TOTEM Experiment MasterClasses

B. Bressan and G. Latino

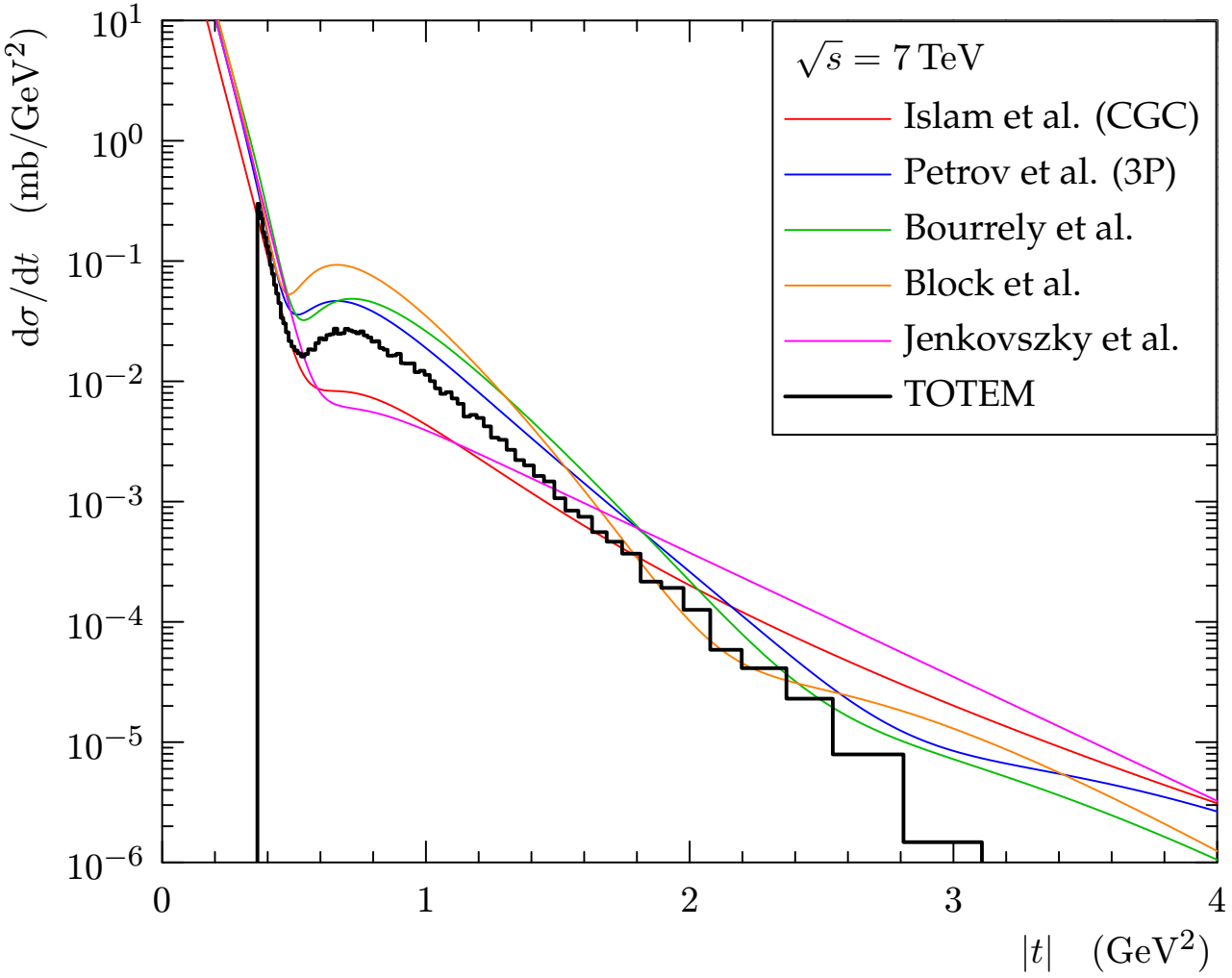
(TOTEM Collaboration)

Measurement of dN_{el}/dt in p-p collisions at LHC

IPPOG Meeting, Berlin 14/05/14

TOTEM Results at √s = 7 TeV (E_b = 3.5 TeV)

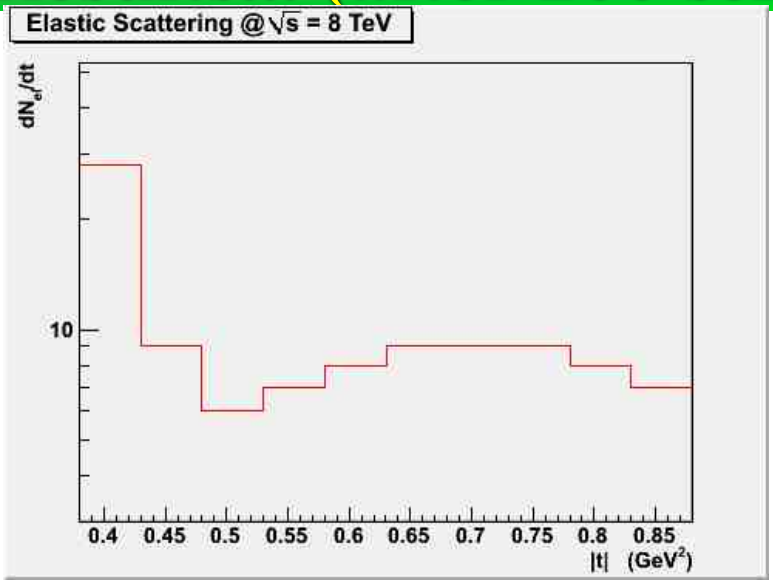
.... Compared to several theoretical predictions...



B (t=-0.4 GeV²)	t_{DIP}	t^{-n} [1.5–2.5 GeV²]
20.2	0.60	5.0
23.3	**0.51**	**7.0**
22.0	**0.54**	**8.4**
25.3	0.48	10.4
20.1	0.72	4.2
23.6 ± 0.5	**0.53 ± 0.01**	**7.8 ± 0.3**

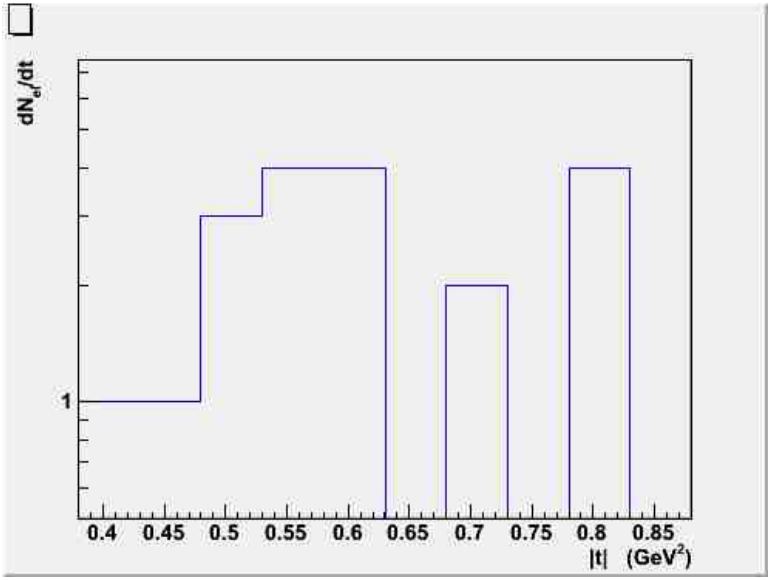
None of the models really fit

Results... (after 200 selections "Event-Display Based")

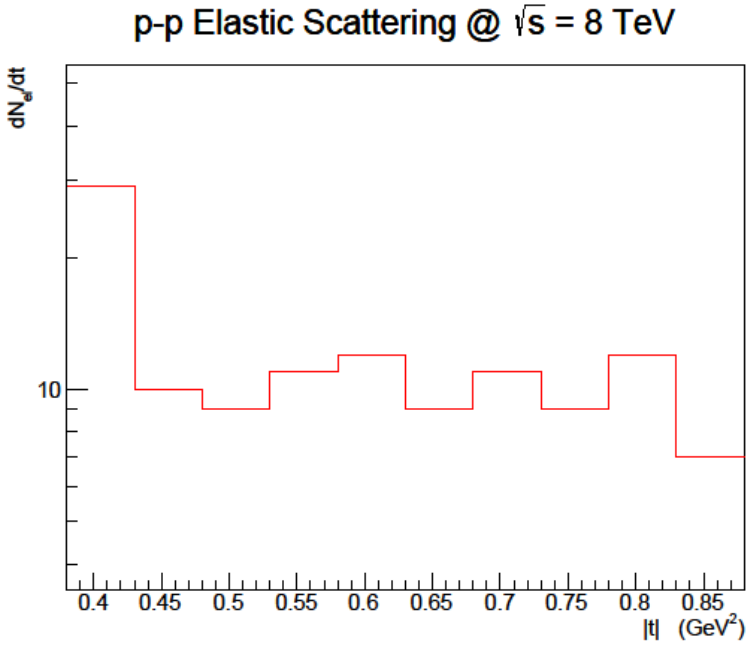


Analysis performed on data taken on July 2012 @ √s = 8 teV

dNel/dt distribution for signal (proper selection)



dNel/dt distribution for background (proper selection)



dNel/dt distribution for signal + background (NO selection)

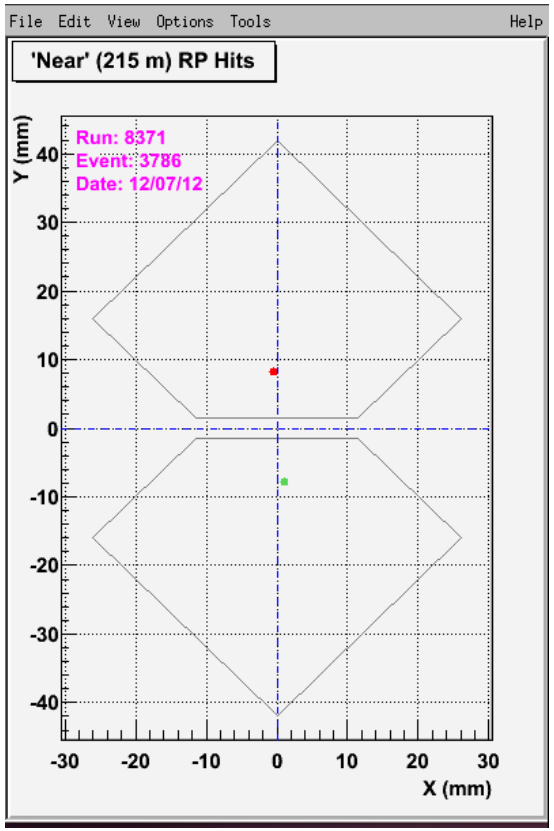
TOTEM MasterClasses Task .....

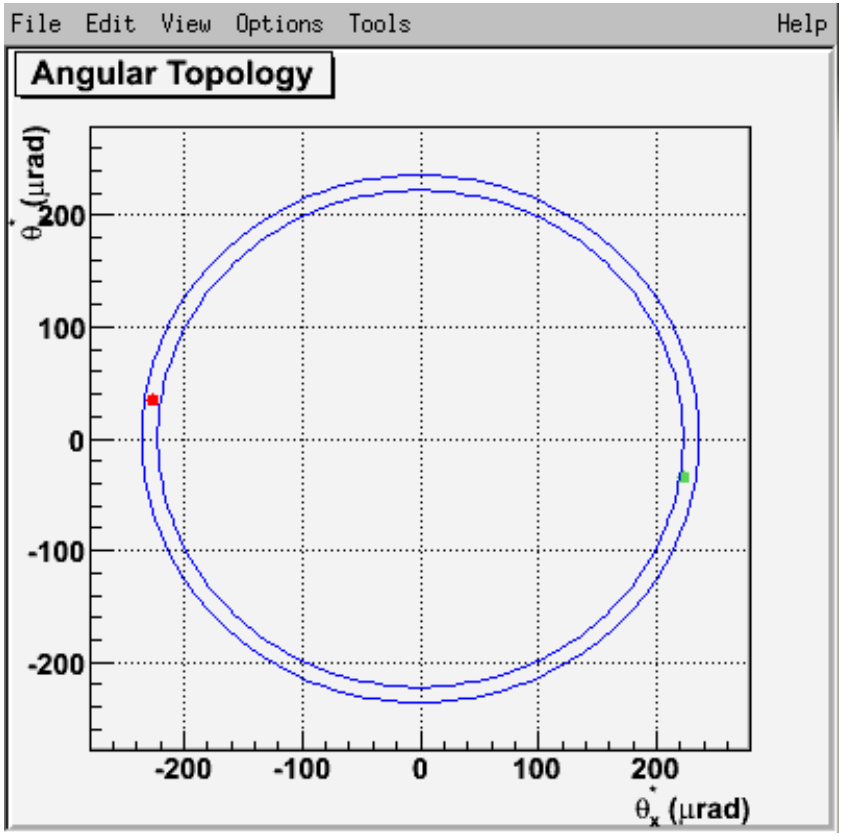
Can we distinguish nuclear scattering from background?

Events have to be selected/rejected on a ROOT based event display visual analysis

Nuclear scattering events (p-p elastic scattering):

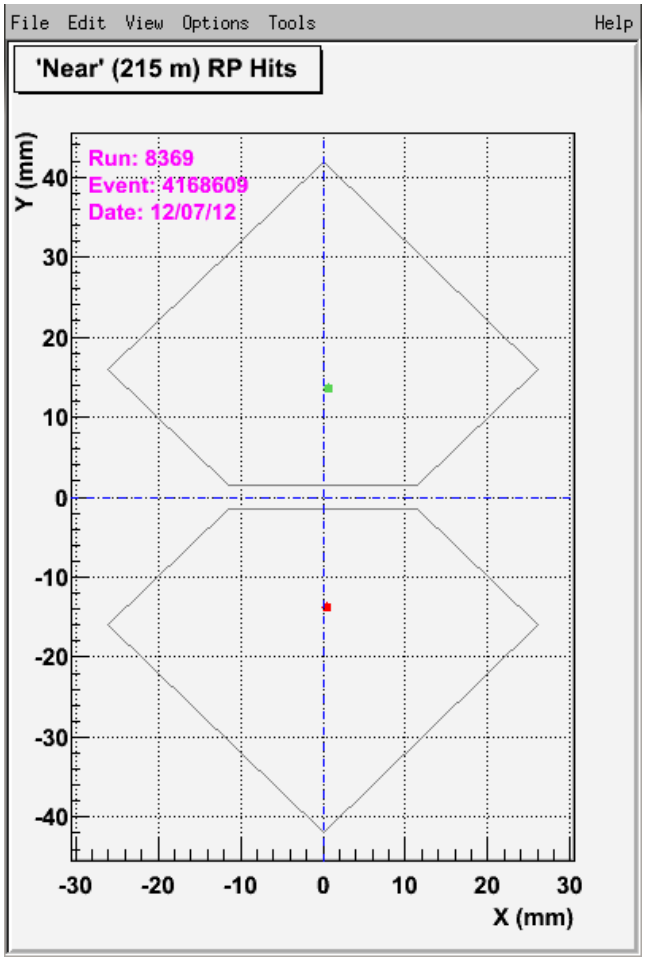
- **RP hits with similar or opposite x, opposite y.**
- **AT shows hits on opposite sides of the diameter of a circle.**

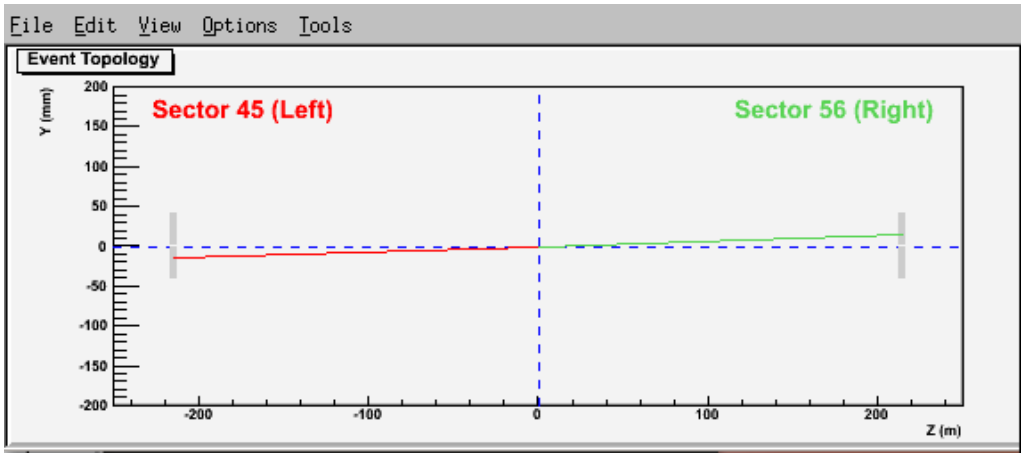


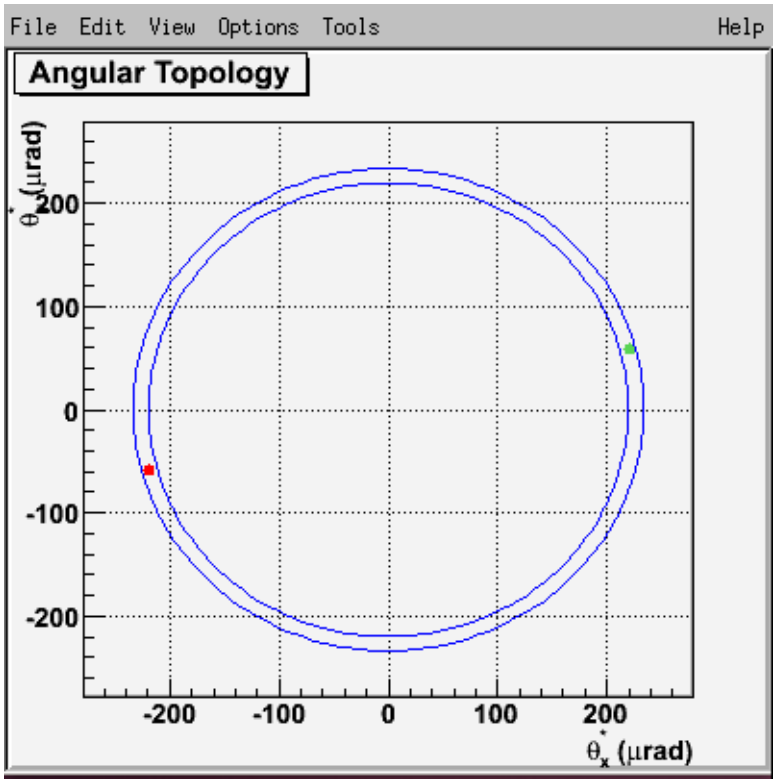


Try it! Signal or Background ?

1. Nuclear scattering or
2. background?







TOTEM MasterClassess Pilot Activity 1

10th December 2013

Pilot activity, Case Western Reserve University, US (K. Cecire)

https://quarknet.i2u2.org/content/totem-masterclass-cwru

- MasterClasses “structure” (10 students)
- First implementation of analysis code only on linux (some limit tech. problems)
- Samples to each group of students for open discussions on the results…

TOTEM MasterClassess Pilot Activity 1: Students comments

What were the best things about the MastercClass today?

- Data analysis, understanding of theory-experimental results correlation
- Videoconference with TOTEM control room
- Studying something not found in a high school physics class program

Would you recommend this MasterClass to other high school?

- Yes!

How can the MasterClass be improved?

- More than 200 events available
- More for the students to analyze in each event (not only "1" or "2”)

TOTEM MasterClassess Pilot Activity 2

15th April 2014

Pilot activity, Siena University, Italy (G. Latino)

- MasterClasses (20 students)
- Improved version of the code (previous tech. problems solved)
- Code running on Windows 7 (ROOT package & analysis code stand-alone)
- Samples to each group of students for open discussions on the results…

TOTEM MasterClassess Pilot Activity 2: Students comments

Which aspects of this MasterClass were more interesting?

- Experimental phase and the particle accelerator description

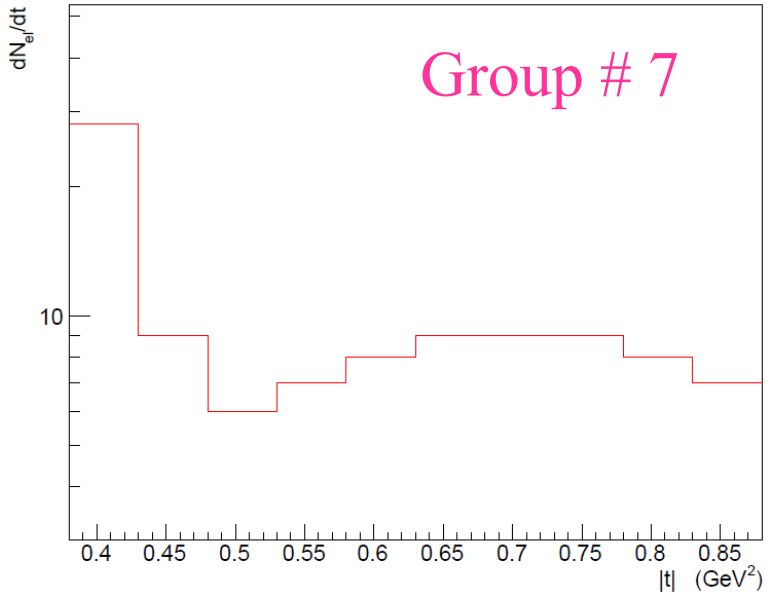
Would you recommend this MasterClass to other high school?

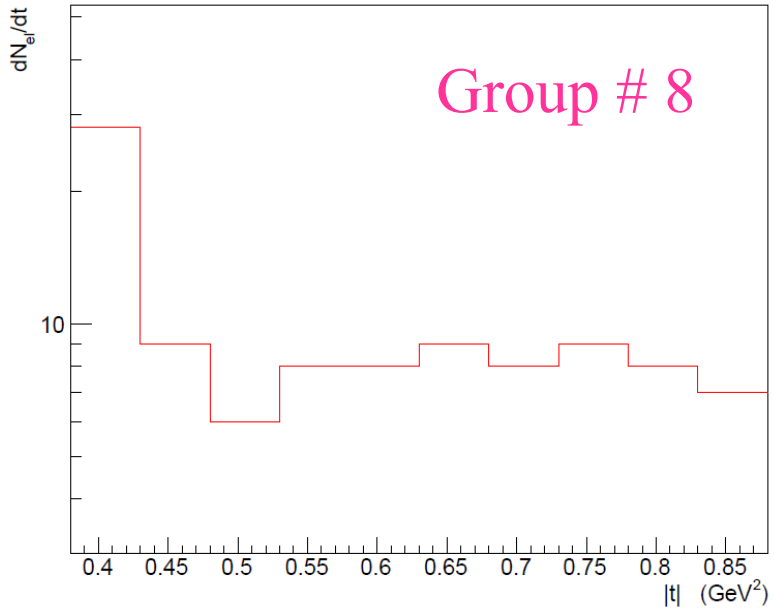
- Yes!

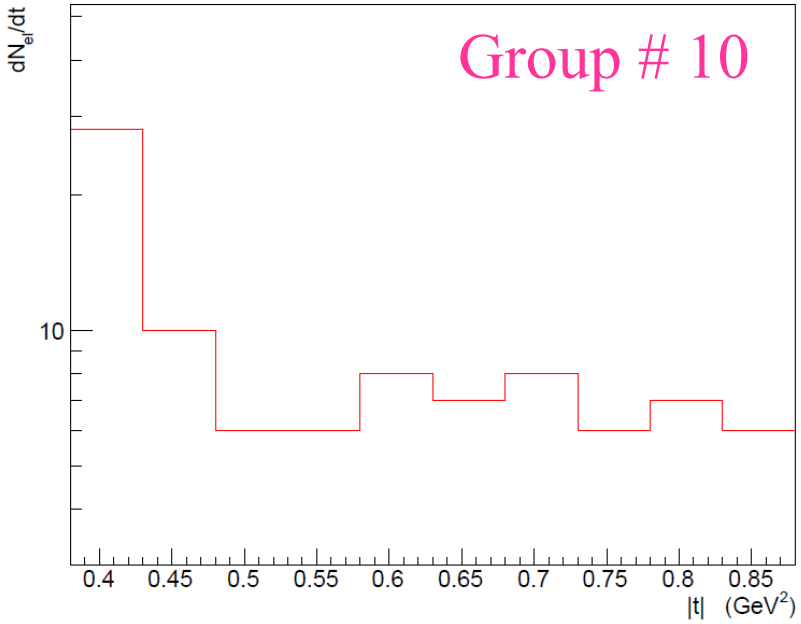
How can the MasterClass be improved?

- More interaction teacher-students
- More time to the experimental phase
- More explanation about the project

Studying the Same Data Sample: Results from 3 Groups



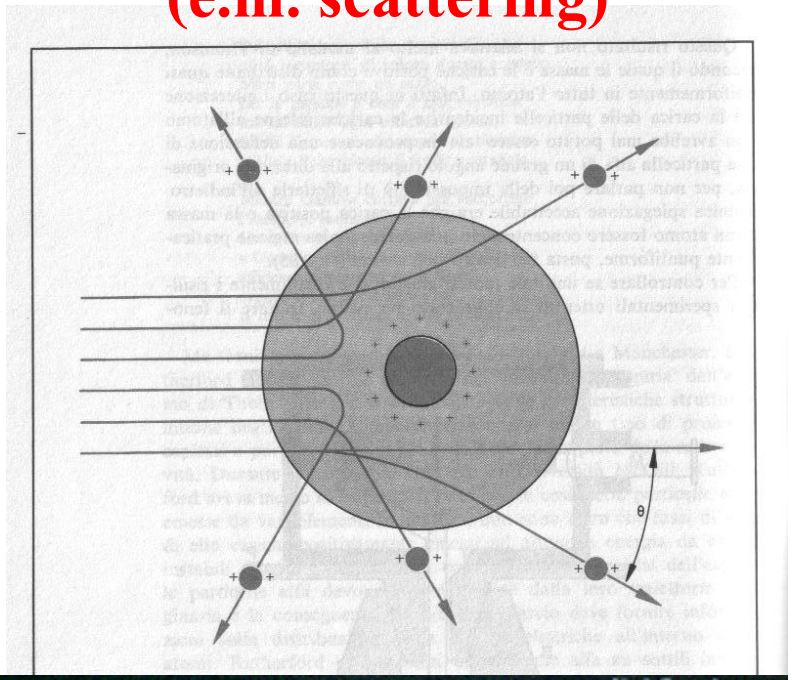


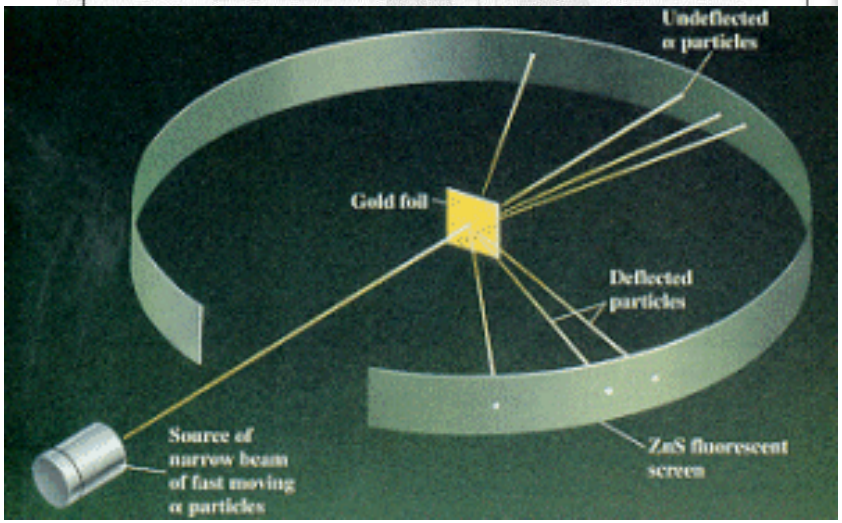


Nice discussion followed …

Backup Slides

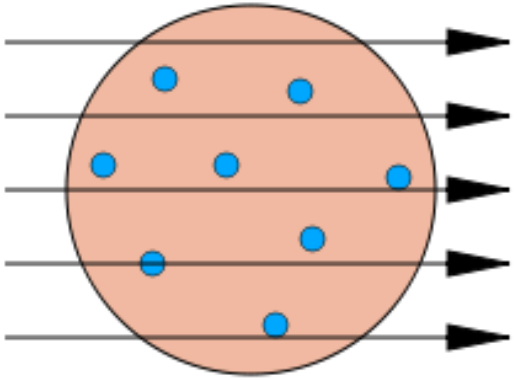
A historical example: the Rutherford experiment (e.m. scattering)





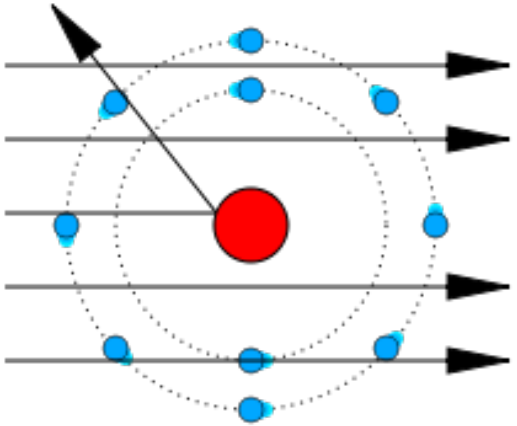
Importance of Angular Measurements in Scattering Processes

Thomson Model



versus

Rutherford Model



Today we will study the nuclear interaction scattering !

Kinematics of p-p elastic scattering

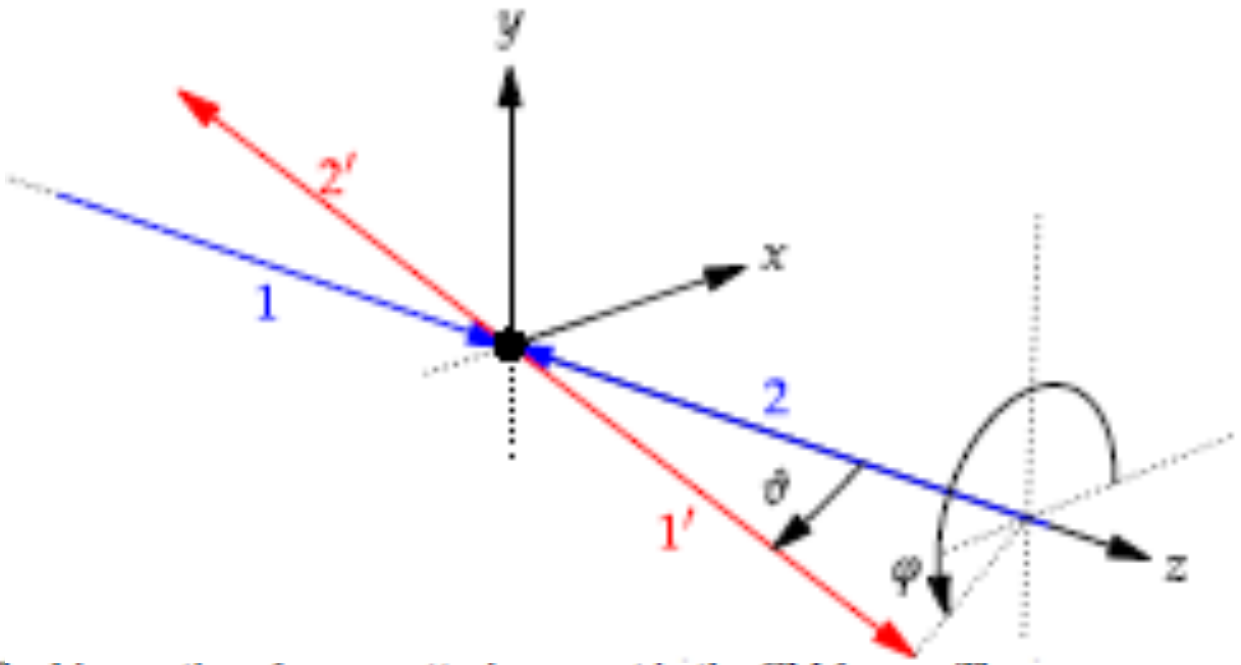


Figure 1.1: The kinematics of a pp scattering event in the CM frame. The arrows represent the momenta of the incident (blue) and scattered (red) protons. The black dot in the origin marks the interaction.

A typical kinematical variable is t, defined as:

$$-t \approx p^2 \theta^2$$

p = proton momentum

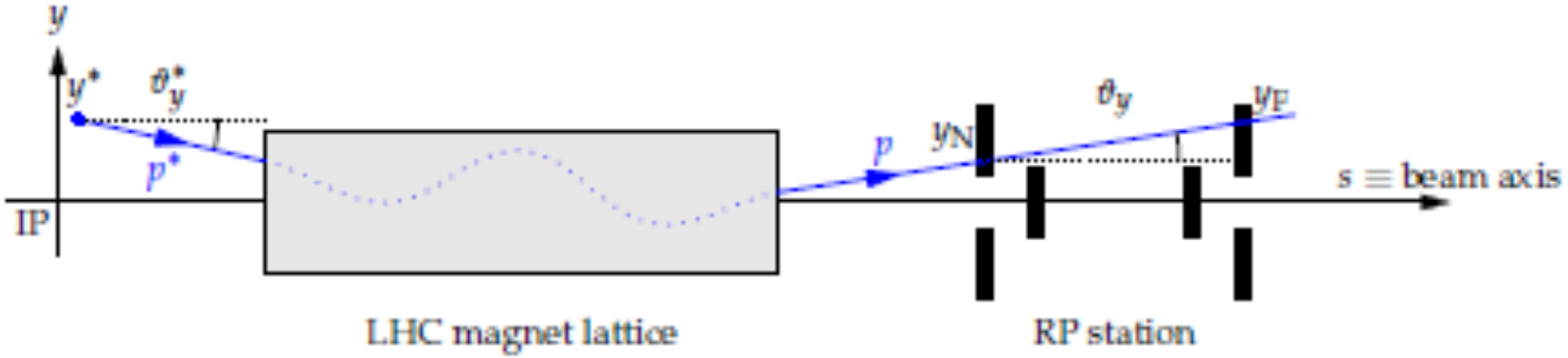
θ = scattering angle

The scattering process can be studied on the x and y "projections"

$$-t_x \approx p^2 \theta_x^2 \; ; \; -t_y \approx p^2 \theta_y^2$$

$$\theta_x = \theta \cdot \cos\varphi; \quad \theta_y = \theta \cdot \sin\varphi$$

Proton Transport from IP5 to RP Location



Proton transport equations for Roman Pots @ 220m:

$$x = v_x \cdot x^* + L_x \cdot \theta_x^*$$
$$y = v_y \cdot y^* + L_y \cdot \theta_y^*$$

With: (x, y): hit position at Roman Pot (RP) location
(x^*, y^*): vertex position at Interaction Point (IP)
(θ_x^*,θ_y^*): scattering angle at IP

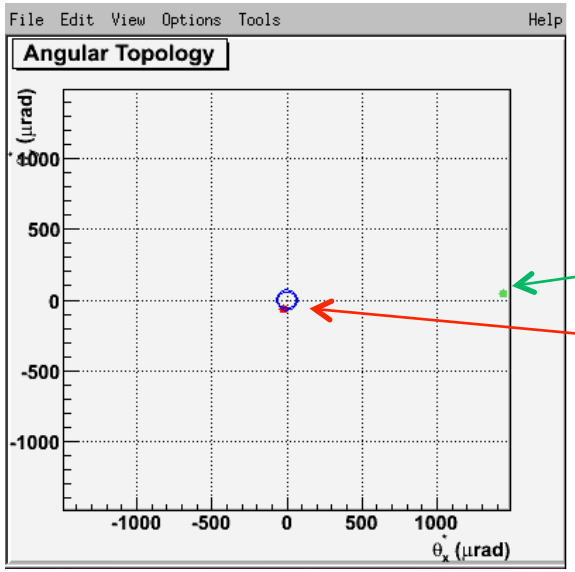
→ **Elastic proton kinematics reconstruction (θ_x^*, θ_y^*):**

$$\begin{cases} \Theta_x^* = \left(\Theta_x - \dfrac{dv_x}{ds}x^*\right) \Big/ \dfrac{dL_x}{ds}, \quad x^* = x / v_x \\ \Theta_y^* = y / L_y \end{cases}$$

L_x, L_y, v_x, v_y (optical functions):

- Describe the explicit path of particles through the magnetic elements as a function of the particle parameters at IP
- Depend on the RP position ***s*** along the beam line
- Depend on LHC machine optics configuration

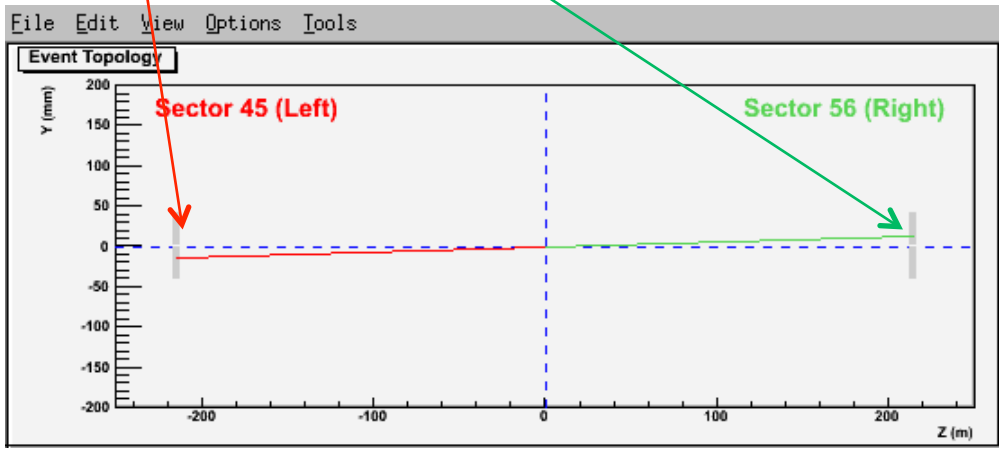
TOTEM Events in RP: Elastic Candidate?



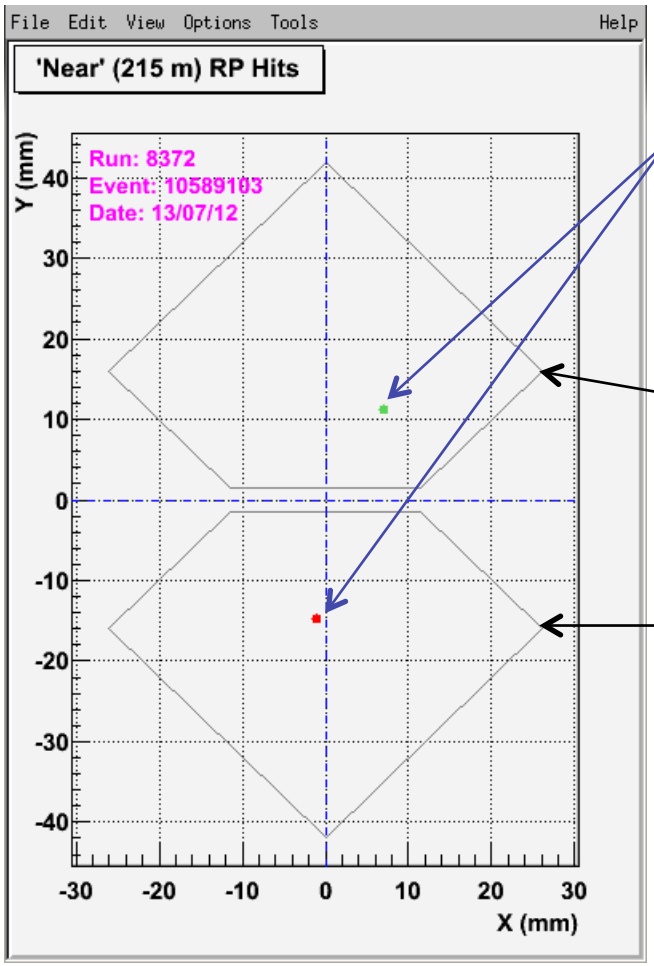
Angular and Event Topologies:

Hit 1

Hit 2



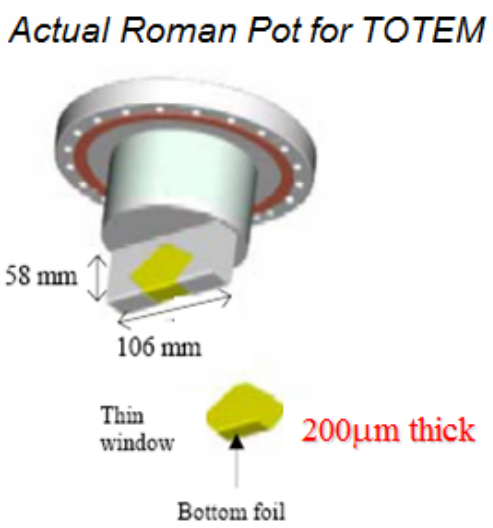
TOTEM Events in RP: Elastic Candidate?



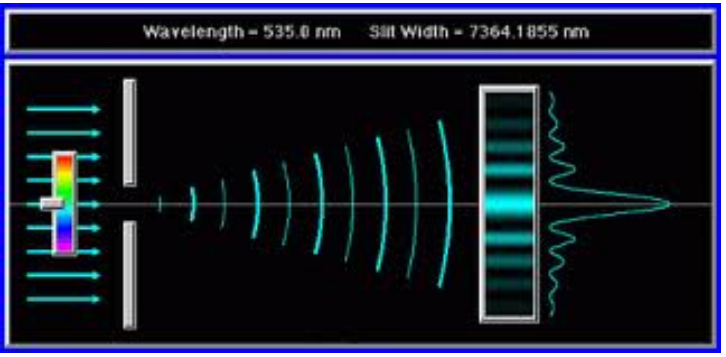
Event Display from Roman Pots: dots show beam "hits" in x-y plane

Upper RP on one side of IP

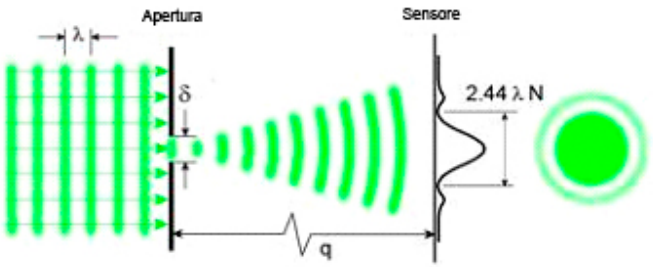
Lower RP on opposite side

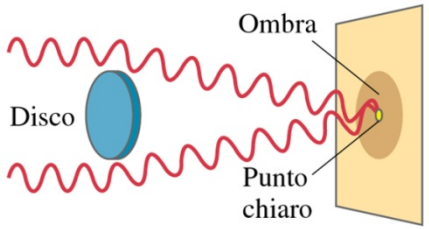


Results "Similar" to Diffraction in Optics



Babinet Principle…





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An example of "wave-particle" duality ?

Anyway: this "behavior" gives the name of diffractive events to these kind of processes in high energy physics