan Hollar

CMS-TOTEM Memorandum of Understanding

between

The European Organization for Nuclear Research ('CERN'), an Intergovernmental Organization having its seat at Geneva, Switzerland, as the host laboratory,

and

The CMS Collaboration ('CMS"), for the purpose of signature of this MoU represented by the Spokesperson and the chairperson of the Collaboration Board;

and

The TOTEM Collaboration ('TOTEM'), for the purpose of signature of this MoU represented by the Spokesperson and the chairperson of the Collaboration Board;

Whereas:

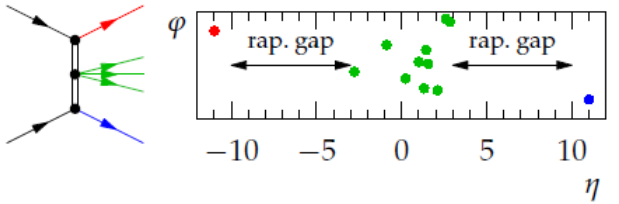
- CMS wants to integrate in the detector apparatus a new Proton Spectrometer at ~210m from the Interaction Point (IP) allowing proton tagging, with the aim of studying, during standard low β* running at high luminosity, low cross section Electroweak (EW) and QCD physics in Central Exclusive Processes (CEP). The CMS Collaboration Board (CB) has approved the physics motivations and detector concept, recognizing it as a potentially important part of the CMS physics programme.
- TOTEM, with its own detector apparatus and relative upgrades, will pursue the high cross section forward physics programme at 14 TeV in high β* special runs, which will be supported by CMS as common data-takings in terms of trigger and detector readout. Moreover, TOTEM is interested in studying low cross section EW and QCD physics in CEP processes with CMS.
- This common low cross-section physics programme implies new detectors in the same beam region ~210m.
- CMS and TOTEM are willing to combine efforts to commonly undertake the initial phase of the CEP low cross section physics programme through a Joint Project.
- The Joint Project is defined in this MoU.

Scope:

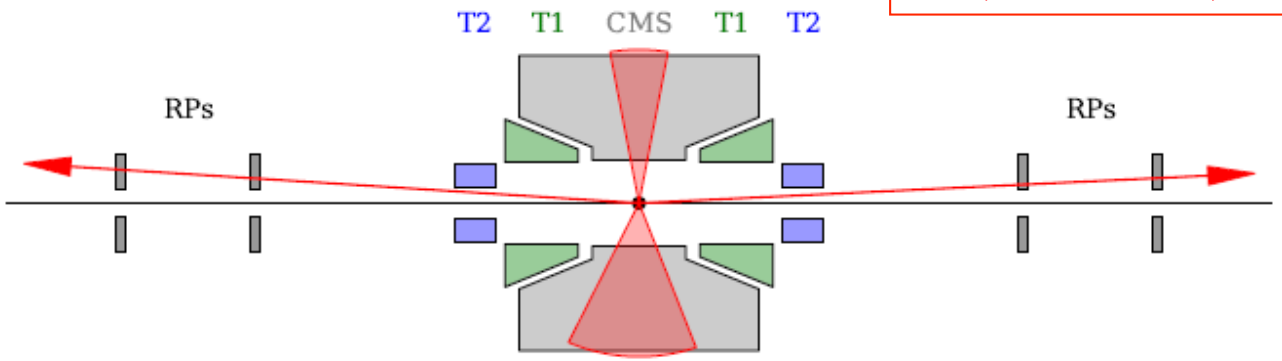
- This CMS-TOTEM MoU is valid for the initial phase and will be reviewed before Long Shutdown 2 (LS2).

Diffractive Physics Program LHC Run II

- TOTEM: standard measurement of elastic scattering
(from the largest to the smallest *t*)
and of the total and inelastic cross section at the new LHC energy
- TOTEM+CMS: physics search on low mass spectroscopy (1-3GeV)
  - gluonic states and glueball searches
  - diffractive χ_c production
- TOTEM+CMS: central-diffractive jet product
- TOTEM+CMS: missing/escaping mass

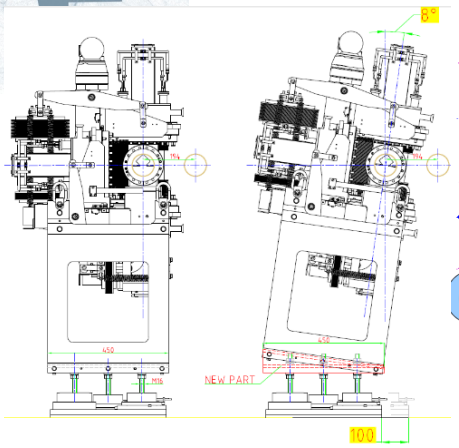


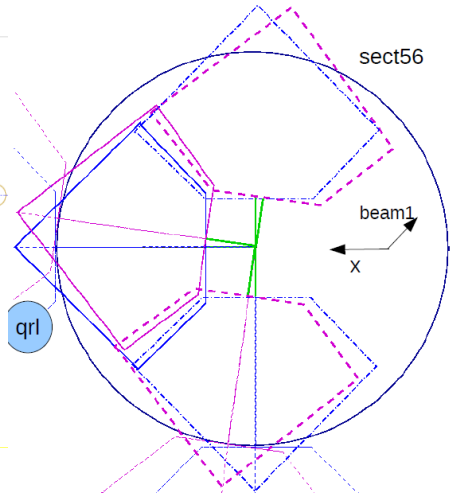
$$\Delta\eta_{1,2} = -\ln \xi_{1,2}, \quad M^2 = \xi_1 \xi_2 s$$

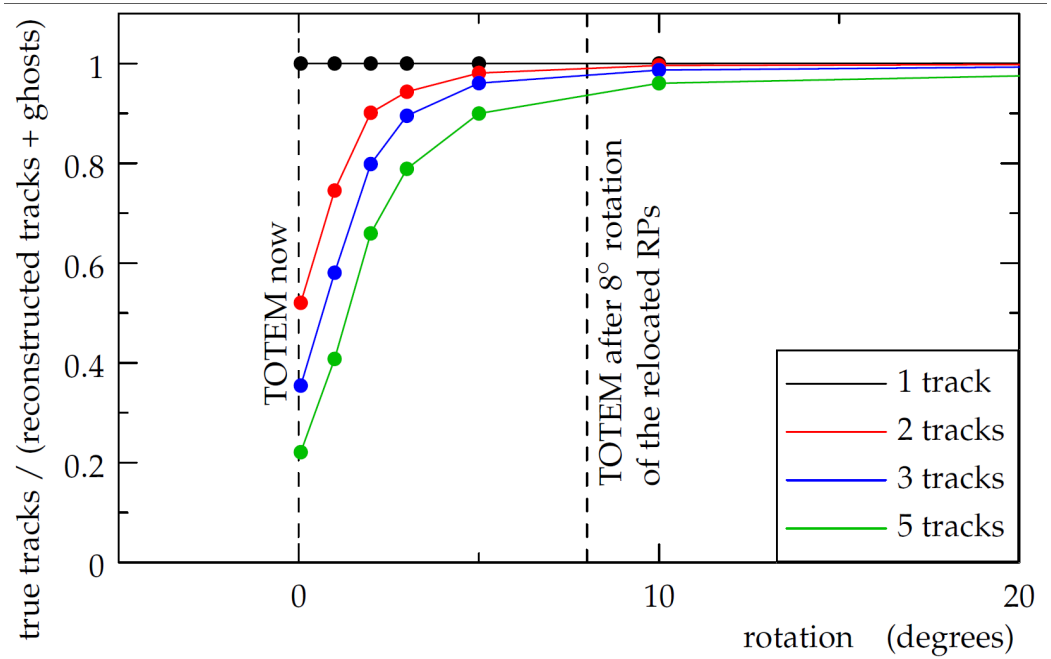


Preliminary investigation of some physics channels in progress with the analysis of data from joint CMS-TOTEM high β^* run (90m) , 8 TeV , July 2012

RPs Performance

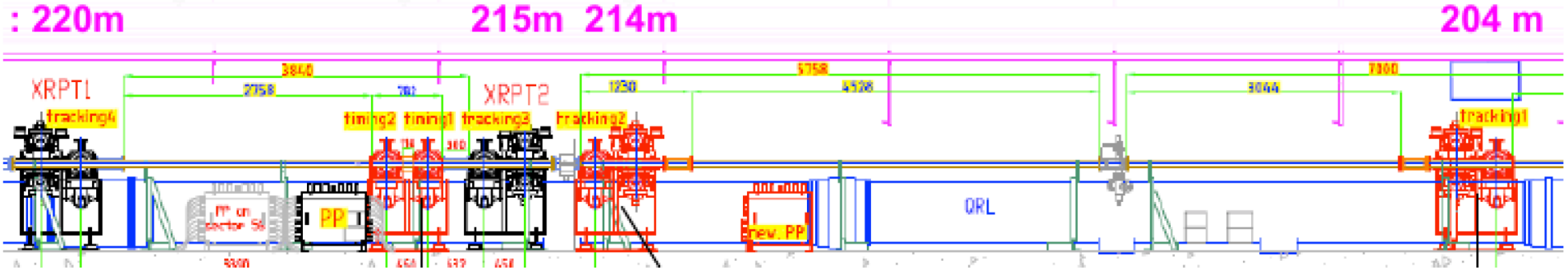




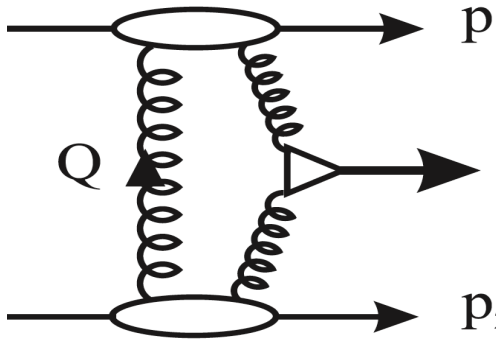


new layout:

- 147 m station relocated to 204 and 214 m (increased lever arm ⇒ better angular resolution)
- RPs at 214 m rotated by 8° ⇒ multi-track capability
- ≈ 216 m new two horizontal RPs for timing detectors (improved proton left–right correlation)



Central Exclusive Production (CEP)



p_1 (ξ_1) $M^2 = \xi_1 \xi_2 s$

X at rapidity y_X gg collider

p_2 (ξ_2) $y_X = \frac{1}{2} \ln \frac{\xi_1}{\xi_2}$

also $\gamma\gamma$ fusion & photoproduction

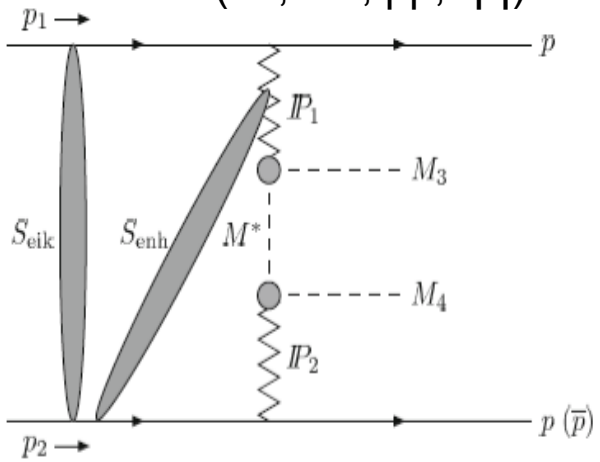
- exchange of colour singlets with vacuum quantum numbers
  $\Rightarrow$ selection rules for system X: $J^{PC} = 0^{++}, 2^{++}, \ldots$ resonances, jets,?….
- With double-arm proton detection:
  $\beta^* = 90$m runs: all M(pp), $\mu \sim$ **0.05 - 0.5** $\Rightarrow$ O(0.1-10 pb^{-1}/day)
  low β^* runs: M(pp) > ~ 350 GeV, μ **~ 30 - 50** $\Rightarrow$ O(1 fb^{-1}/day)
- Comparison/prediction from forward to central system:
- M(pp) =? M(central), $p_{T,z}$(pp) =? $p_{T,z}$(central), vertex(pp) =? vertex(central)
- Prediction of central particle flow topology from proton ξ's (rapidity gaps): $\Delta\eta_{1,2} = -\ln\xi_{1,2}$

- CMS & TOTEM common runs: access to O(pb) production cross-sections

CEP low-Mass States & Glueballs

LHC: a unique lab to study CEP low M states

X = low M resonance / meson pair
($\pi\pi$, KK, $\rho\rho$, $\eta\eta$)



- small p_T's of final state mesons ⇒ **CMS tracking** $\Delta M \sim 10$ MeV (<< ISR, RHIC, Tevatron)
- $\pi/K/p$ separation using CMS tracker dE/dx
- proton tagging in $\beta^* = 90$m runs ⇒ $p_T \sim 40$ MeV
- **RP proton tagging** ⇒ no need to invoke rapidity gaps
- large η coverage & protons ⇒ exclusivity ensured with excellent S/B
- spin determination from decay angles & proton azimuthal correlations

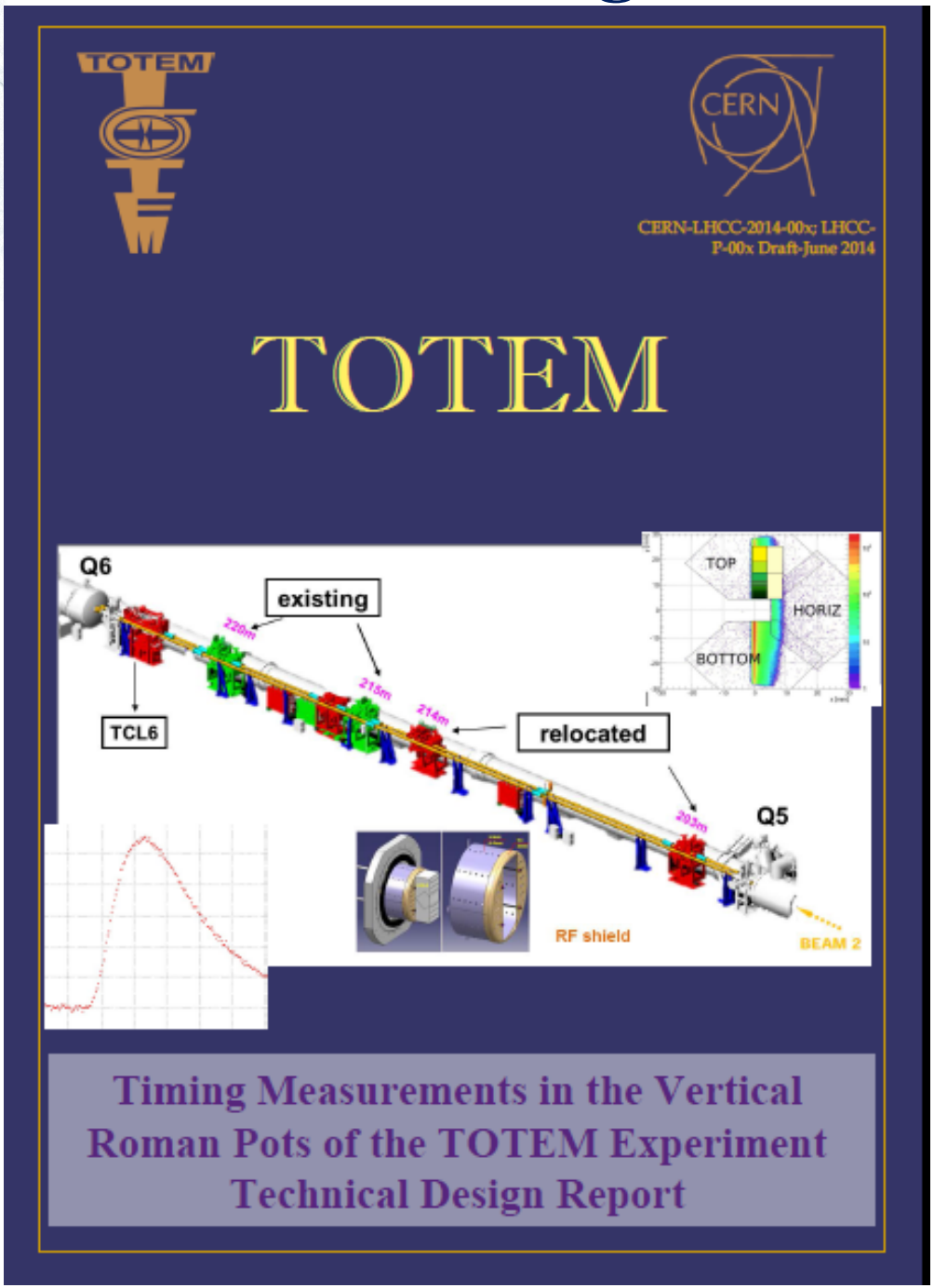
Small ξ **~10^{-3} 10^{-4} at LHC** from RP vertices ⇒ pure gluon pair ⇒ masses ~ 1-3 GeV

Pomeron ≈ colourless gluon pair/ladder

⇒ Pomeron fusion likely to produce glueballs

- Past luminosity: ~ 0.003 pb^{-1} ⇒ need × 300 (~ 1 pb^{-1}) to produce resonances
- Study of glueballs & χ_c in hadronic modes require × 3000 (~ 10 pb^{-1})
- Increase in integrated luminosity in high β runs may be obtained :
  - > Increasing bunch number~1000 (requires crossing angle for high β runs)
  - > Increasing beam intensity (from μ=0.05 to μ=0.5 or more > pileup suppression)

TDR – Timing Vertical RP Project



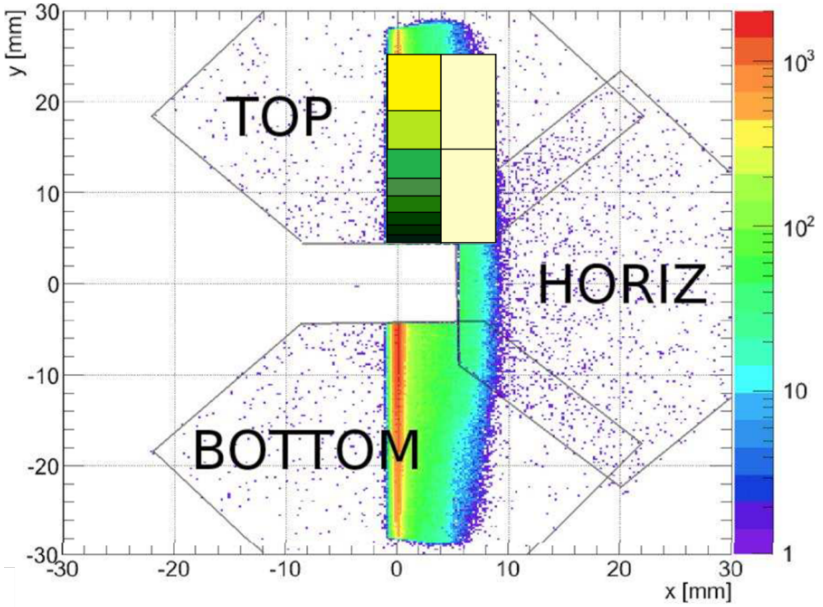
- Goal to use production technologies to implement it by end 2015
- Status and progress on TDR preparation
- Test beam campaigns during summer (PSI, PS, SPS)
- Delivery of TDR to LHCC in September 2014

Vertical RPs Timing Detectors

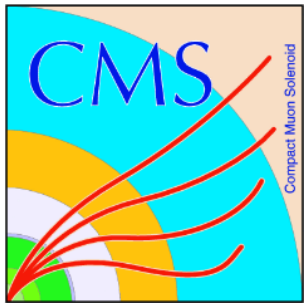
Optimization driven by physics and technical choices

- Minimize number of channels without compromising the physics program
  - Map plane with different size pads with same occupancy
  - Minimum number optimized with simulation

- Detector
  - Dimensions: 10mm X 20mm
  - 10 pixels with dimensions adapted to track density
  - A stack of 4 Planes improves the single plane timing resolution (1/2)
  - Available on the market is 5X10 mm and 10X10 mm, 500 μm thick
  - Diamond or Silicon



- Timing Specifications
  - Measure time of arrival of proton with a resolution better than 50ps



TDR – CTPPS Project

June 2, 2014

DRAFT
CMS-TOTEM Precision Proton Spectrometer
Technical Design Report

Abstract

Section	Editor
Overview	Joao Varela
Physics with the CMS-TOTEM Precision Proton Spectrometers	Mike Albrow, Ken Osterberg, Michele Arneodo
Strategy and Running Scenarios	Joachim Baechler, Mario Deile
Detector and physics performance	Michele Gallinaro, Valentina Avati
Moving Beam-Pipe	Jonathan Hollar
Roman Pots	Joachim Baechler
Silicon Sensors	Nicolo Cartiglia
Silicon Readout and Mechanical	Maurizio Lo Vetere
Fast Timing Cherenkov Detectors	Mike Albrow
Fast Timing Silicon Detectors	Nicola Turini
Fast Timing Electronics	Joao Varela
Reference Timing System	Doug Wright, Nicola Turini
Trigger Strategy	Nicola Turini
Organization, Cost, Schedule	Doug Wright, Joachim Baechler

Totem Pisa/Siena in 2015

- R&D on diamond timing detectors
  - R&D started in 2014 (4 test beam periods)
- Development of a full detector (1 plane) to be installed for tests in the winter shut-down 2015-2016
  - Preamplifier
  - TDC/Sampler (to be defined this year)
- Reference clock on detector side (Bari responsible for source side)

Richieste per servizi

- Nessuna richiesta per officina meccanica
- Supporto ingegneristico per lo sviluppo dell'elettronica di front-end del timing detector.
  - Supporto per lo sviluppo delle mother boards e ibridi. (2/3MU ingegnere elettronico)
  - Supporto per eventuale bonding dei detectors sugli ibridi (da quantificare, ma minimo)

Composizione del gruppo

	%		
Berretti	100		*Fellow*
Bossini	100		*Dottorando*
Bottigli	50		*P.O.*
Lami	50		*Primo Ricercatore*
Latino	70		*Assegnista*
Losurdo L.	100		*Dottorando*
Sanguinetti	0		*Primo RIcercatore*
Scribano	0		*P.O.*
Turini	100		*Ricercatore Universitario*
Cecchi	50		*Tecnologo*
Magazzù G.	30		*Tecnologo*
Spinella	10?		*Tecnologo*

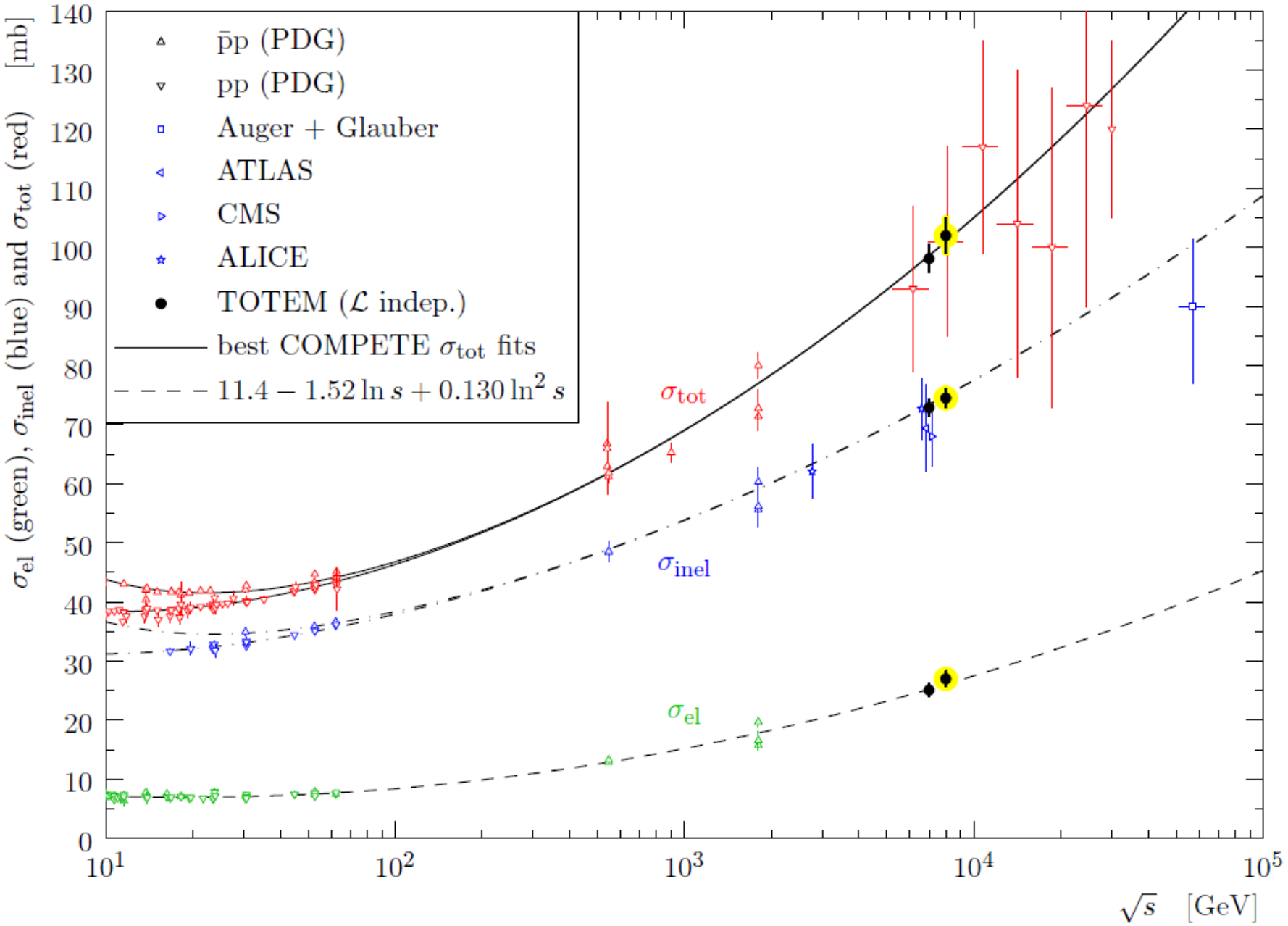
5.7 FTE Ricercatori
0.90 FTE Tecnologi

Preventivi di spesa 2015

Capitolo	Descrizione	Richiesta	SJ	Totale
MISSIONI	*Contatti Pi-Ge-Ba-Referee*	6		
	Riunioni al CERN (4MU)	16		
	Responsabilità Chairman CB (2MU)	8		
	Responsabilità Deputy SP/Deputy PM CT-pps (5MU)	20		
	Commissioning T2 (1MU)	8		
	Analisi dati (2MU)	8		
	TB R&D Timing (3MU) istallazione Ck Ref.	12		**78**
CONSUMI	*Metabolismo in sede e al CERN* *Test Beams*	15		**15**
APPARATI	7K Layout 3K maschere 1K produzione (ottimistico) 25K mother board	36		
	19K receivers ottici 7K accessori	26		**62**
	TOTALE TOTEM Pisa	Keuro		**155**

Backup

Elastic, Inelastic, Total Cross-Sections [8TeV]

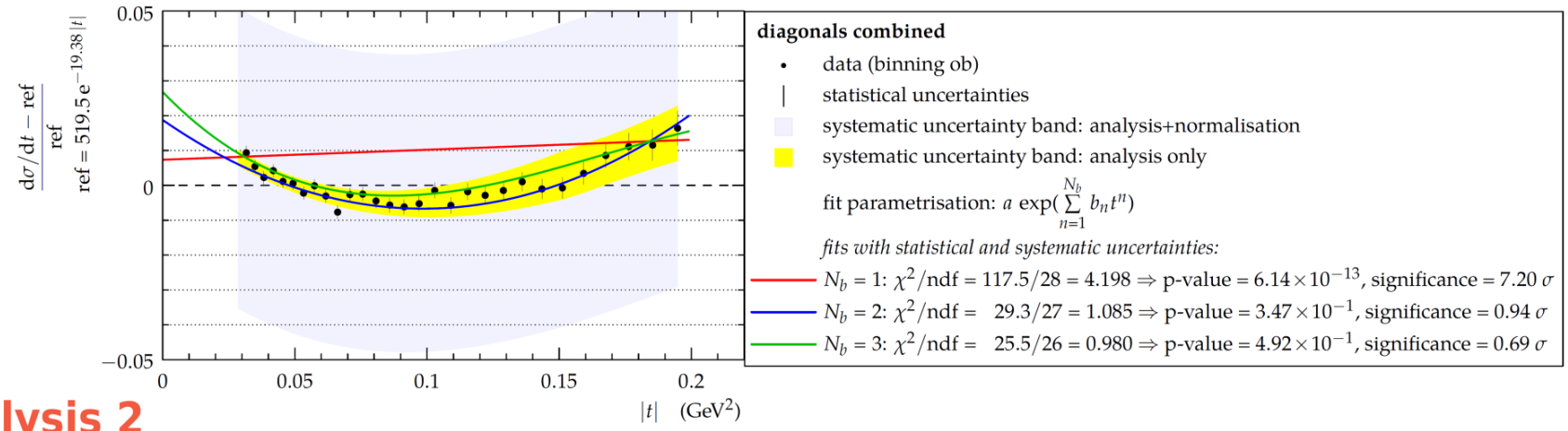


Non-perturbative QCD of Elastic Scattering

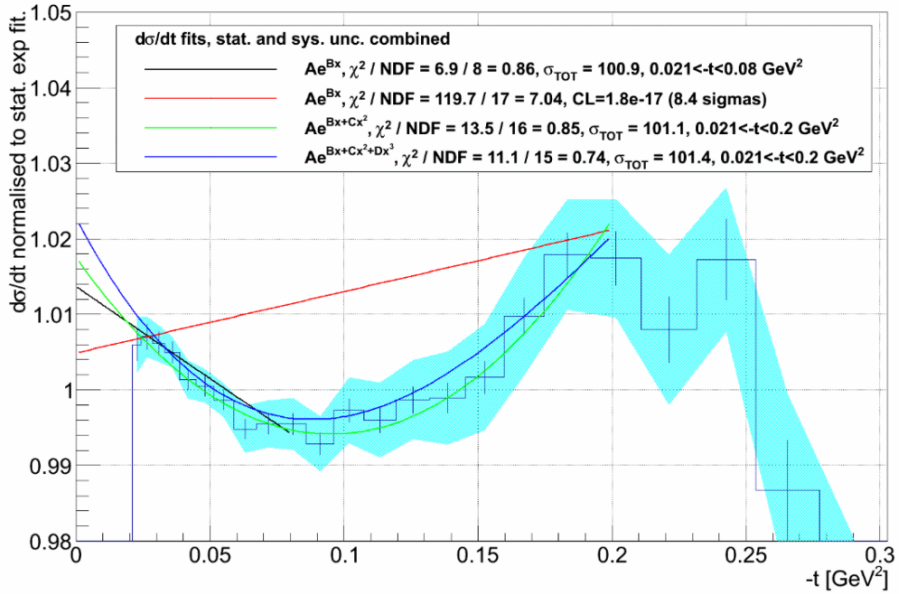
From Pomerons to diquark-quark models to coherent amplitudes of gluon exchange between fermionic lines

Analysis 1: fits $A\exp(b_1 t + b_2 t^2 + \ldots)$, N_b parameters in exponent

DS4



Analysis 2



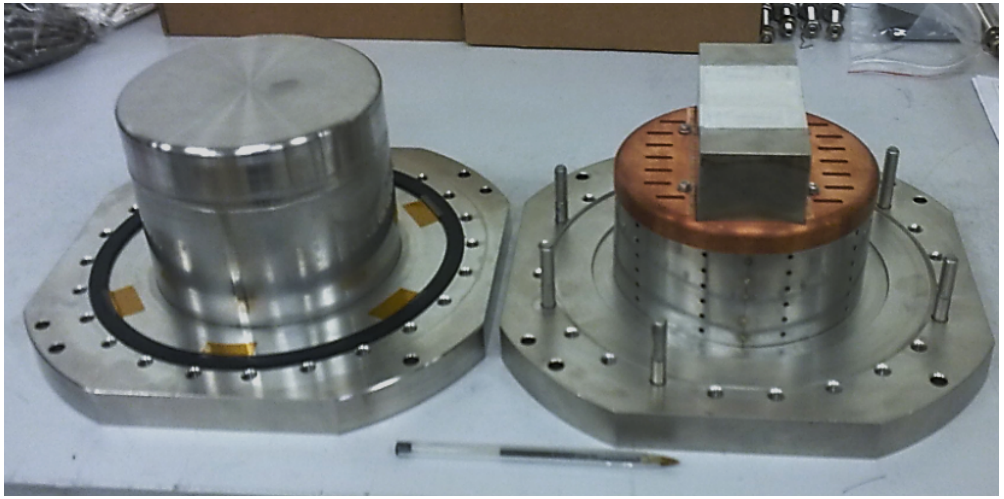
⇓

purely exponential fit excluded at more than 7σ significance

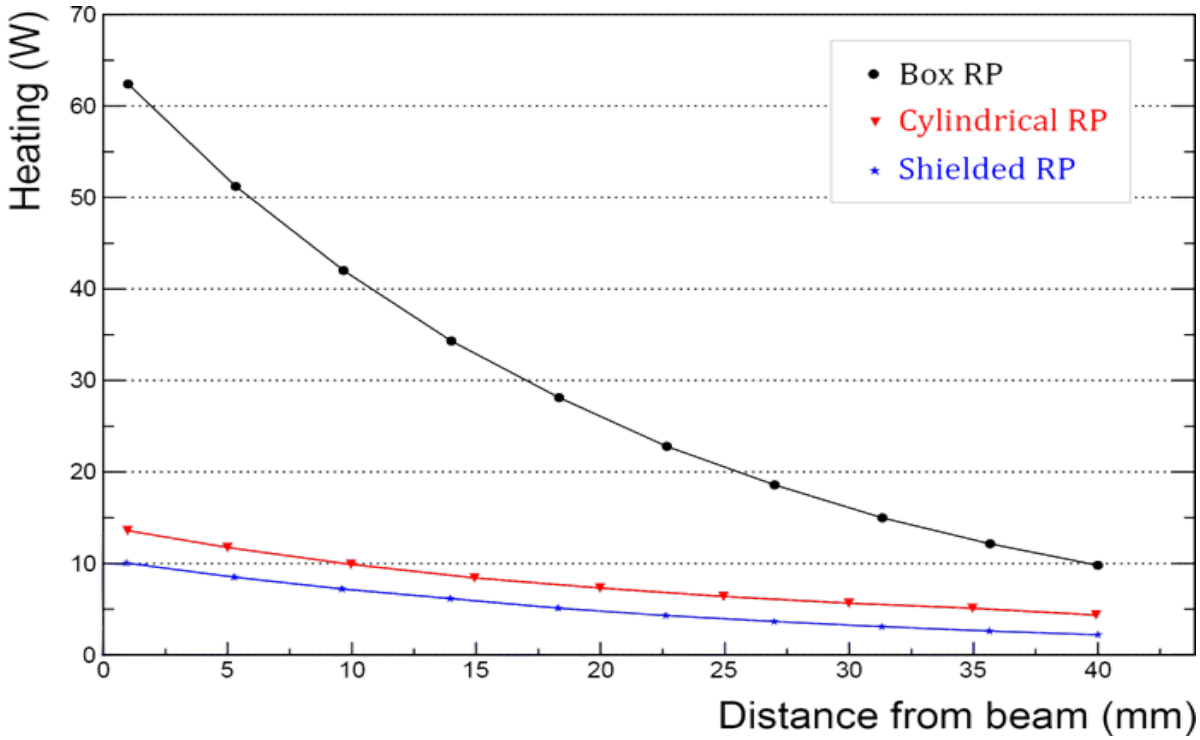
new determination
σ_{tot} = (101.4± 2.0) mb

study amplitudes and central vs peripheral phase of nuclear elastic scattering

RPs Safety



RF studies (impact on machine),
RF shield for square pots of Run I,
New ferrites to control induced RF,
New Pots cylindrical with thin window



50 ns
I_B=0.6 A

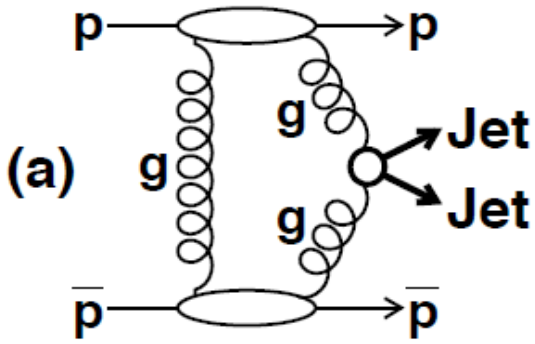
CEP Jets

$$pp \rightarrow p + \text{dijet} + p$$

- $J_z = 0$ selection rule: $g\bar{g} \not\rightarrow q\bar{q}, b\bar{b}$ suppressed by a factor 10^2-10^3
- CEP dijets: unique possibility to observe enhanced gluon jets at LHC
  ⇒ clean probe of properties of gluon jets (multiplicity, particle correlations...).
- cross-sections extremely sensitive to important & subtle QCD effects:
  - generalized gluon PDFs, rapidity gap survival probabilities, "Sudakov" factors.

- test model predictions:
  study proton azimuthal correlations & CEP 3-jet topologies
  Durham model: $gg \not\rightarrow gq\bar{q}$ (more Mercedes-like) & $gg \rightarrow ggg$ ("more back-to-back").

Durham group (KHARYS MC)

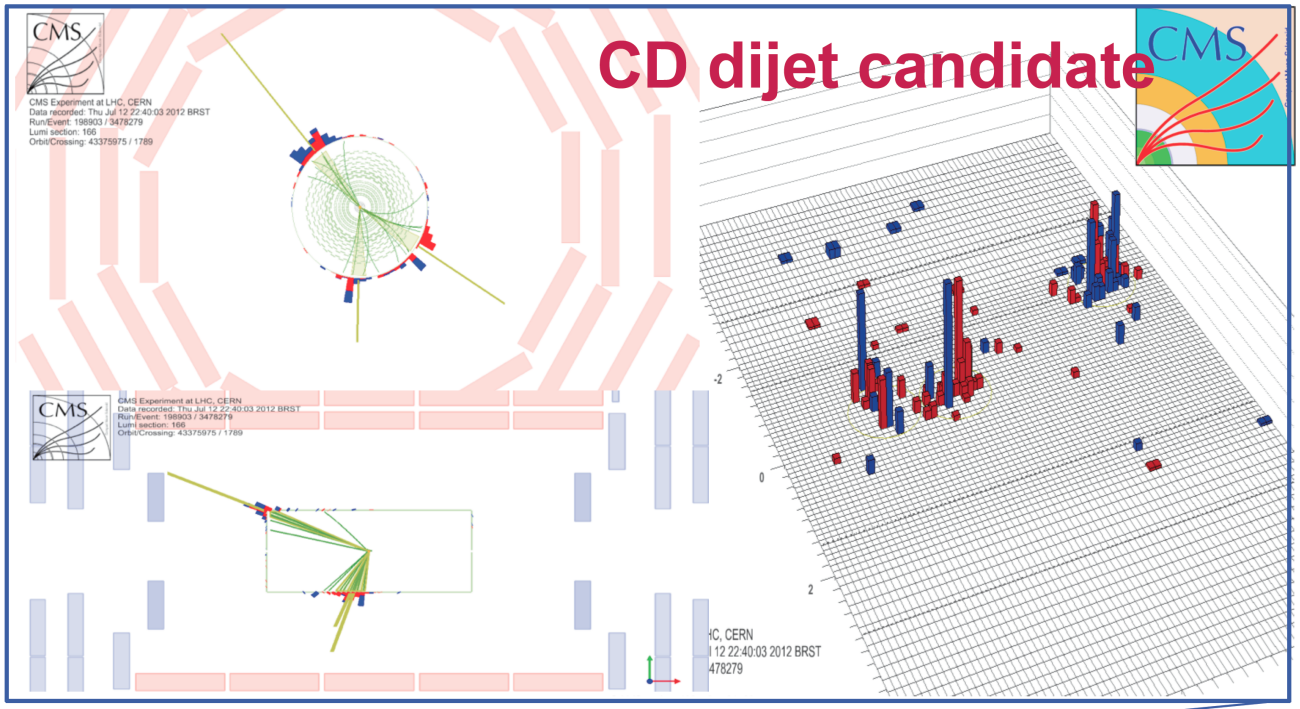


Predictions for CMS-TOTEM selection:

Central: $|\eta_j| < 4.4$, $|p_\perp^j| > 30$ GeV (jets)
Protons: $|p_\perp^y| > 0.1$ GeV, $p_{1\perp}^y * p_{2\perp}^y > 0$
$\Rightarrow \sigma(gg) \approx 100$ pb

Past luminosity: ~ 0.1 pb^{-1} ⇒ need × 1000 (~ 100 pb^{-1}) for sufficient statistics (~ 10k)

CMS-TOTEM di-Jets Analysis



CMS + TOTEM 90m β*
Run/Event 198903/3478279
Jets E_T = 65,45,27 GeV
ξ+
MM(pp) = 244 GeV; M(CMS) = 219 GeV
Σp_T(CMS) = 3.4 GeV
FSC empty both sides

M(pp) = 244 GeV ≈ M(central)
ξ_1 = 0.1 ξ_2= 0.01