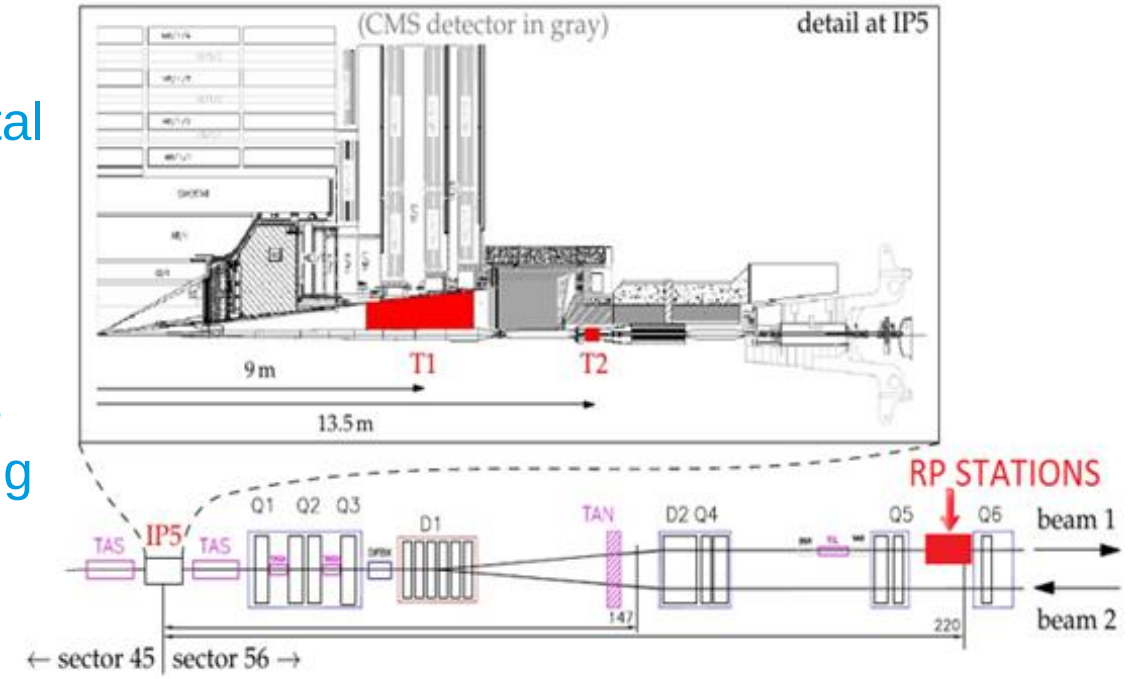
New T2 detector for TOTEM at 13.6 TeV: elastic and inelastic uses

Fredrik Oljemark
Saariselkä, 3.7.2024

HELSINKI INSTITUTE OF PHYSICS

TOTEM inelastic telescopes

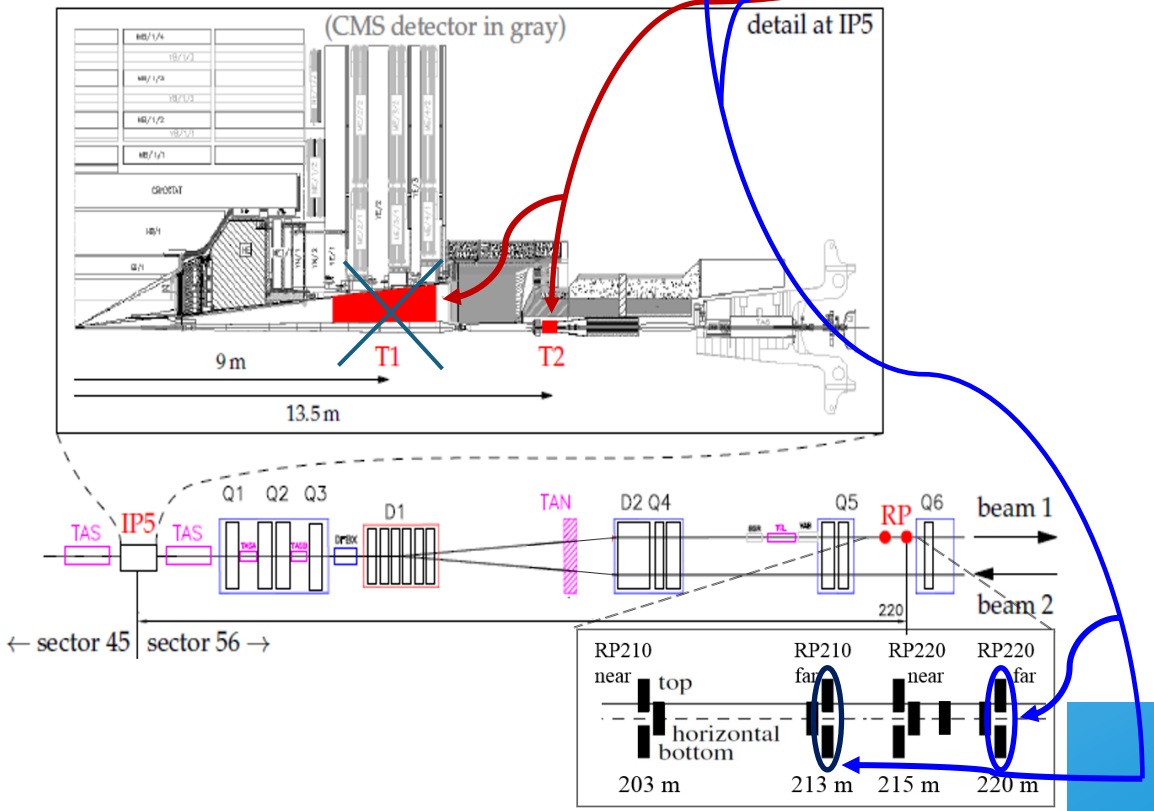
- T1 and T2 telescopes, covered $|\eta|$ = 3.1 – 4.7 and 5.3 – 6.5.
- Used to measure the inelastic event rate for the luminosity independent total cross section measurement. They detect >94% of the inelastic events.
- T2 has been used to measure the charged particle multiplicity at 7 and 8 TeV. It has also been used for requiring rapidity gaps in central exclusive events.
- Removed 2016



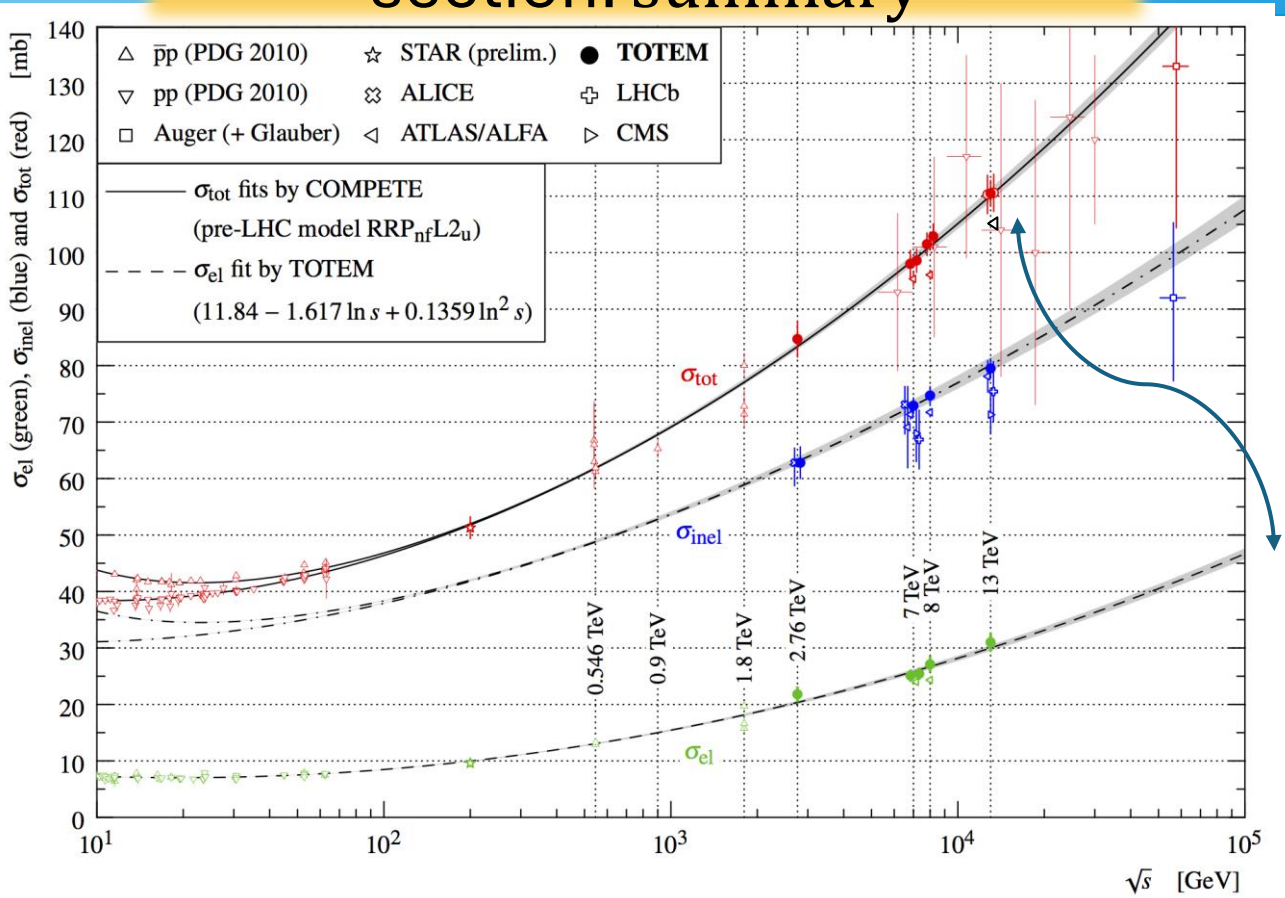
Luminosity independent total cross section

Luminosity independent method:

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



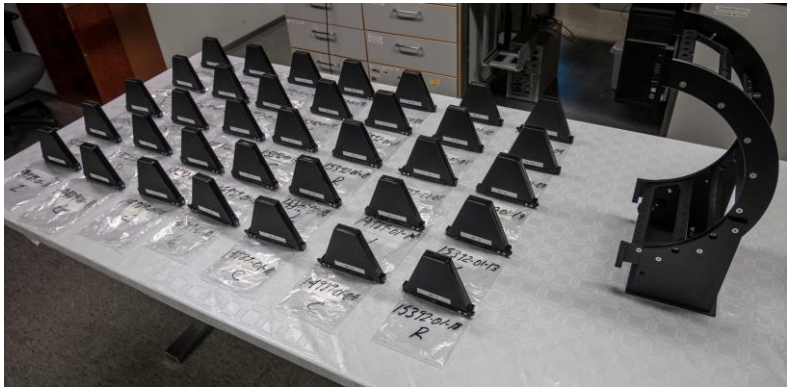
Total pp cross section: summary



Cross section measurement analyses ongoing at 13.6 TeV & 900 GeV

$\sigma_{tot} \propto \ln \sqrt{s} \rightarrow \ln^2 \sqrt{s}$ @ LHC: good agreement with COMPETE preferred model

TOTEM new inelastic telescope

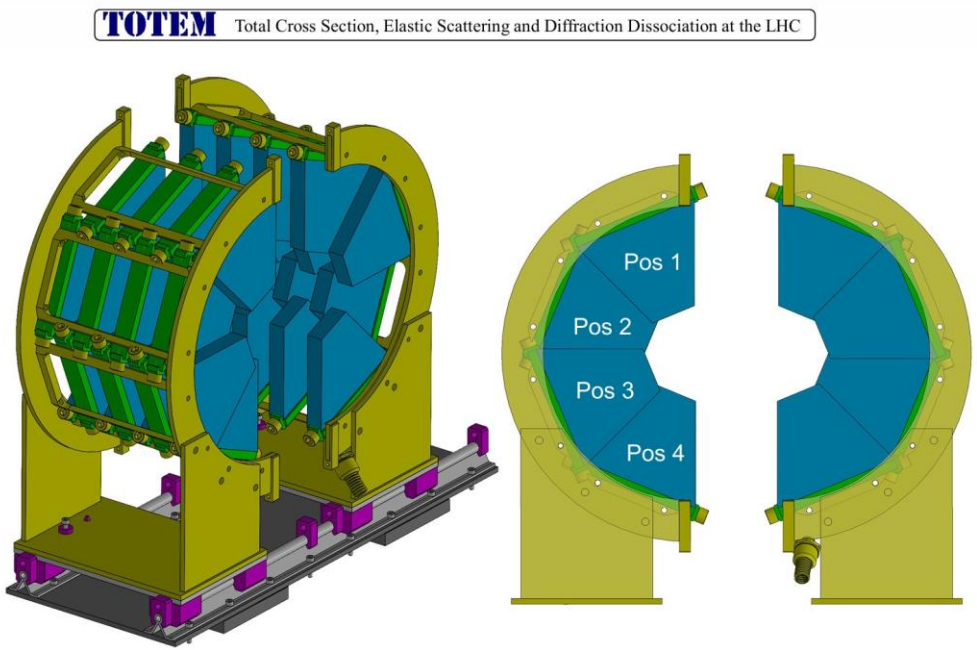


- New T2 telescope, covering same $|\eta| = 5.3 – 6.5$.
- Scintillator tiles, 64 total, produced in Helsinki
- In both arms around CMS, 8 octants * 4 planes per track

- Test-beam after assembly, July 2022

TOTEM new inelastic telescope

- Used during special low-luminosity run at β*=120m as inelastic veto, Midsummer 2023.
- Installed June 2023, removed very soon after run.
- In storage now, discussions about later use in Heavy Ion run?



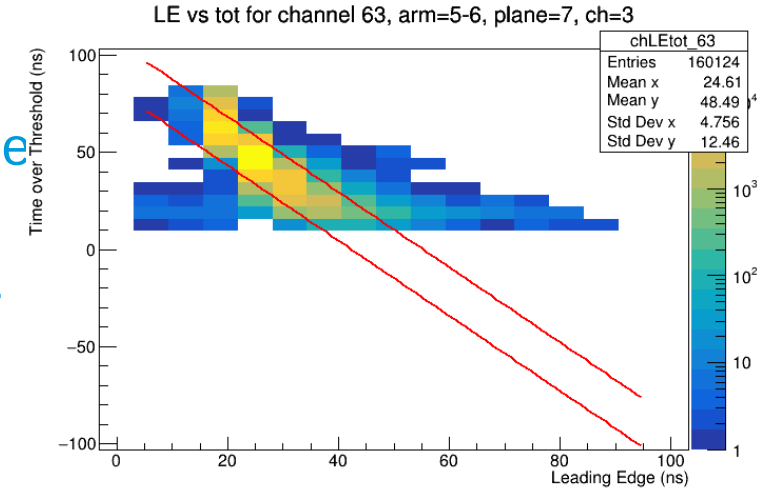
- Scintillator tiles, 8 octants
- Straight tracks, N/4 hits

T2 Track finding in Midsummer ‘23 special run

- Straight tracks only: done in DQM & later offline data analysis
- T2 not used for triggering or veto: Zero Bias readout
- Residual T2 channel noise: require at least 2 planes out of 4.

nT2 background removal veto

- T2 readout electronics output per channel: Signal Leading Edge (LE), Trailing Edge; their difference, Time over Threshold (ToT) is calculated in DQM and offline.
- Fitted straight line to (LE,ToT) profile histograms over range where most of the signal is (fit per nT2 channel)
- Found dispersion in ToT vs slices of LE to be ~0.95*(time resolution, TR=6.25ns), except first bin where it was ~1.2*TR
- Veto background per channel : anything further than 2*TR from best-fit signal line (approximately ±2σ)



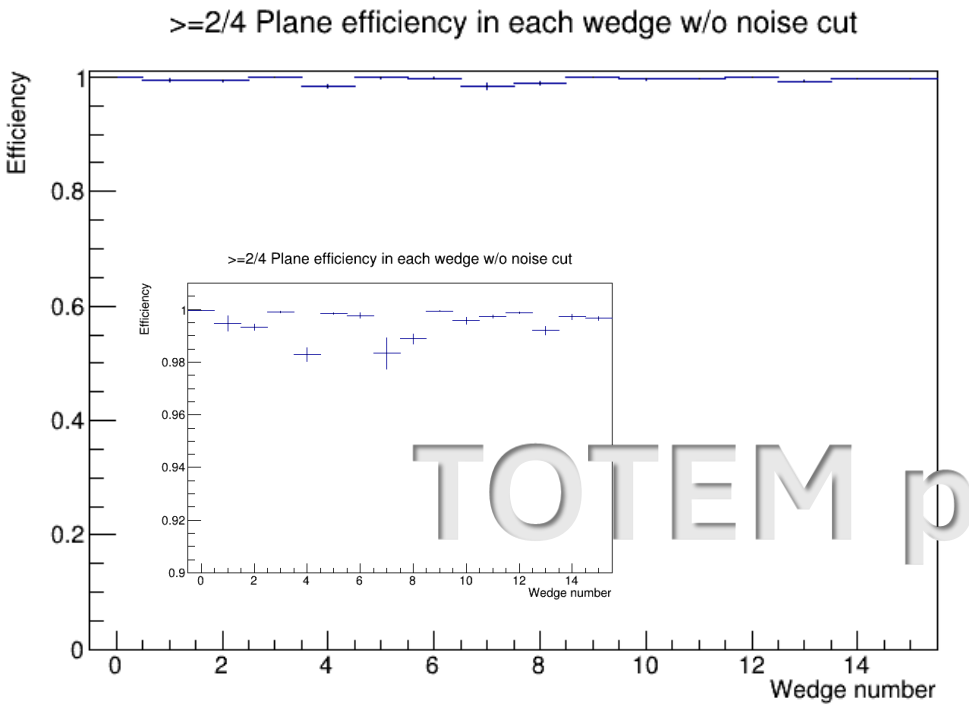
LE vs ToT plotted for one channel, showing veto lines in red.

Multi-plane efficiencies after veto

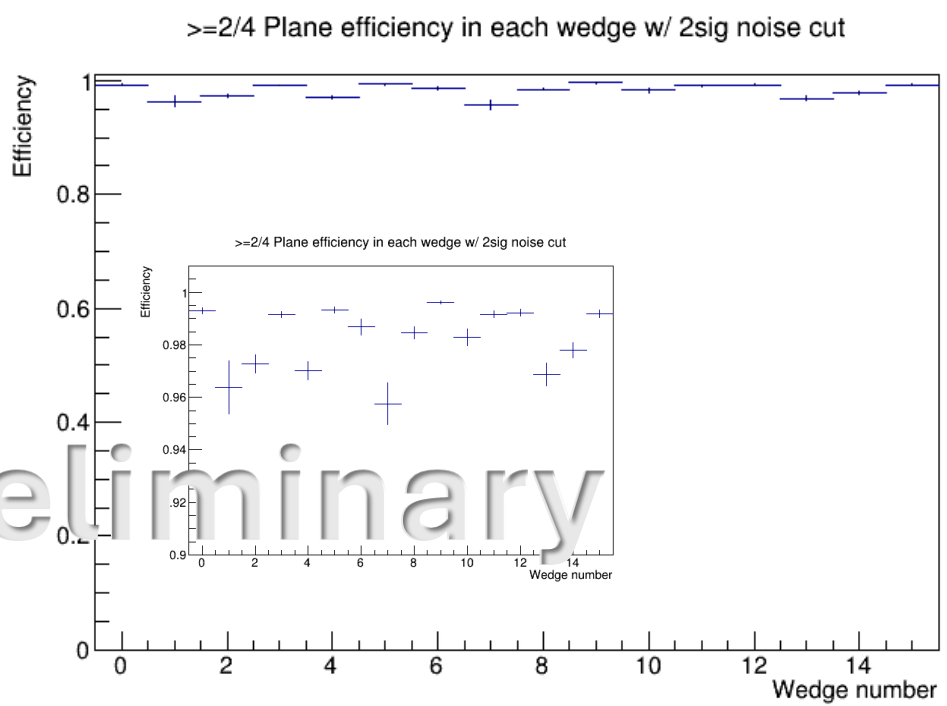
- Compare “tracking” efficiencies before & after background signal removal, for sparse track multiplicity (plot efficiency at 4/16 tracks having multiple hits)
- Assuming independent plane efficiencies, calculate efficiency for ≥2 planes out of 4
- Next two plots based on first physics run of the special run, with 2.8 million events

≥ 2 / 4, 4/16 wedges have 2..4 hits

No background removal: median 99.7%



Background removal: median 98.6%



Comparison with non-colliding bunches

- Non-colliding bunches were dominated by beam-gas interactions with T2 tracks boosted to the same side as the proton seen in our Roman Pot detectors
- Signal-to-noise ratio of track reconstruction increased from <10 to >100 for the “at least 2 out of 4 planes” requirement when comparing T2-RP same side with T2-RP opposite side events
- 2 / 4 planes + background removal is good enough to use with the higher signal-to-noise ratio >>100 for colliding bunches, although signal efficiency went down ~1% to 98.6% (median wedge)

Conclusions

- New T2 detector was assembled and tested in Finland and at CERN test-beam facilities, and successfully took data during a high β^*=120m low-luminosity run, together with Roman Pot vertical detectors, that are sensitive to small t-values (10^{-2} GeV^2 and above in previous 90m runs, exact region of coverage awaiting final analysis)
- Alignment corrections for the moveable RP's still ongoing, as is elastic analysis of β^*=3/6km special TOTEM run in September 2023 that will provide measurements of the total cross section and ρ at 13.6 TeV
- Also ongoing analysis of total cross section and rho for 900 GeV sample taken in 2018
- These were the final runs for TOTEM standalone, data analysis ongoing for the next few years