TOTEM intention for pA data taking

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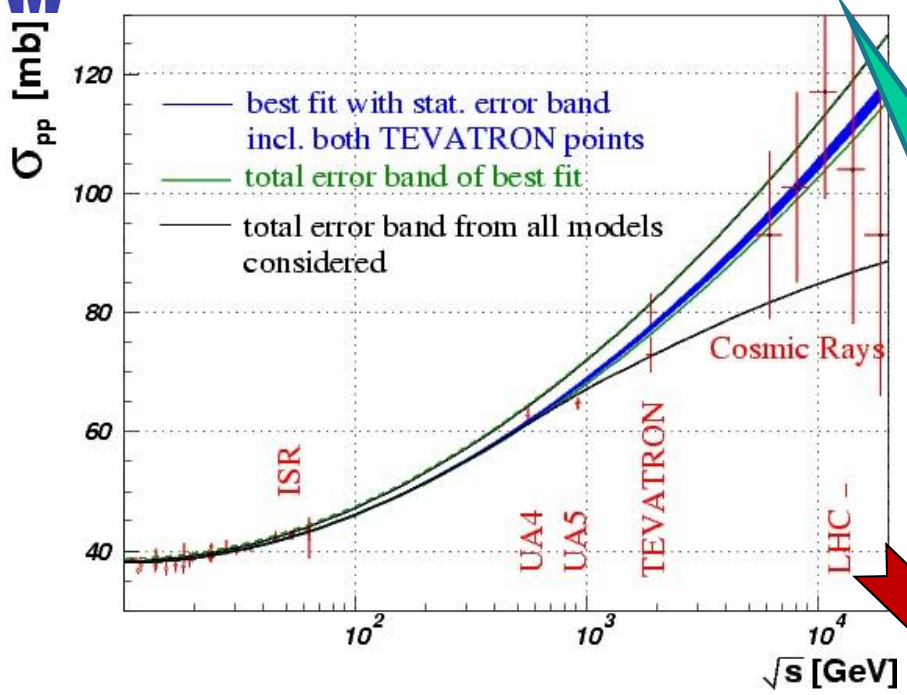
on behalf of
TOTEM collaboration

- **TOTEM physics**
- **TOTEM experiment**
- **data taking with CMS**
- **TOTEM intentions for pA**

TOTEM physics

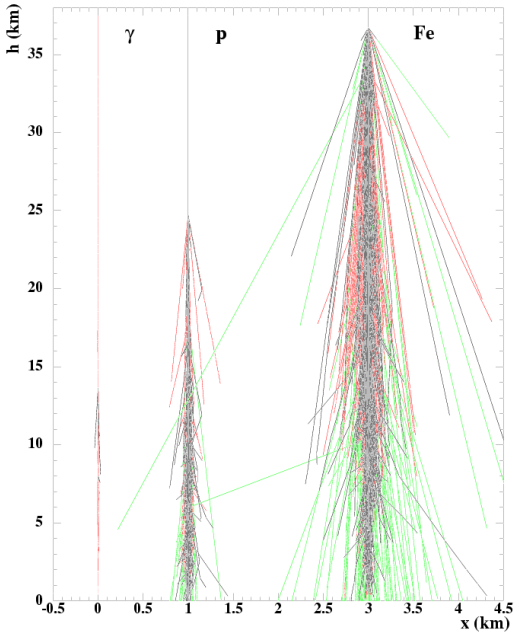
Total pp cross-section



Ultimately ~1-2 % precision

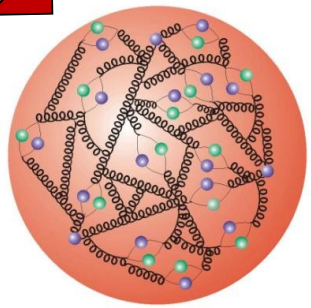
Forward particle production

Cosmic ray connection



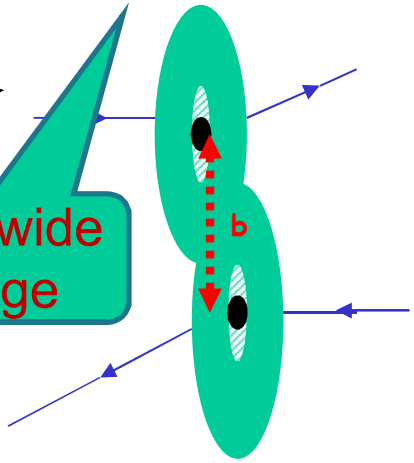
Together with CMS !

Elastic pp scattering

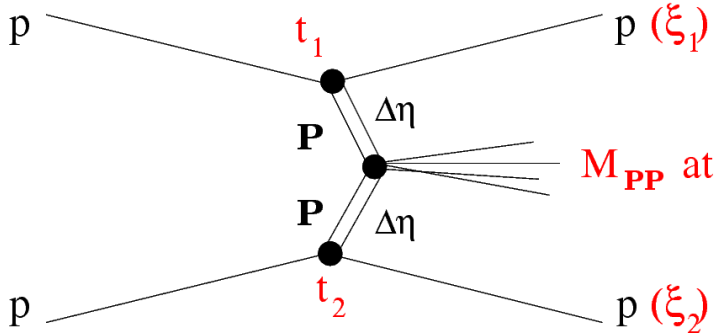


Proton

Over a wide $|t|$ range



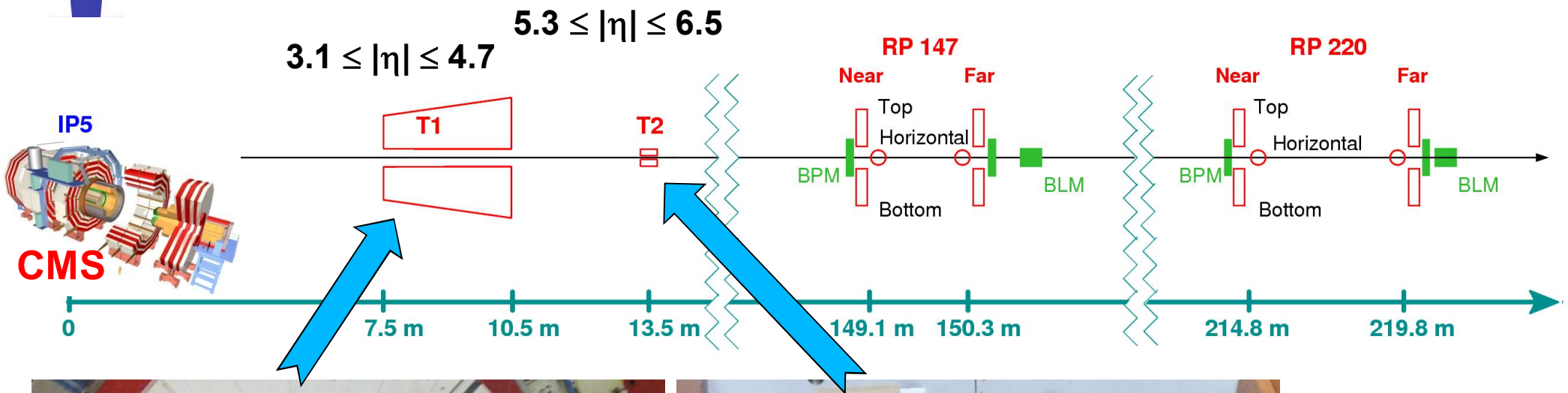
Diffraction: soft and hard

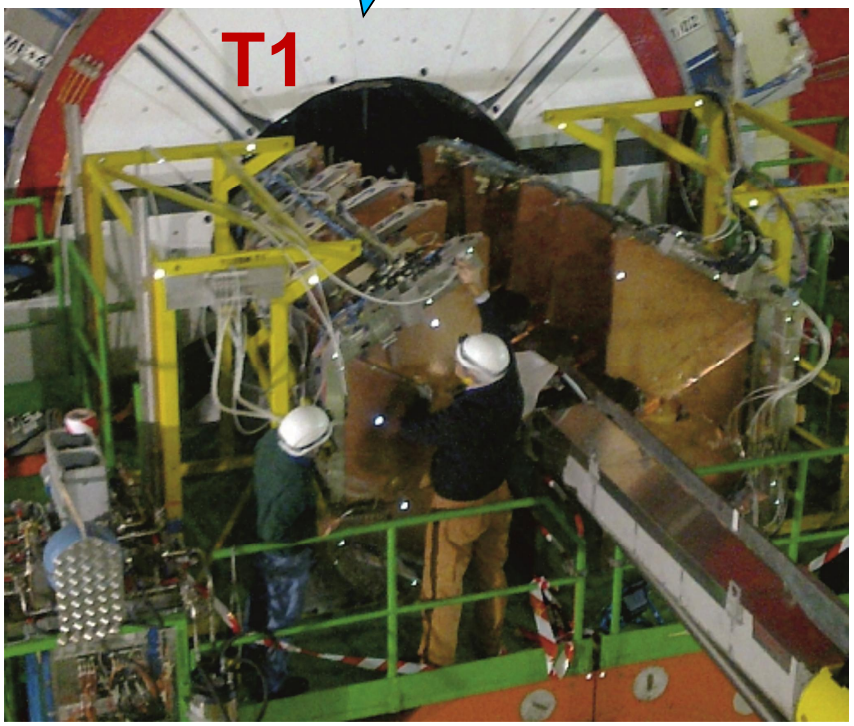


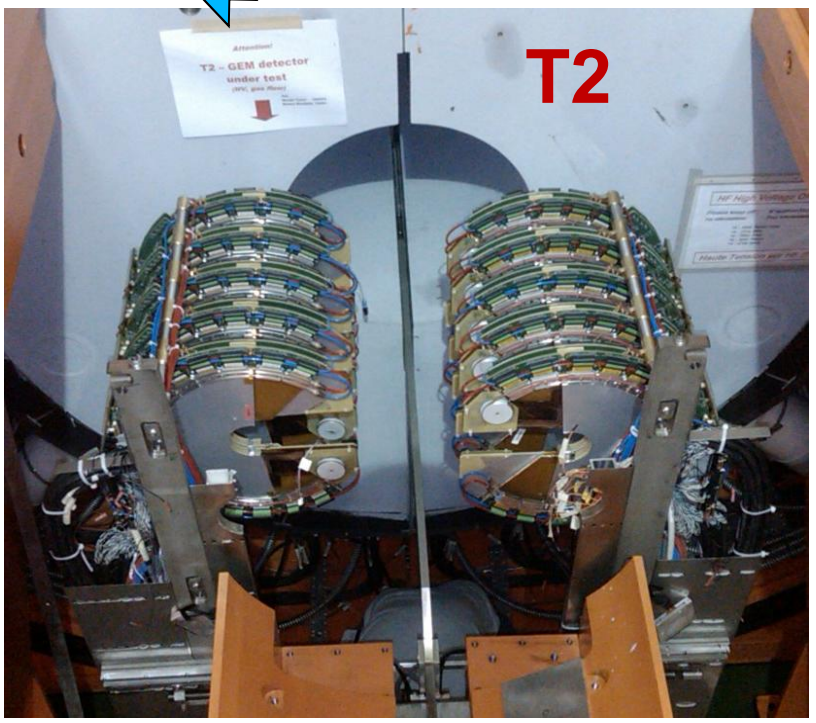
Understand QCD nature

Together with CMS !

TOTEM inelastic telescopes







T1: 5 half-planes of CSCs / quarter

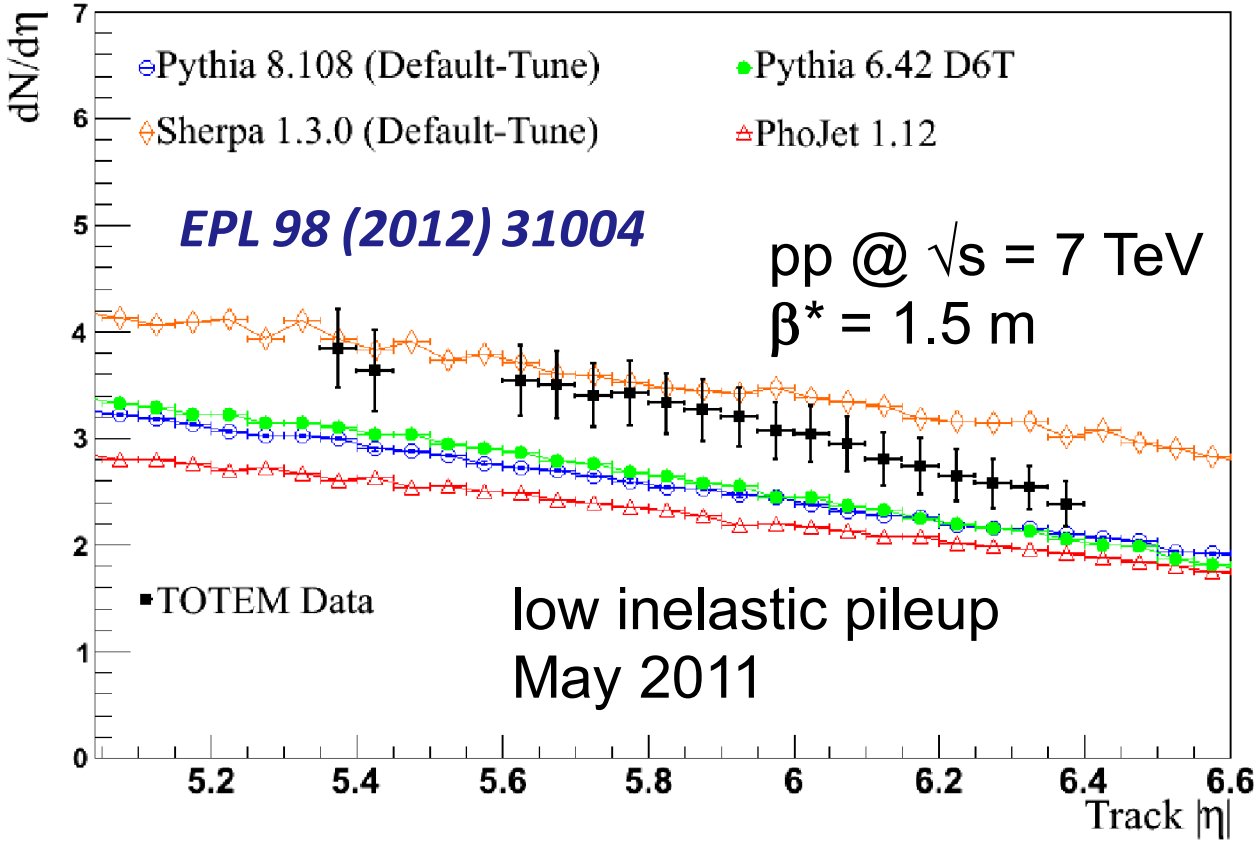
T2: 10 half-planes of triple-GEMs / quarter

Inelastic telescopes: inelastic event counting, charged multiplicity, rapidity gaps…

$dN_{charged}/d\eta$ & $\sigma_{inelastic}$ measurement with T2/T1

Keypoints:

- modeling of material in and around T1/T2
- primary-secondary charged particle separation
- understanding of track reconstruction & backgrounds



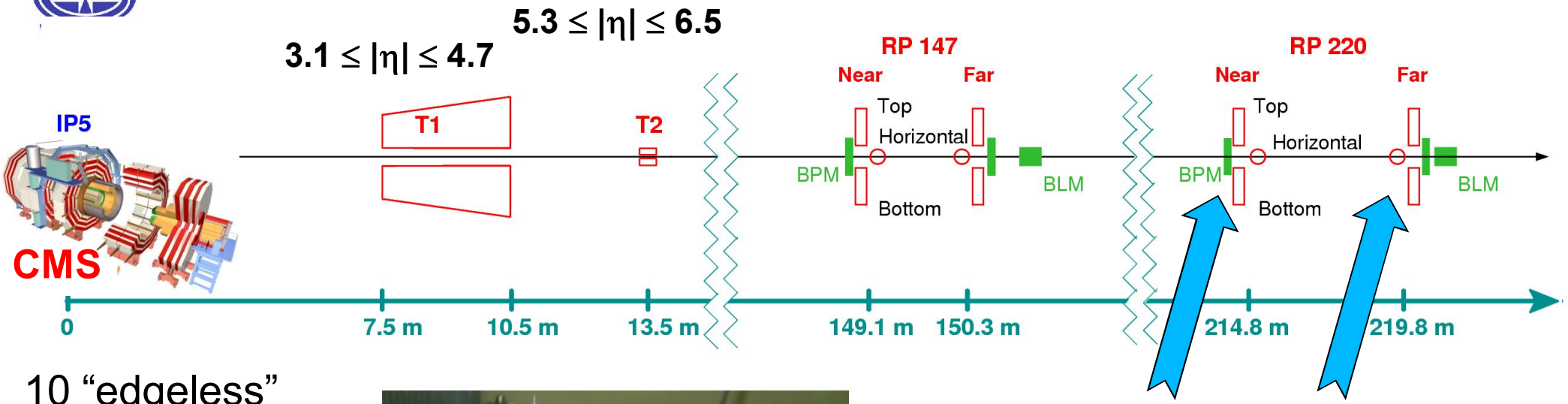
T1 following ...

√s = 7 TeV, β* = 90 m:

$\sigma_{pp,inelastic}$ = 73.4 ± 0.1 (stat) ± 1.9 (syst) ± 2.9 (lumi) mb

Preliminary !

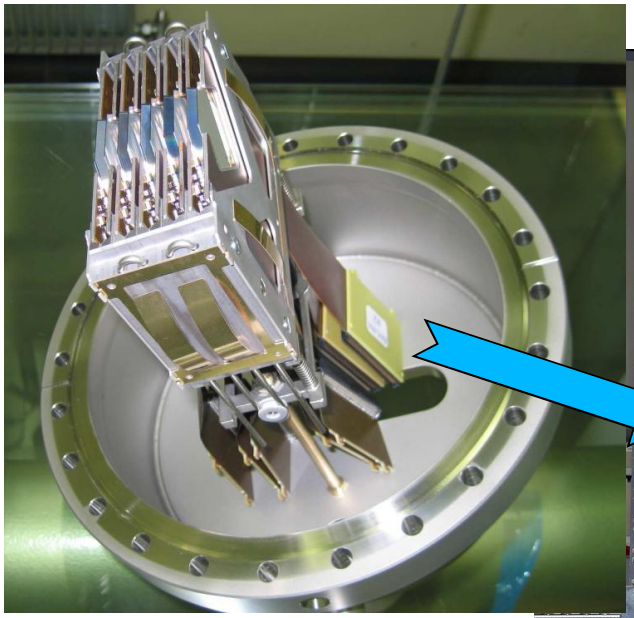
TOTEM Roman Pot detectors

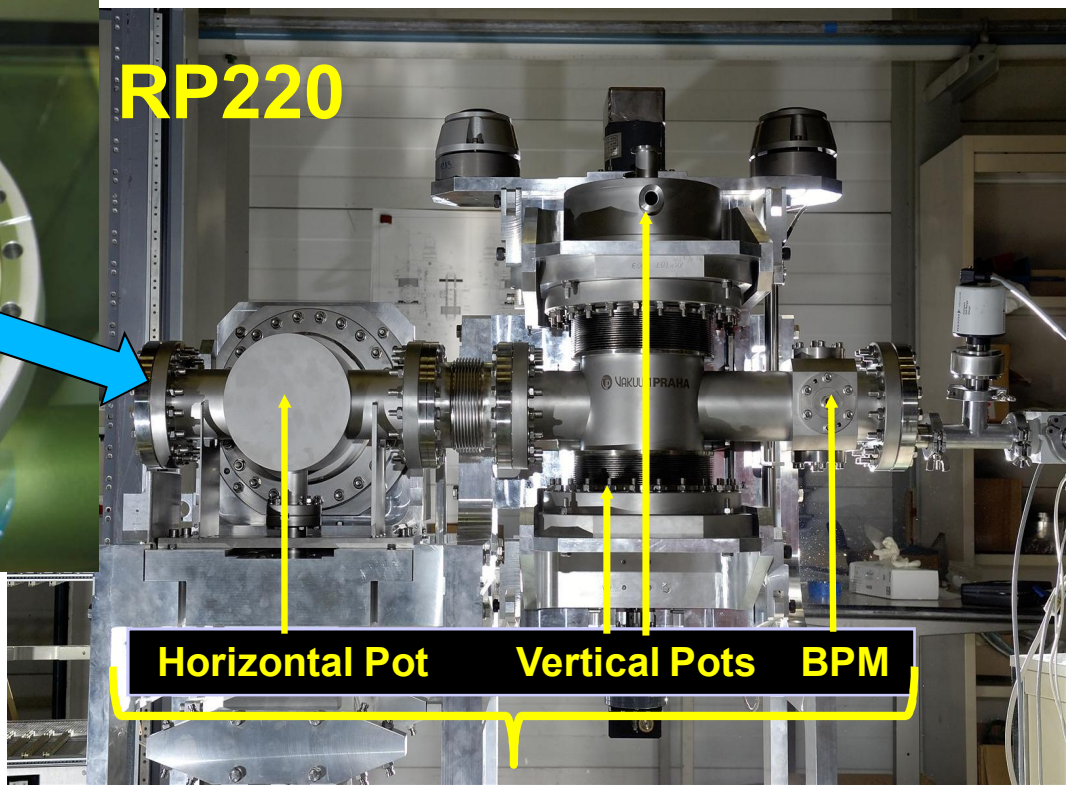


10 “edgeless” (< 50 μm) Si micro strip detectors measuring u or v projection / RP

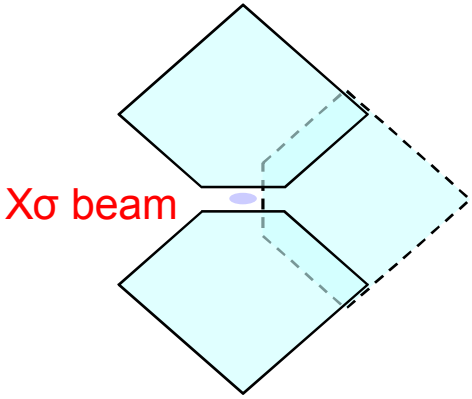
leading p detection

resolution: ~15 μm



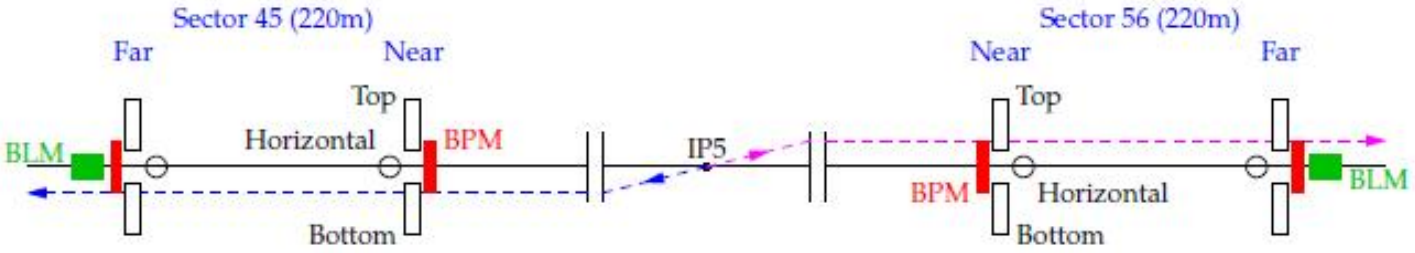


RP unit



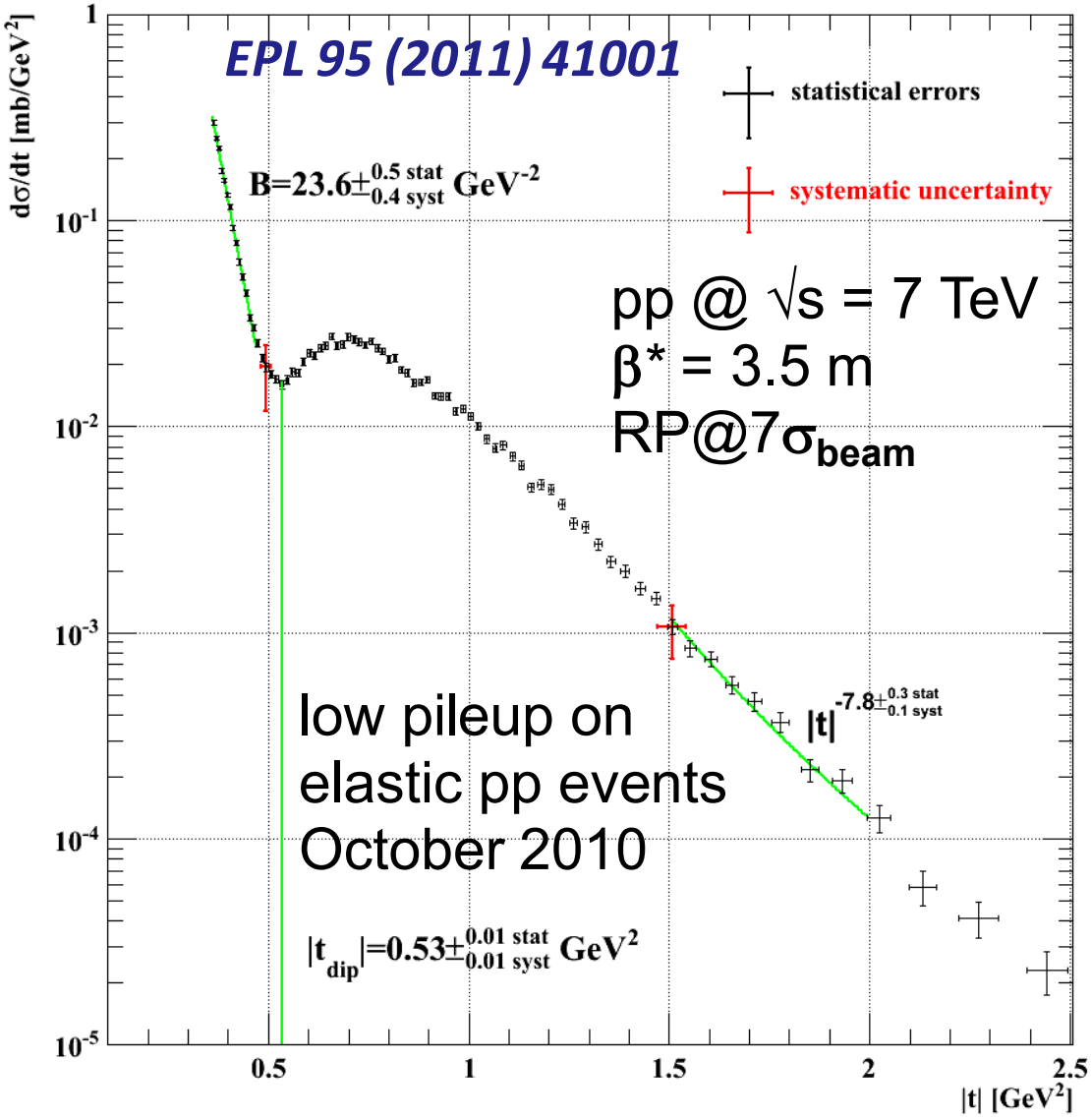
horizontal RPs:
- alignment
- diffraction

Elastic pp scattering with RP@220m



Keypoints:

- optics
- RP alignment
- scattering angle reconstruction
- acceptance
- background



Total pp cross section @ β* = 90 m: 4 strategies

RP@10σ_{beam} June 2011

1) Luminosity ("low") + Elastic Scattering+ Optical Theorem
depends on CMS luminosity for low-L bunches & elastic efficiencies & ρ

2) Luminosity ("high") + Elastic Scattering + Optical Theorem
compare the CMS luminosity measurement for high-L vs low-L bunches

$$\sigma_{tot}^2 = \frac{16\pi}{(1+\rho^2)} \frac{1}{L} \left(\frac{dN_{el}}{dt} \right)_{t=0}$$

RP@ 4.8/5.5/ 6.5σ_{beam}

***3)* Luminosity ("high") + Elastic Scattering + Inelastic Scattering**
minimizes dependence on elastic efficiencies and no dependence on ρ

$$\sigma_{tot} = \sigma_{el} + \sigma_{inel}$$

October 2011

***4)* (L-independent) + Elastic Scattering + Inelastic Scattering+ Optical T.**
eliminates dependence on luminosity

$$\sigma_{tot} = \frac{16\pi}{(1+\rho^2)} \frac{(dN_{el}/dt)_{t=0}}{(N_{el}+N_{inel})}$$

Total pp cross section: results

1) Luminosity (“low”) + Elastic Scattering+ Optical Theorem

EPL 96 (2011) 21002

$$\sigma_{TOT} = 98.3 \text{ mb} \pm^{2.2}_{2.0} \text{mb}$$

2) Luminosity (“high”) + Elastic Scattering + Optical Theorem

$$\sigma_{TOT} = 98.2 \text{ mb} \pm^{2.4}_{2.2} \text{mb}$$

3) Luminosity (“high”) + Elastic Scattering + Inelastic Scattering

$$\sigma_{TOT} = 98.7 \text{ mb} \pm 4.4 \text{ mb}$$

Preliminary !

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

$$\sigma_{TOT} = 97.8 \text{ mb} \pm^{2.9}_{2.4} \text{mb}$$

CMS + TOTEM: full acceptance detector

Successful common data takings proving trigger exchange and data combination

- PbPb November 2011
- pp April & May 2012

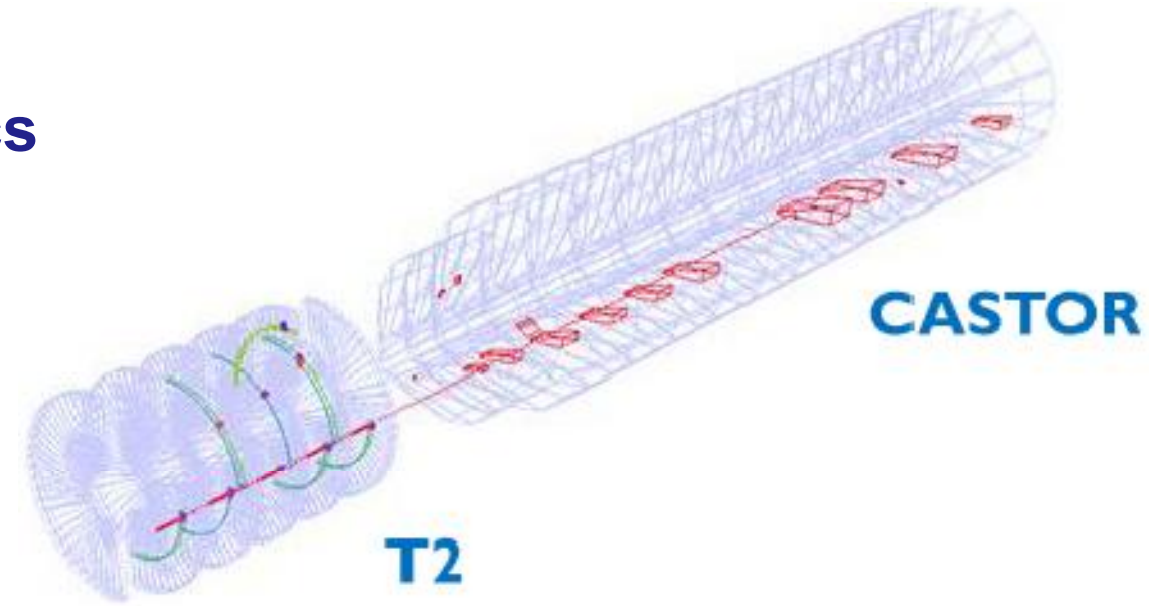
- TOTEM trigger → CMS L1 bits, CMS L1 accept → TOTEM

A common working group for data combination

Main topics:

- **minimum bias physics**
- **diffraction**

- **Common data taking planned for $\beta^* = 90$ m, high $\mathcal{L}$ & pA**



Minimum bias physics

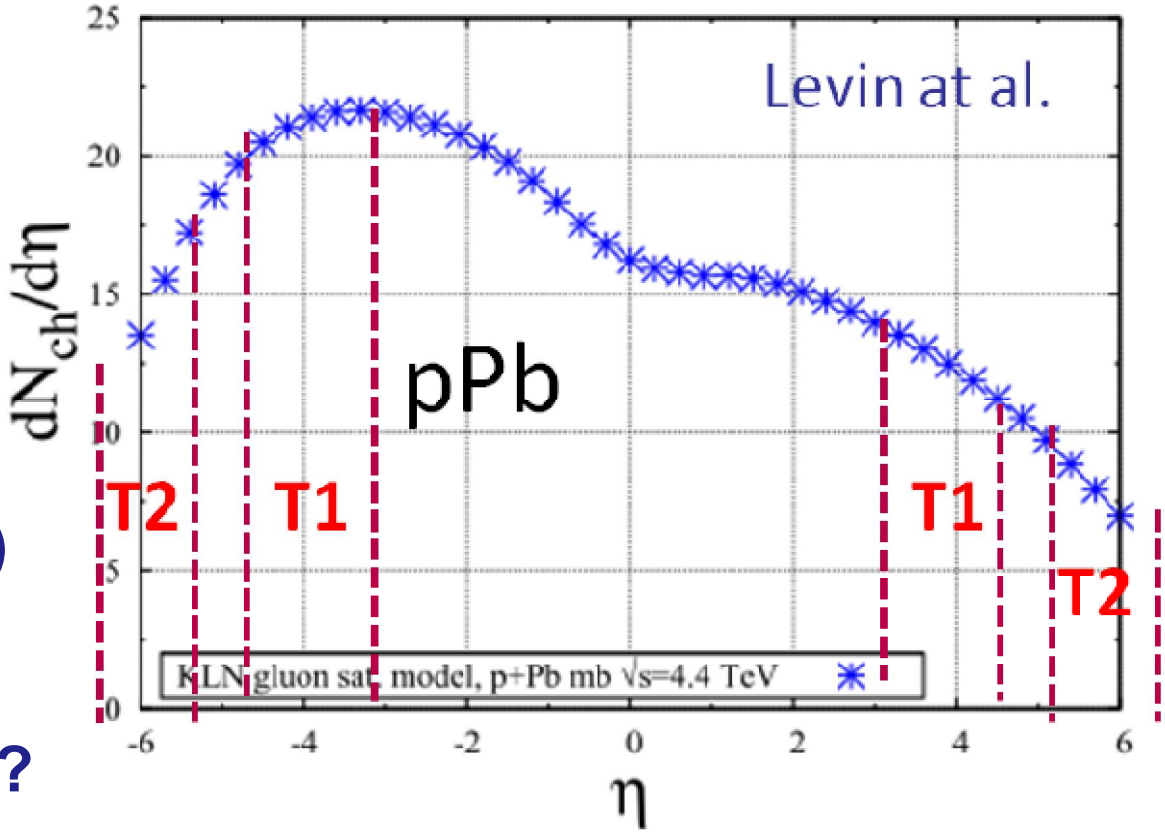
Charged particle acceptance (together with CMS): $|\eta| \leq 6.5$

Trigger: one T2 track(?)

$dN/d\eta_{pPb}$ using T1 & T2 (vs centrality from CMS)

Forward-backward multiplicity correlations?

Central-forward multiplicity correlations?



Pattern recognition at high multiplicity to be optimized

Energy flow & small x: T1+HF, T2+Castor

Leading proton

Assumption: $\beta^* = 0.6$ m, $\varepsilon_N = 2.5$ μm, $L_{y,RP220} = 13.07$ m
$D_{x,\,RP220} = 0.08$ m, x-angle = 142.5 μrad, RP@15 σ_{beam}

"Diffractive protons": $0.028 < -\Delta p/p < 0.25$ **(horizontal RP's)**
"Elastic" protons: $|t| \geq 5.9$ GeV^2 @ $E_p = 4$ TeV **(vertical RP's)**

|t| acceptance could be improved by closer vertical RP approach (or smaller ε_N): RP@10 $\sigma_{beam} \Rightarrow |t| \geq 2.9$ GeV^2

Will need time to do RP beam based alignment (~150 μm precision)

RP alignment: any azimuthally symmetric process with protons (diffraction?) used as calibration sample (~ 50 μm)

Cross-sections

Test of dynamics:

- **knockout: p Pb → p + d + (A–2)*** $\xi^{p}_{fragment} = (1 - (A/Z)_{fragment} / (A/Z)_{Pb})$

  - measure both p & d (= "p with $\Delta p/p = -0.21$") + veto hadron activity.

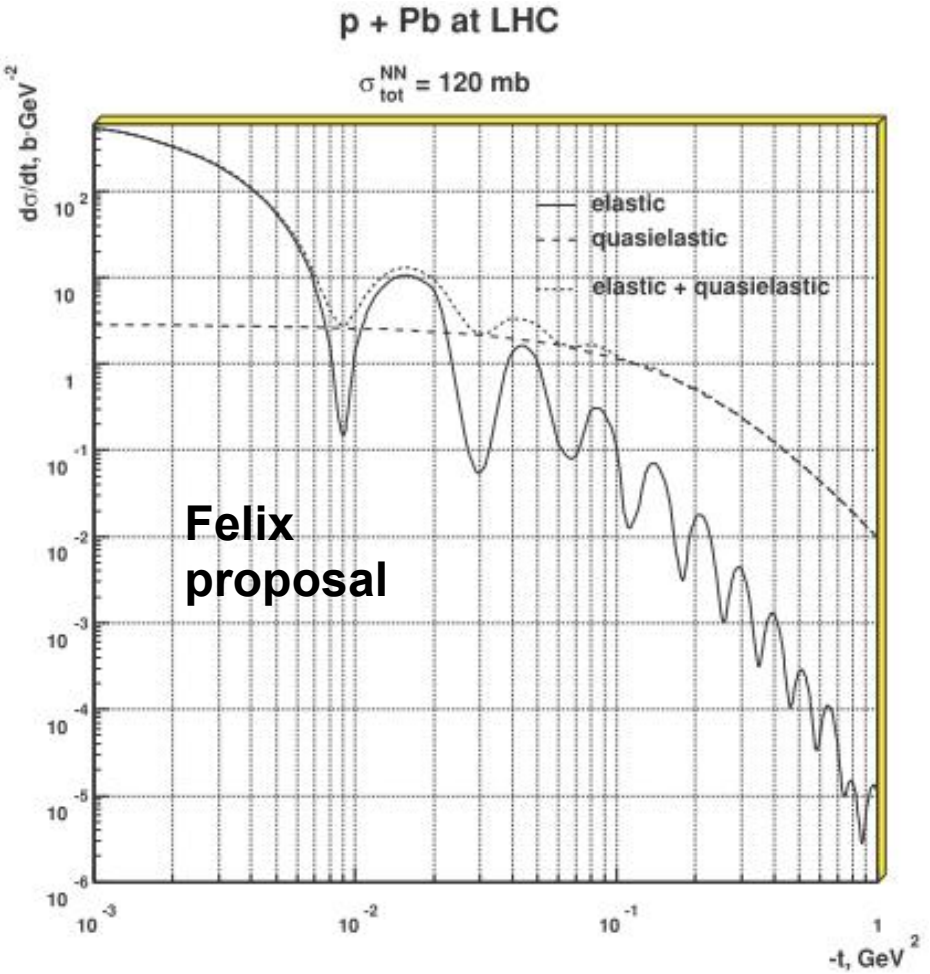
Need large t for p or significant $\Delta p/p$. Study $\Delta p/p$ & t dependence.

- **quasielastic: p Pb → p Pb***

dominates at large t

  - measure xi & t of p + only γ

on opposite side (veto hadrons)



Diffraction & $\gamma\gamma$

- very large Pomeron & γ fluxes

but nothing measured in RP on outgoing Pb side (rate problem?)

p with signficant $\Delta p/p$ (or large t) + central object (jets, J/Ψ, Υ etc..)

TOTEM conclusions

- Will participate in pA data taking (together with CMS)

- Trigger:

low intensity: minimum bias, single proton

any intensity: double arm proton and CMS (jets & leptons)

- Charged particles: $3.1 \leq |\eta| \leq 6.5$

- Protons (assuming $\varepsilon_N = 2.5\ \mu m$ & RP@$15\sigma_{beam}$):

$0.028 \leq -\Delta p/p \leq 0.25$ OR $|t| \geq 5.9\ GeV^2$

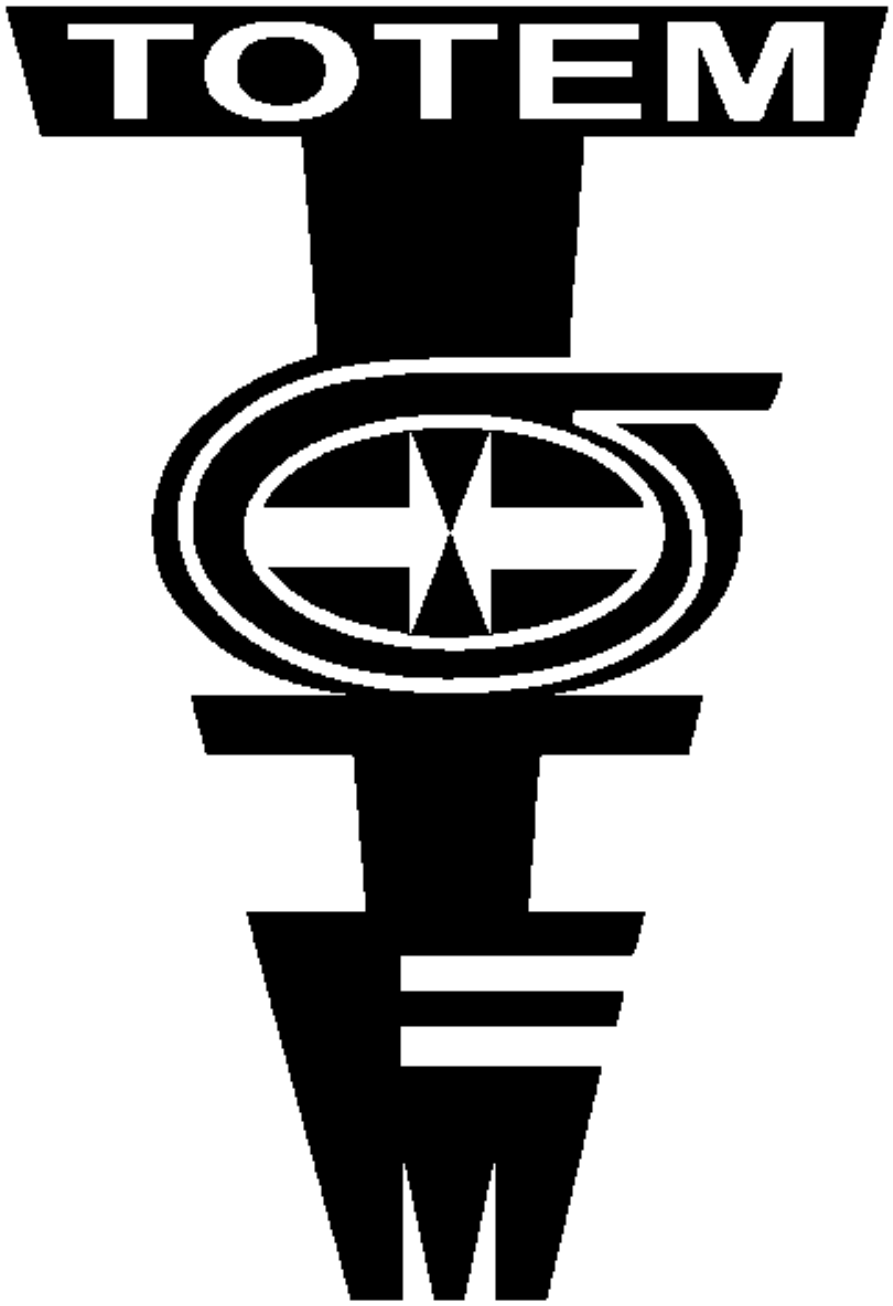
|t|-acceptance improved going closer with vertical RPs

- Will need time for RP beam-based alignment

- Minimum bias physics, small x, quasi-elastic processes, diffraction, p+X+d etc...

Thank you for your attention !!

The End



pA run scenarios at LHC

J. Jowett

- $P_A = Z \cdot P_p$ (both beams in same dipole $\Rightarrow$ same B-field)

  Z = 82, A = 208 for Pb $\Rightarrow$ cm frame boosted β = 0.98 – 0.975

- P_p > 2.7 TeV (RF unequal for injection+ramp, then matched)

	p-p	Pb-Pb	p-Pb
E / TeV	0.45-7	287-574	(2.7-7,287-574)
E_N / TeV	0.45-7	1.38-2.76	(2.7-7, 1.38-2.76)
$\sqrt{s}$ / TeV	7-14	73.8-1148	48.9-126.8
$\sqrt{s_{NN}}$ / TeV	7-14	0.355-5.52	3.39-8.79
y_{CM}	0	0	-2.20
y_{NN}	0	0	+0.46

(soft interactions)

(hard interactions

- Pb filling scheme (few-300 bunches, N_p = ~10^{10}, N_{Pb} = ~10^8)

- Rates: $\mathcal{L}$ = 10^{26} – 10^{28} cm^{-2}s^{-1}, $\sigma_{inelastic}$ ~ 2 b $\Rightarrow$ 200 Hz – 20 kHz

$\sqrt{s_{NN}} \approx 2P_p\sqrt{Z_1Z_2/A_1A_2}$ $\quad$ y_{NN} = ½ log (Z_1A_2/A_1Z_2)

Total pp cross section

luminosity independent method:

$$\sigma_{\text{total}} = \frac{8\pi}{p\sqrt{s}} \operatorname{Im} F_{\text{elastic}}(s,t)\big|_{t=0}$$ Optical Theorem

$$\Downarrow$$

$$\mathcal{L}\sigma_{\text{total}}^2 = \frac{16\pi}{1+\rho^2} \times \left.\frac{dN_{\text{elastic}}}{dt}\right|_{t=0}, \quad \rho = \left.\frac{\operatorname{Re} F_{\text{elastic}}}{\operatorname{Im} F_{\text{elastic}}}\right|_{t=0}$$

$$\mathcal{L}\sigma_{\text{total}} = N_{\text{elastic}} + N_{\text{inelastic}}$$

$$\Downarrow$$

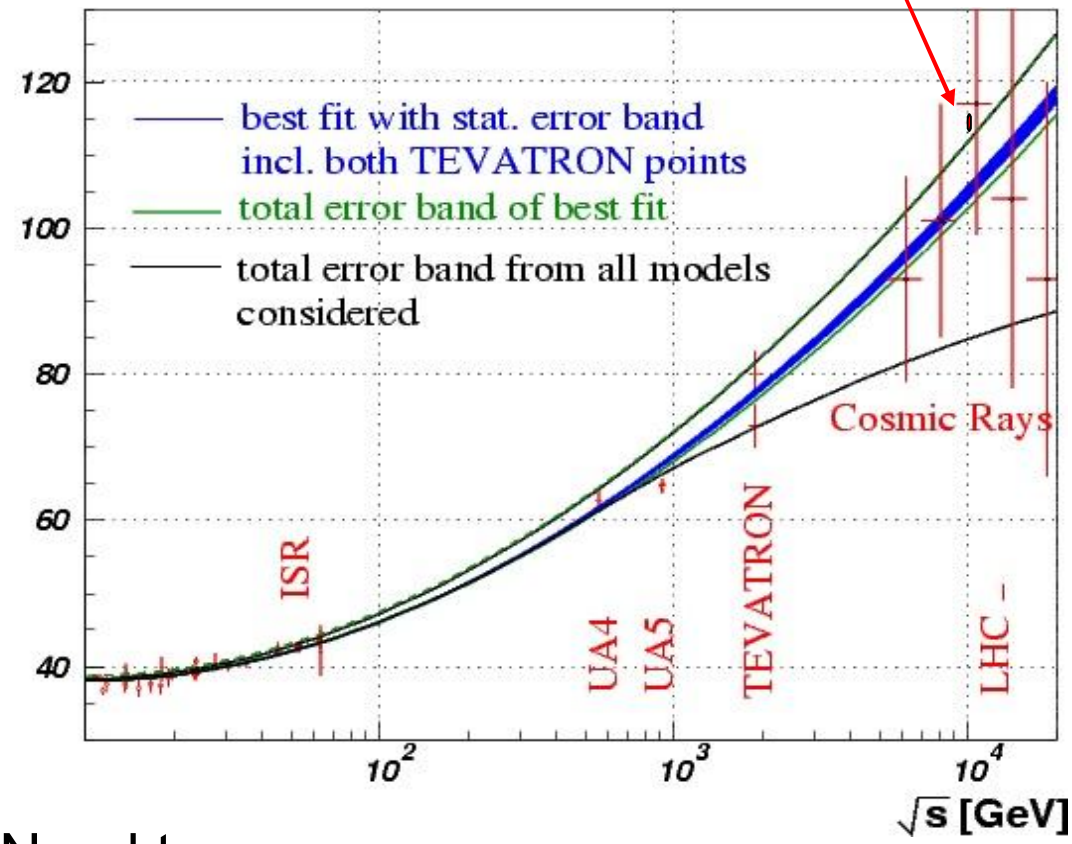
$$t \cong -p^2\Theta^2$$

$$\sigma_{\text{total}} = \frac{16\pi}{1+\rho^2} \times \frac{(dN_{\text{elastic}}/dt)\big|_{t=0}}{N_{\text{elastic}} + N_{\text{inelastic}}}$$

$$\mathcal{L} = \frac{1+\rho^2}{16\pi} \times \frac{(N_{\text{elastic}} + N_{\text{inelastic}})^2}{(dN_{\text{elastic}}/dt)\big|_{t=0}}$$

ultimately: ±1 %
(2011: ± 3 %)

COMPETE Collaboration:



Need to measure:

- elastic rate N_{elastic}
- dN_{elastic}/dt extrapolation to $t = 0$
- inelastic rate $N_{\text{inelastic}}$

} **require high β***

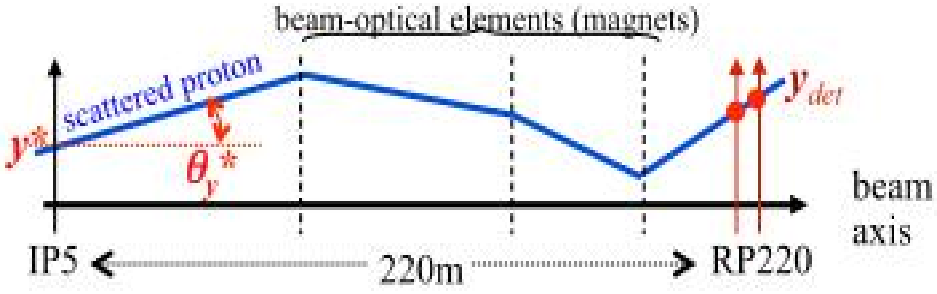
Only needed input: ρ

Optics

(x^*, y^*): vertex position

(θ_x^*, θ_y^*): emission angle: $t \approx -p^2 (\theta_x^{*2} + \theta_y^{*2})$

$\xi = \Delta p/p$: momentum loss (diffraction)



$$y_{det} = L_y \theta_y^* + v_y y^*$$

$\beta^* = 3.5$ m: $L_y \approx 25$ m, v_y small

$\beta^* = 90$ m: $L_y \approx 260$ m, $v_y \approx 0$

$\Rightarrow \theta^*_y$ reconstructed from track position

$$x_{det} = L_x \theta_x^* + v_x x^* + D\xi$$

Elastic: $\xi = 0$

$\beta^* = 3.5$ m & 90 m: $L_x \approx 0$ m, v_x sizable

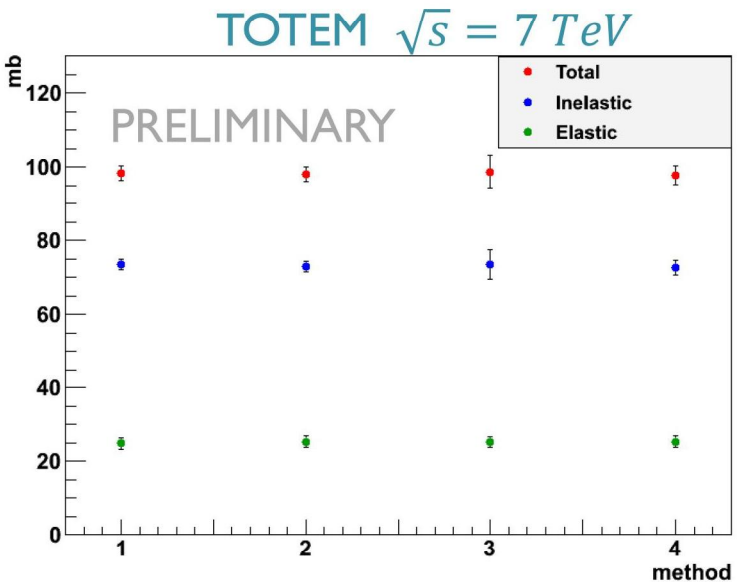
$\Rightarrow \theta^*_x$ reconstructed from track angle

$$\frac{dx_{det}}{ds} = \frac{dL_x}{ds}\theta_x^* + \frac{dv_x}{ds}x^*$$

	Beam width @ vertex $\sigma^*_{x,y} = \sqrt{\varepsilon\beta^*}$	Angular beam divergence $\sigma^*_\Theta = \sqrt{\frac{\varepsilon}{\beta^*}}$	Min. reachable $\lvert t\rvert$ $\lvert t_{min}\rvert = n_\sigma^2 \frac{p^2\varepsilon}{\beta^*}$
Standard optics $\beta^* \sim 1$–3 m	$\sigma_{x,y}^*$ small	$\sigma(\theta_{x,y}^*)$ large	$\lvert t_{min}\rvert \sim 0.3$–$1$ GeV^2
Special optics $\beta^* = 90$ m	$\sigma_{x,y}^*$ large	$\sigma(\theta_{x,y}^*)$ small	$\lvert t_{min}\rvert \sim 10^{-2}$ GeV^2

Cross sections

Total, elastic and inelastic cross sections well constrained by the 4 methods



TOTEM results in agreement with COMPETE predictions