The TOTEM experiment at the LHC

Stato dell'esperimento

Attivita` di Pisa/Siena

Composizione Gruppo

Richieste 2013

Stefano Lami

on behalf of the
TOTEM PISA/SIENA Group

TOTEM misura la σ_{TOT} (*pp*) a LHC misurando rate elastico e inelastico e sfruttando il Teorema Ottico (in run speciali con ottica dedicata):

$$\sigma_{TOT}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \left.\frac{d\sigma_{EL}}{dt}\right|_{t=0}$$

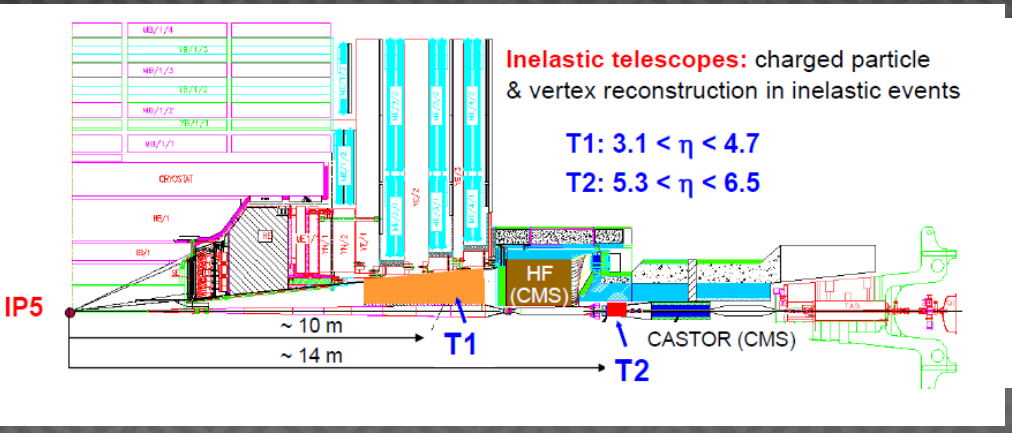
Using luminosity from CMS

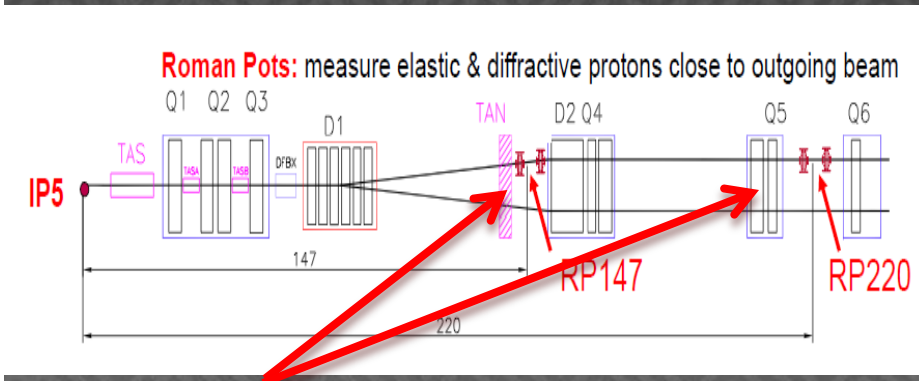
$$\frac{d\sigma_{EL}}{dt} = \frac{1}{L} \bullet \frac{dN_{EL}}{dt}$$

$$\sigma_{TOT} = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \frac{\left.\frac{dN_{EL}}{dt}\right|_{t=0}}{N_{EL}+N_{INEL}}$$

Luminosity independent

ρ parameter from Compete fit





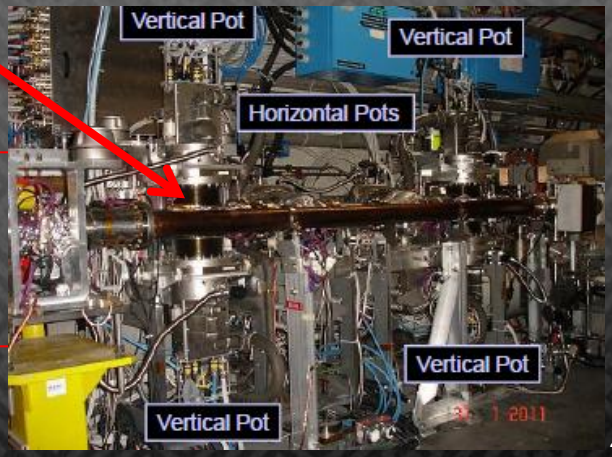
Protons are transported in LHC beam-pipe from IP 5 to the Roman Pot stations

T1
5 planes of CSC Chambers (wire & cathode strips

T2
10 planes of GEM Chambers (pads&strips)

- ❑ T1 & T2 integrated in CMS
- ❑ Roman Pot integrated in LHC

Roman Pot: detector enters inside the LHC beam tube



- **TOTEM ha pubblicato a $\sqrt{s}$ = 7 TeV** :

1) scattering elastico (dati 2010) ***EPL 95 (2011) 41001***,
2) sezione d'urto totale p-p (dati 6/2011) ***EPL 96 (2011) 21002,***
3) forward charged particle pseudorapidity density (dati 5/2011) ***EPL 98 (2012) 31002***

- ***Dal run speciale a β^*=90m di Ottobre 2011*** *(RPs a $4.8\sigma_{beam}$)* ***sono in preparazione 3 pubblicazioni:***

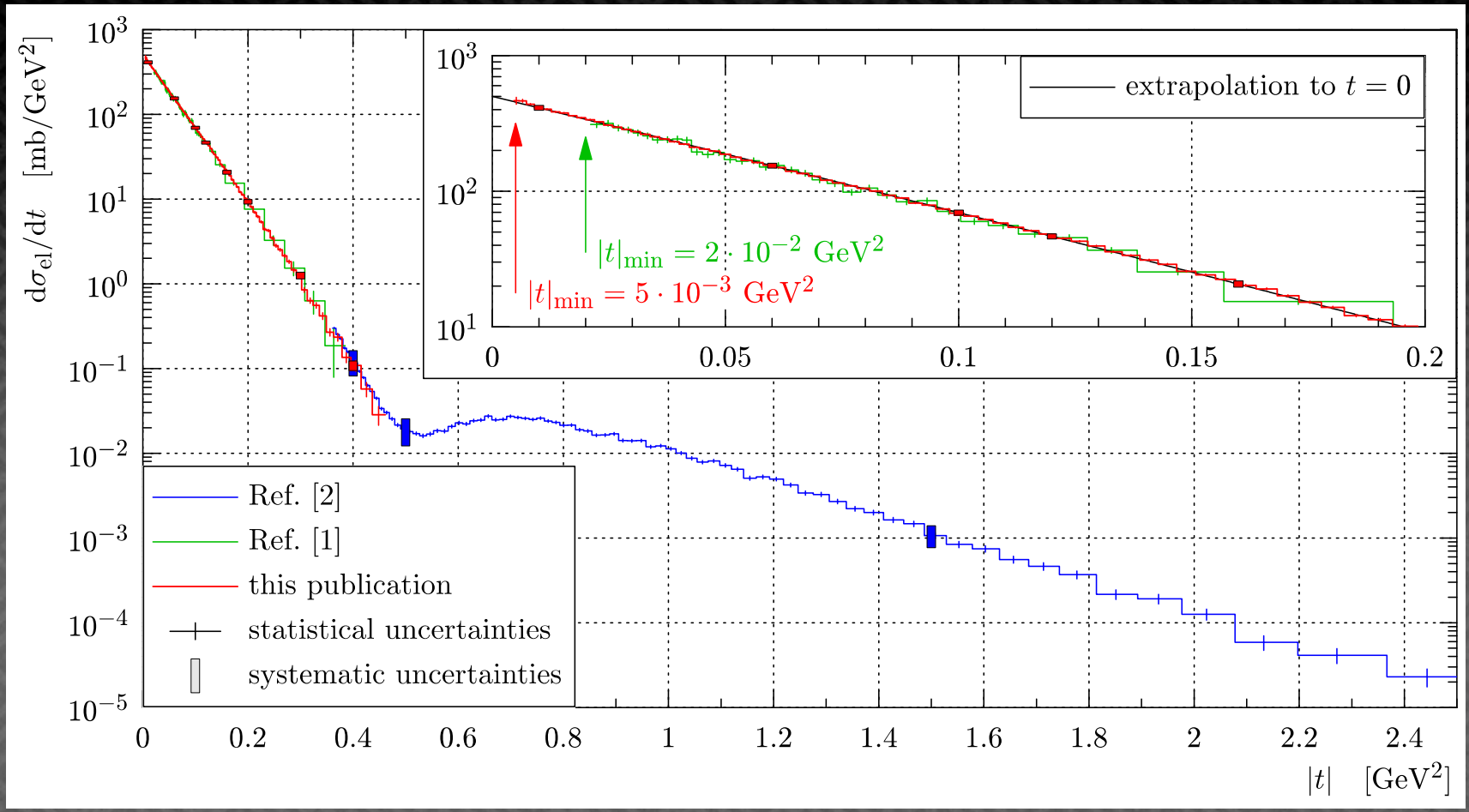
P1. Measurement of proton-proton elastic scattering and total cross-section

New elastic differential cross-section measurement down to t-values of $5\ 10^{-3}$ GeV^2

Compared to our previous publication EPL96:

– 15 x higher statistics

– $|t|_{min} \sim 5\ 10^{-3}$ GeV^2 ⇨ 91% of cross-section observed (only 67% before)



σ_{tot} = 98.6 mb + 2.5 – 2.2 mb

σ_{el} = 25.43 mb 1.1 mb

σ_{Inel} = 73.2 mb + 2.4 – 2.1 mb

$d\sigma_{el} / dt$ (at t=0) = 506.4 23 mb/GeV^2 B = 19.89 0.05

P2. Measurement of the inelastic pp cross-section

Tracks in both arms: *Non-diffractive minimum bias & double diffraction*
Tracks in one arm: *Mainly single diffraction with $M_X > 3.4\ GeV/c^2$*

After corrections for trigger efficiency (2.3%), track reconstruction efficiency (1%), beam-gas bkgd (0.5%), pile-up (1.5%):

$\sigma_{\text{inelastic, T2 visible}}$ = 69.7 0.1 (stat) 0.7 (syst) 2.8 (lumi) mb

$\sigma_{\text{inelastic, T2 visible}} \Rightarrow \sigma_{\text{inelastic, }|\eta|<6.5}$

After corrections for non visible events (Tracks in T1 & T2 empty), Rapidity gap covering T2:

$\sigma_{\text{inelastic},|\eta|<6.5}$ = 71.0 0.1 (stat) 0.7 (syst) 2.8 (lumi) mb

$\sigma_{\text{inelastic, }|\eta|<6.5} \Rightarrow \sigma_{\text{inelastic}}$

Several models studied, correction for low mass diffraction based on QGSJET-II-4 ~ 3.7% 2% (syst), imposing observed 2hemisphere/1hemisphere event ratio & taking into account seen "secondaries"

$\sigma_{\text{inelastic}}$ = 73.7 0.1 (stat) 1.7 (syst) 2.9 (lumi) mb

P3. Luminosity-independent measurements of total, elastic and inelastic cross-sections

Complementary measurements:

- to control and reduce systematic effects
- to remove dependence on luminosity
- to remove dependence on the ρ parameter

Proton-Proton Cross-Sections @LHC: 4 Methods

1. **Low_L(CMS) + Elastic + Optical T.**

$$\sigma_{TOT}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \left.\frac{d\sigma_{EL}}{dt}\right|_{t=0}$$

depends on CMS luminosity for low-L bunches & elastic efficiencies & ρ

2. **High_L(CMS) + Elastic + Optical T.**

$$\sigma_{TOT}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \left.\frac{d\sigma_{EL}}{dt}\right|_{t=0}$$

- checks the CMS luminosity for high-L vs low-L bunches

3. **High_L(CMS) + Elastic + Inelastic**

$$\sigma_{TOT} = \sigma_{EL} + \sigma_{INEL}$$

- minimizes dependence on elastic efficiencies and no dependence on ρ

4. **(L-independent) + Elastic + Inelastic + Optical T.**

$$\sigma_{TOT} = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \frac{\left.\frac{dN_{EL}}{dt}\right|_{t=0}}{N_{EL}+N_{INEL}}$$

- eliminates dependence on luminosity

Total Cross-Section

Published EPL96

σ_{TOT} = 98.3 mb $^{2.2}_{2.0}$ mb

$$\sigma_{TOT}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \left.\frac{d\sigma_{EL}}{dt}\right|_{t=0}$$

σ_{TOT} = 98.6 mb $^{2.5}_{2.2}$ mb

$$\sigma_{TOT}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \left.\frac{d\sigma_{EL}}{dt}\right|_{t=0}$$

σ_{TOT} = 99.1 mb 4.3 mb

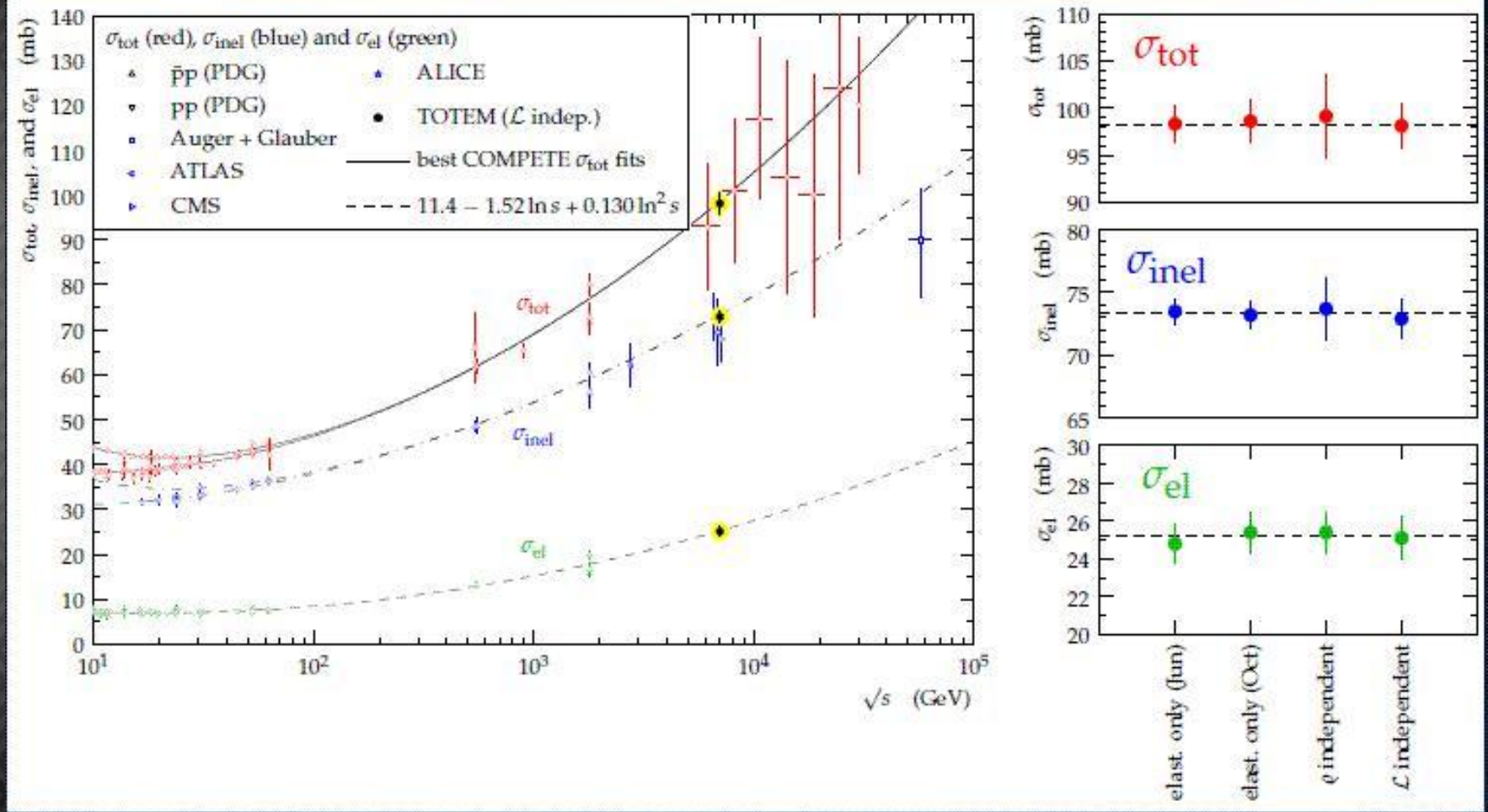
$$\sigma_{TOT} = \sigma_{EL} + \sigma_{INEL}$$

σ_{TOT} = 98.1 mb $^{2.7}_{2.2}$ mb

$$\sigma_{TOT} = \frac{16\pi(\hbar c)^2}{1+\rho^2} \cdot \frac{\left.\frac{dN_{EL}}{dt}\right|_{t=0}}{N_{EL}+N_{INEL}}$$

4 Methods for Cross-Section

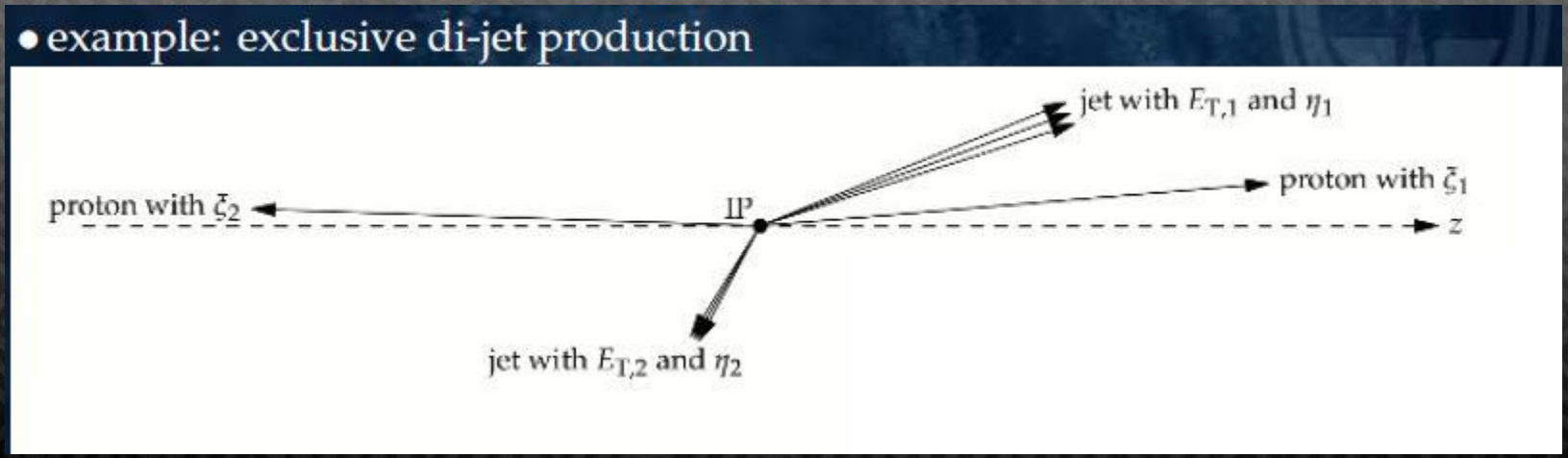
perfect consistency among all 4 cross-section determinations



low uncertainty ⇒ important for extrapolations

Presa dati CMS+TOTEM

- Aprile 2012: Engineering Run (Allineamento RPs) - Trigger CMS<>TOTEM - **Sincronizzazione Dati OK**
- Maggio 2012: **Run basso pile-up, 8M eventi** (RPs non inserite), **scambio di triggers**: TOTEM -> CMS: trigger menu -> TOTEM , entrambi gli esperimenti **hanno registrato gli stessi eventi**. Analisi in corso.
- CMS trigger con RPs ora possibile grazie a nuovo trigger elettrico (entro latency L1 CMS) + grande copertura CMS+T1+T2 (- 6.5 < η < +6.5)
  - $dN_{ch}/d\eta$ su completo range con stesso min. bias trigger
  - sezione d'urto inelastica
  - rapidity gap
  - jets – underlying event – energy flow nella regione in avanti
  - central, single diffraction: trigger – CMS jets + TOTEM RPs: 1 o 2 protoni



Presa dati 2012

Special run at $\beta^* = 90$ m, 156 bunches

- CMS + TOTEM T1, T2 and Roman Pots = very large acceptance
- proton acceptance: $|t| \gtrsim 0.02\ \mathrm{GeV}^2$, any ξ
- soft and medium-hard diffraction, elastic and total cross-section
- expected early July

Standard runs at $\beta^* = 0.6$ m, ≈ 1400 bunches

- TOTEM Roman Pots + CMS
- proton acceptance: $\xi \gtrsim 2 - 3\%$, any t
- high luminosity $\Rightarrow$ high masses accessible

Special run at $\beta^* =$ 1 Km , low luminosity

- low-$|t|$ elastic scattering
- determination of ϱ

TOTEM Upgrade Scenarios

RP Detector Upgrade Baseline and Beyond

Low luminosity physics programme @14TeV >> use current RPs + spares + swap 220 vs 147

TOTEM-CMS joint programme @14TeV >> develop common RP upgrade

Physics requirement	Detector performance	Baseline solution
Multi p+ reconstruction	>> RP 3 coordinates	>> Si-pixels
Pile-up / vertex	>> RP timing	>> Si-plane
High luminosity / stat	>> RP radiation hardness	>> Si-3D

T1 Detector Upgrade Baseline

Low luminosity physics programme @14TeV >> keep T1 as useful tracker for CMS calorimeter

T2 Detector Upgrade Baseline and Beyond

Low luminosity physics programme @14TeV >> Consolidate current T2:

New simplified 11-th card, transmitter board, new cables/connectors (~8% dead DAQ/trigger signals)

New HV divider

Full physics programme @14TeV >> Timing sensor planes inserted to reconstruct and tag CMS vertices to disentangle pile-up + faster tracking (add CF4 + reduce drift time)

DAQ Consolidation

Full physics programme @14TeV >> see Bari slides…

Towards a CMS – TOTEM Upgrade synergy

From: Joseph Incandela
Sent: 09 August 2012 12:07
To: Simone Giani
Subject: Collaboration with CMS

Dear Simone,

CMS is interested in developing a program of forward physics at high luminosities, with measurement of the scattered protons initially in the warm region of the machine, downstream of TOTEM, and later around 420m from the interaction point. Among the final physics goals is the characterization of the Higgs boson via central exclusive production.

We are developing a design for the High Precision Spectrometer (HPS), with the aim of making tracking and timing measurements of scattered protons at approximately +-240m of the interaction point and later, after LS2, at +-420m.

We are interested in discussing with TOTEM whether a joint effort could be a better option to develop the technical capability and the physics program in the +-220-240m region, combining the impressive apparatus and expertise developed by TOTEM with our ideas for timing and tracking detectors and the related mechanics. This would avoid duplication of hardware, would minimize costs, and would enlarge the community of physicists interested in "forward" physics in both CMS and TOTEM.

If you agree, we could initiate a study in the next few weeks to determine what a joint effort might entail; what developments steps would be needed, and how CMS and TOTEM could work together. The goal of this study would be to prepare a technical proposal to both collaborations by the fall to (a) describe the physics program which would be achievable in the period between LS1 and LS2, and (b) demonstrate the necessary technical developments.

Following consideration of this technical proposal, if approved, CMS and TOTEM could then discuss a formal agreement on carrying out the program jointly. This must be completed in time to allow critical installation, particularly affecting the LHC vacuum pipe, during LS1.

I look forward to hearing from you.
Best regards,
Joe

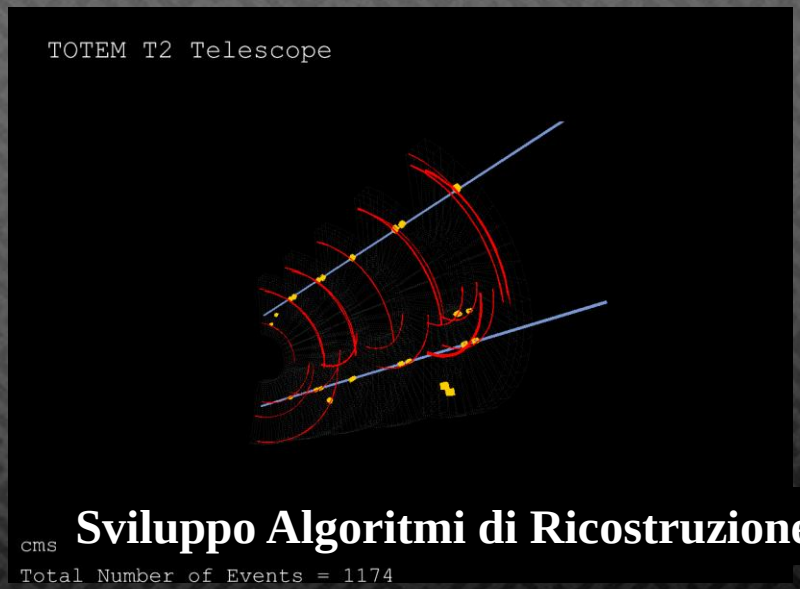
Contributo TOTEM Pisa/Siena

Responsabilita` del gruppo:

Chairman Collaboration Board: Angelo Scribano
Deputy Spokesperson: Stefano Lami
Responsabile Trigger: Nicola Turini
Responsabile T2: Eraldo Oliveri

R&D Rivelatori GEM
Progetto e realizzazione Elettronica T2

Installazione e messa a punto T2

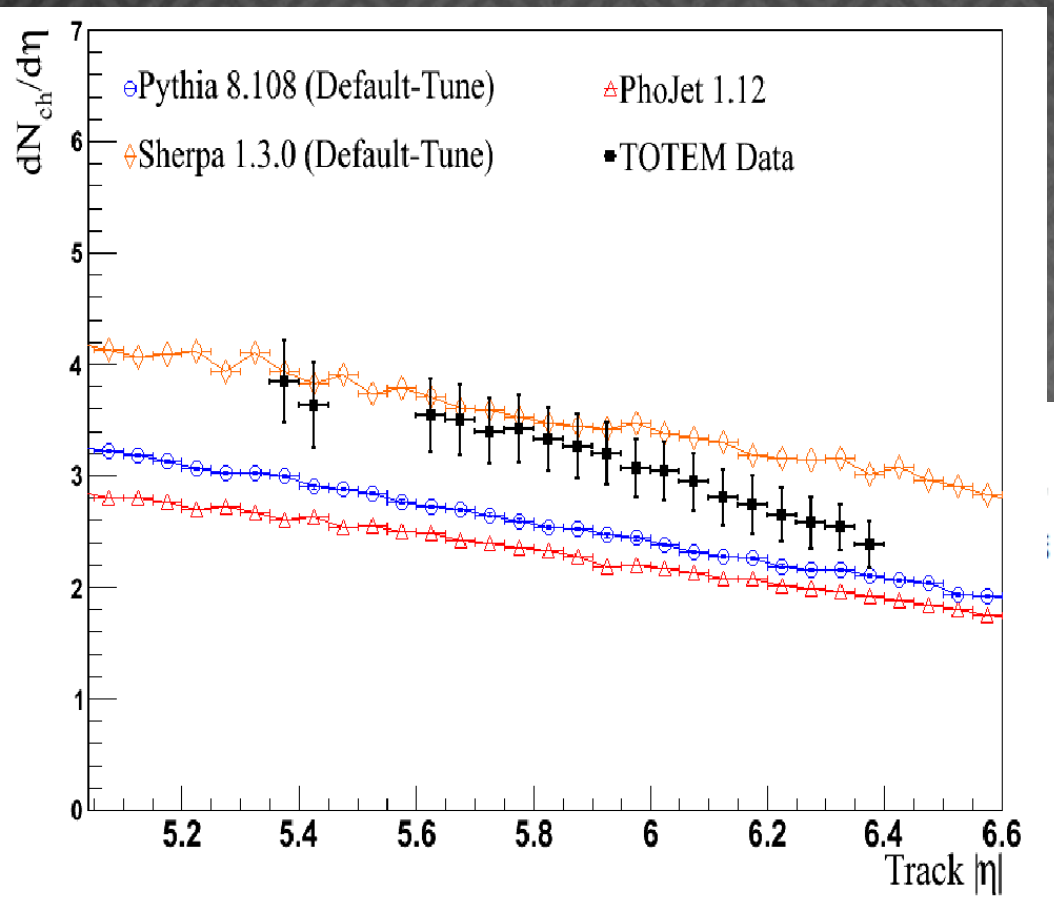


Sviluppo Algoritmi di Ricostruzione

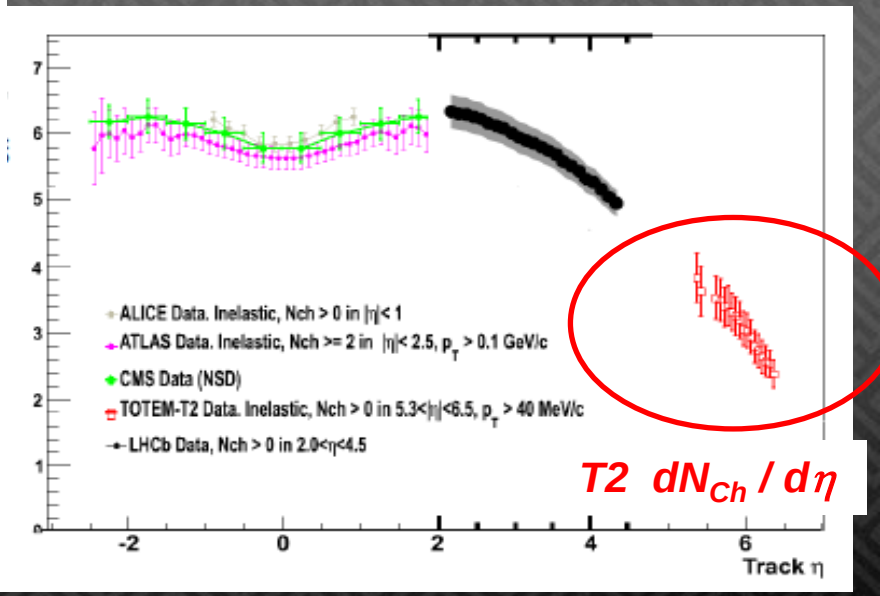
Commissioning, allineamento, analisi dati di T2

Measurement of the forward charged particle pseudorapidity density in pp collisions at √s = 7 TeV with the TOTEM experiment, ***EPL 98 (2012) 31002*** *CERN-PH-EP-2012-106;*

Autori: Mirko Berretti (tesi dottorato), Giuseppe Latino

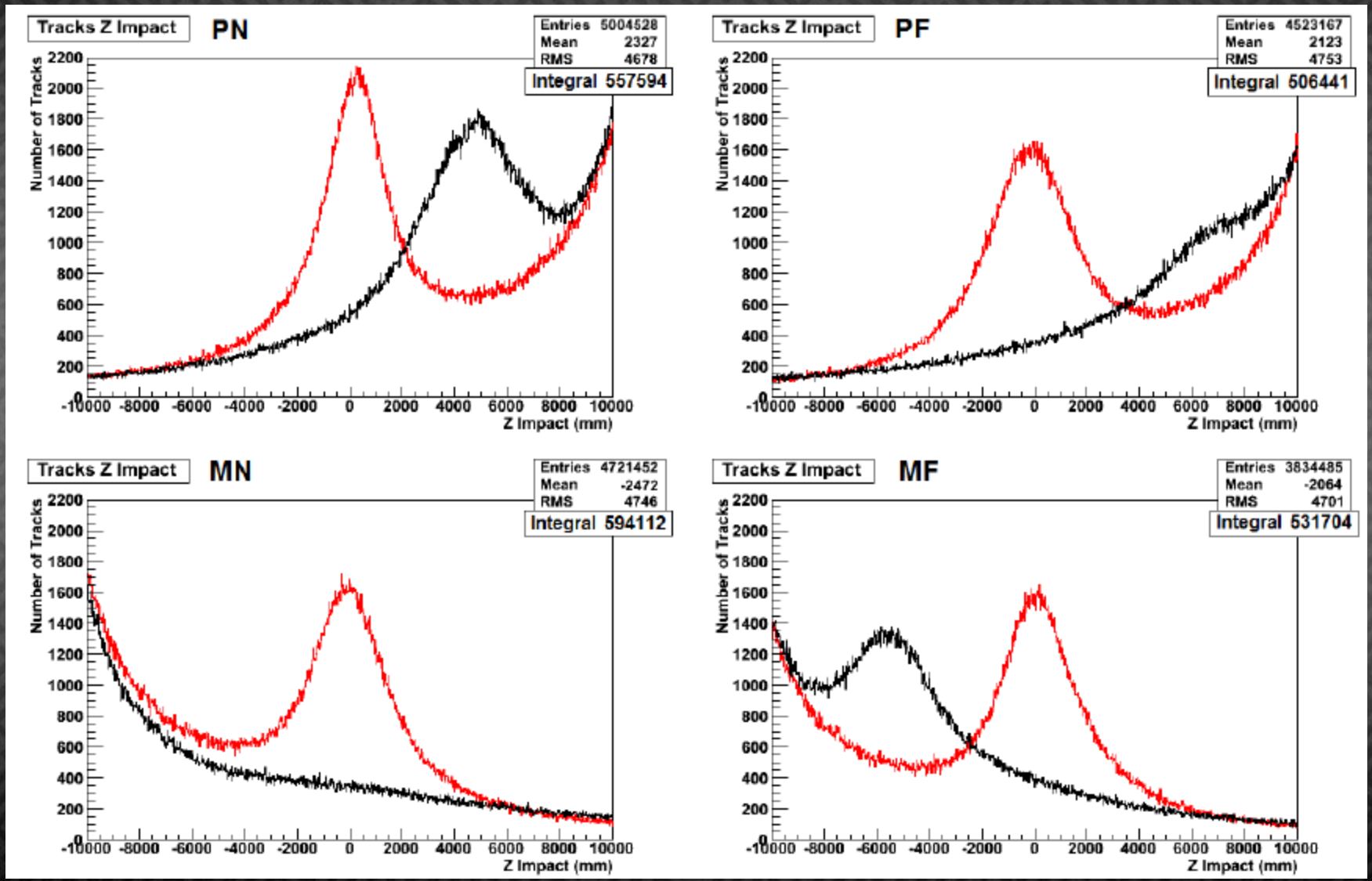


Combined with other LHC experiments



Allineamento T2, dati 2012 a $\sqrt{s}$ = 8 TeV

Summer Student Alessandro Lapertosa (supervisors:M. Berretti e G. Latino)



- Consolidamento di T2 durante Long Shutdown 2013-14:
  - **Nuova 11-esima carta**, tecnologia standard, con **nuova transmitter board** da sistemare vicino allo shielding di T2, al contrario dell'attuale rack + lontano che ha necessitato un groviglio di cavi (responsabili di ~8% dead DAQ/trigger signals)
  - Nuovo partitore HV

- R&D sul timing sia per T2 che per RPs
  - Necessaria identificazione TOF dei vertici di CMS per poter prendere dati ad alta luminosita`/pile-up
  - Confronto Cherenkov Quartz + APD <-> Scintillatore + SiPM
  - Risoluzione necessaria < 20ps

Tagging of the CMS vertex using time-information in the T2 region

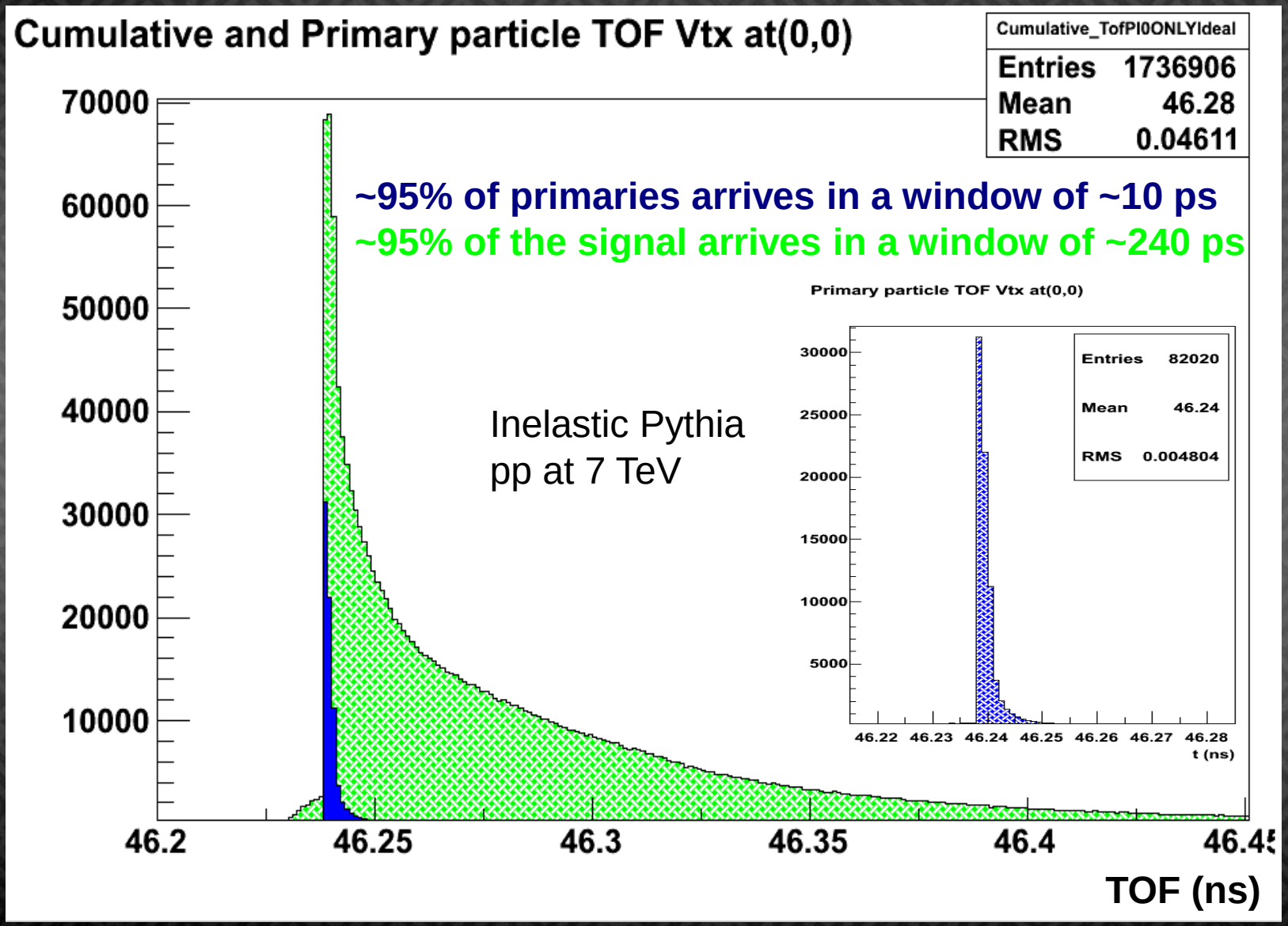
The T2 PiSi group

OUTLOOK:

- The timing signal in the T2 region.
- Capability of vertex reconstruction with double arm events.
- Single vertex spatial resolution and overlap probability for N_{INEL}=10,20,30.
- Conclusions and perspectives.

Timing signal in the T2 region

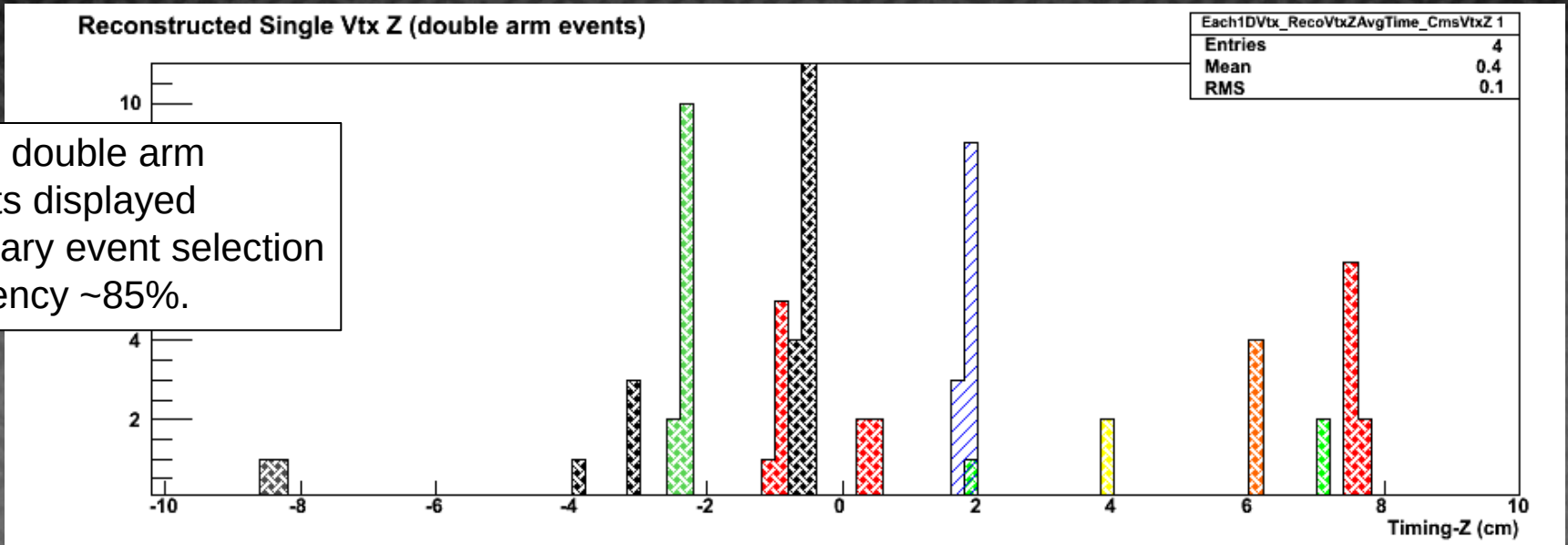
Particle TOF only due to energy and particle nature (vertex at t=0, Z=0)

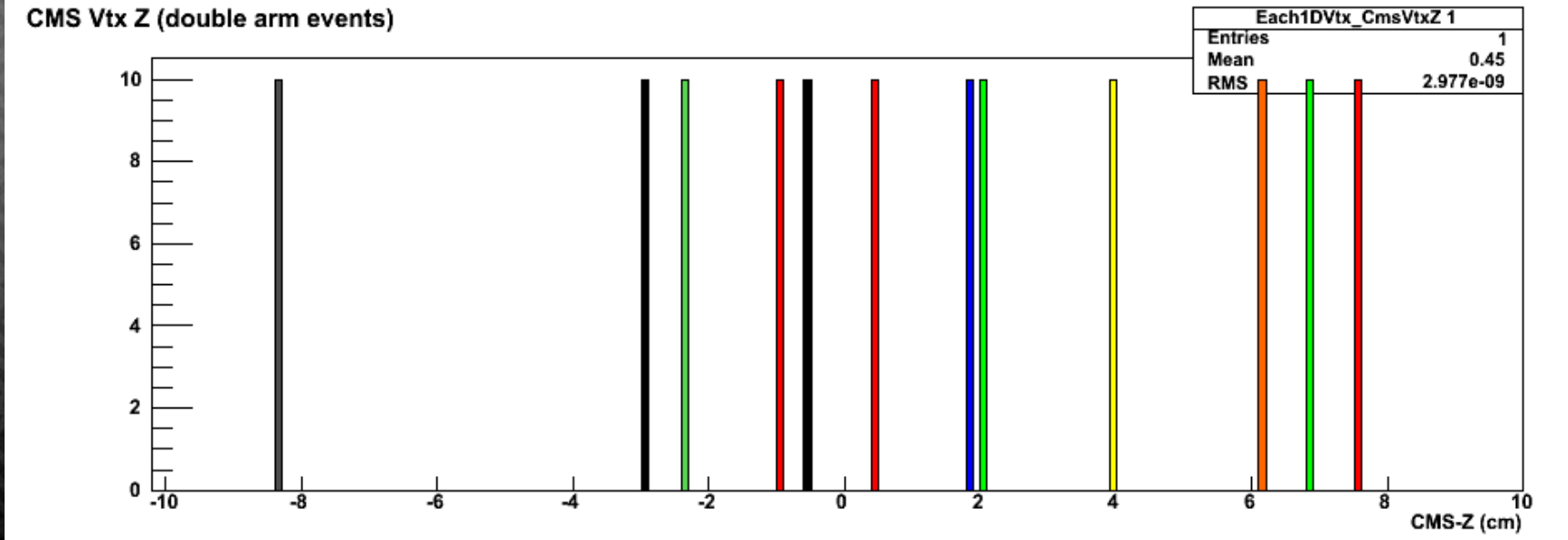


Event display N=20 (assuming independent Vtx-reco and the current T2-track resolution)

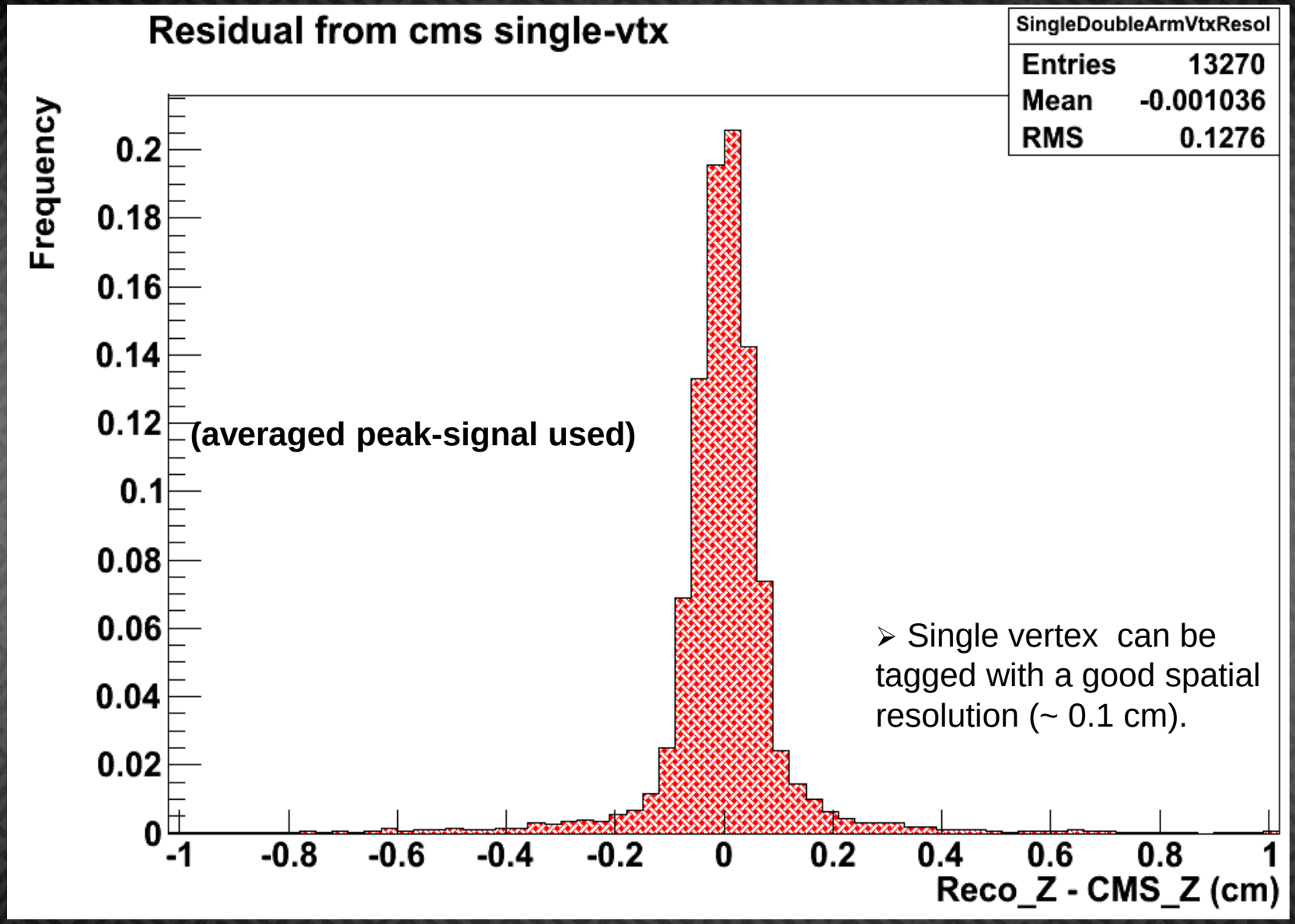
- Tracking capability at high luminosity is assumed.
- Reconstruction performed assuming no track overlap from different vertexes and using the default T2 reconstruction.

-Only double arm events displayed
-Primary event selection efficiency ~85%.





Single vertex spatial resolution



- Single vertex can be tagged with a good spatial resolution (~ 0.1 cm).

Richieste INFN per servizi locali

- Nessuna richiesta per Officina Meccanica
- Supporto per TB al CERN dell' R&D Timing T2,
  - ~ 2 MU, Gherarducci + Tazzioli
- Supporto per nuova parte semplificata di lettura segnali T2:
  - Nuova 11esima carta (realizzazione precedente Greco+Magazzu`)
  - Nuova Transmitter Board (realizzazione precedente Pedreschi+Spinella)
  - Nuovi cavi

Composizione Gruppo

	%		
Berretti	100		*Assegnista*
Bossini	100		*Dottorando*
Bottigli	50		*P.O.*
Lami	50		*Primo Ricercatore*
Latino	70		*Assegnista*
Oliveri	100		*Assegnista*
Sanguinetti	50		*Pensionato*
Scribano	0		*P.O.*
Turini	80		*Ricercatore Universitario*
Cecchi	50		*Tecnologo*
Magazzu` G.	40		*Tecnologo*
Pedreschi	30		*Tecnologo*
Spinella	20		*Tecnologo*

7.4 FTE

Preventivo di spesa 2013

Capitolo	Descrizione	Richiesta	SJ	Totale
INTERNO	*Contatti Pi-Ge-Ba-Referee*	8		**8**
ESTERO	*Riunioni al CERN (4MU)*	16		
	Responsabilita` Chairman CB (2MU)	8		
	Responsabilita` Trigger (6MU)	24		
	Disinstallazione/Manutenzione T2(4MU)	16		
	Analisi dati (4MU)	16		
	TB R&D T2 Timing (2MU)	8		
	Run 2013 (3MU)	12		**100**
CONSUMI	*Metabolismo in sede e al CERN*	10		
	Percentuale MOF 2012 Cat.A	136		
	MOF 2012 Cat. B	82		
	Preparazione beam test R&D timing	20		
	Affitto Auto	6		**254**
INVENTARIO	*Oscilloscopio > 20 Giga sample*	20		**20**
APPARATI	*Nuova 11esima scheda (4+2)*	30		
	Nuova transmitter board (4+2)	24		
	Nuovi cavi kapton 11esima-transmitter	8		
	Nuovo partitore HV	23		**85**
	TOTALE TOTEM Pisa	Keuro		**467**

Backup

luminosity calibration

$$\mathcal{L}_{\text{int}} = \frac{1+\varrho^2}{16\pi} \frac{(N_{\text{el}} + N_{\text{inel}})^2}{dN_{\text{el}}/dt|_0}$$

October: $\mathcal{L}_{\text{int}} = (83.7 \pm 3.2)\ \mu\text{b}^{-1}$ [CMS: $(82.0 \pm 3.3)\ \mu\text{b}^{-1}$]

June: $\mathcal{L}_{\text{int}} = (1.65 \pm 0.07)\ \mu\text{b}^{-1}$ [CMS: $(1.65 \pm 0.07)\ \mu\text{b}^{-1}$]

$\sigma_{\text{el}}/\sigma_{\text{tot}}$ *independent of luminosity and* ϱ

$$\frac{\sigma_{\text{el}}}{\sigma_{\text{tot}}} = 0.257 \pm 0.005$$

ϱ *determination*

$$\rho^2 = 16\pi\, \mathcal{L}_{\text{int}} \frac{dN_{\text{el}}/dt|_0}{(N_{\text{el}} + N_{\text{inel}})^2} - 1$$

TOTEM: $|\varrho| = 0.14 \pm 0.09$ COMPETE extrapolation $\varrho = 0.141 \pm 0.007$

low-mass single diffraction

$M < 3.4\,\text{GeV} \Rightarrow$ all particles more forward than $\eta = 6.5$ = T2 acceptance limit

$$\sigma_{\text{inel}}^{\eta>6.5} = \sigma_{\text{tot}} - \sigma_{\text{el}} - \sigma_{\text{inel}}^{\eta<6.5} = (2.3 \pm 2.2)\ \text{mb}$$ [from MC: ≈ 2.6 mb]