Alignment of the ATLAS-ALFA detectors

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On behalf of ATLAS Forward Detectors
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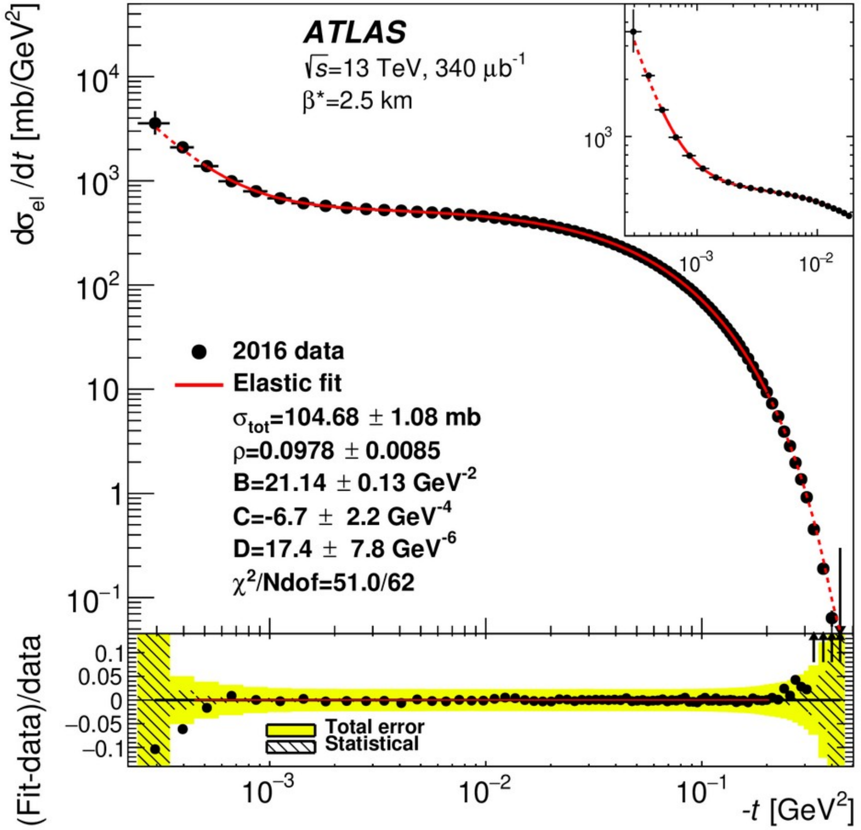
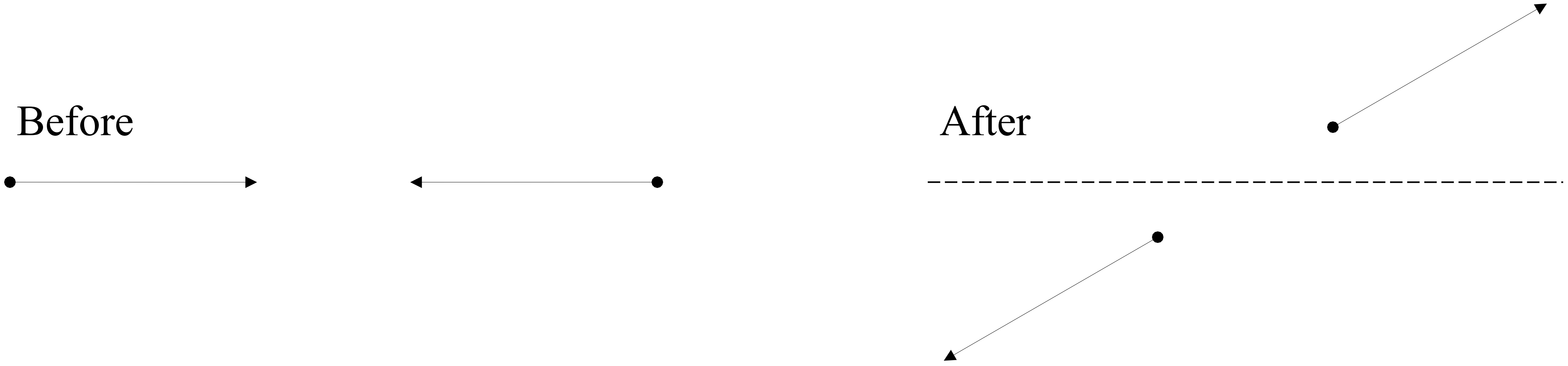


Outline

- Elastic proton-proton scattering
- ALFA detector
- Alignment

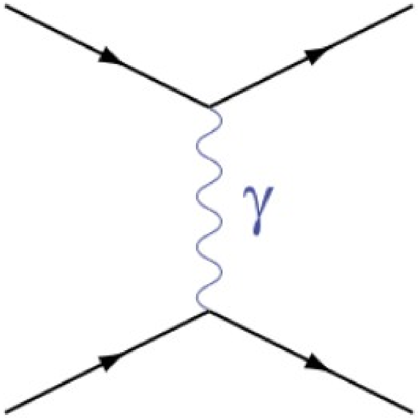
Elastic pp scattering, pp → pp



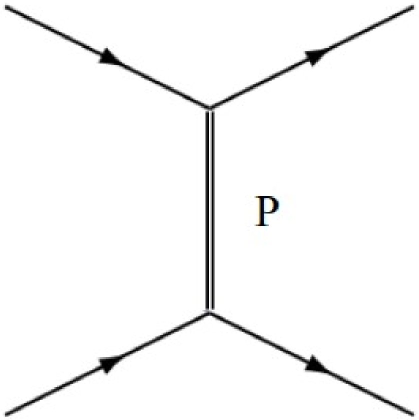
- Energy and momentum conservation
- Two kinematic degrees of freedom: φ (azimuthal angle), θ (scattering angle)
- φ – trivial (uniform)
- $t \approx -p^2\theta^2 = -\, p_T^2$
- Low $|t|$ ≈ large distance, high $|t|$ ≈ small distance

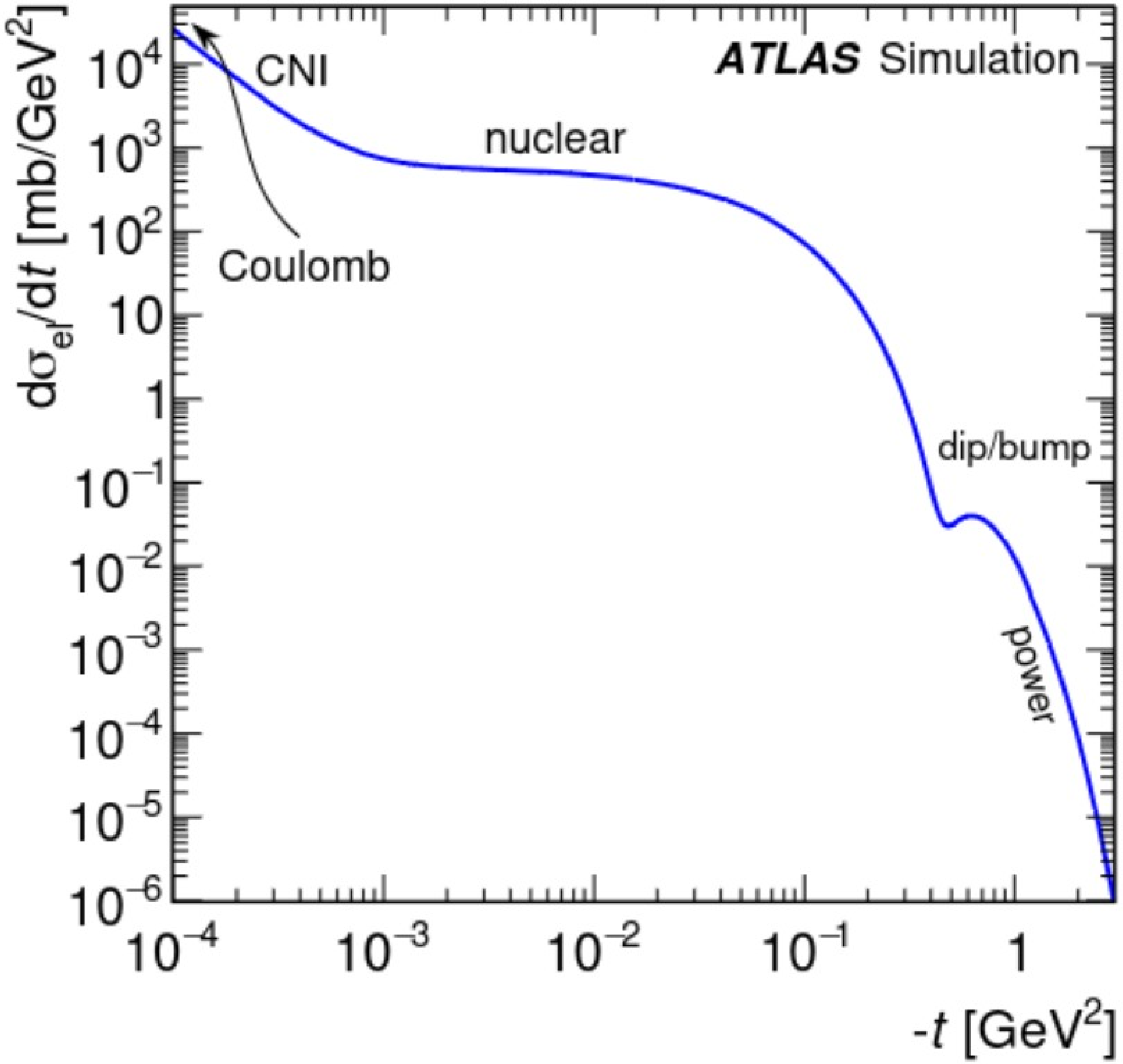
Mechanisms

Coulomb (Electromagnetic)



Nuclear (Strong)





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Differential cross section

$$\frac{d\sigma_{el}}{dt} = \left|F_C(t)e^{i\alpha\phi(t)} + F_N(t)\right|^2$$
$$= \left|-\frac{2\sqrt{\pi}\alpha G^2(t)}{|t|}e^{i\alpha\phi(t)} + (\rho + i)\,\frac{\sigma_{tot}}{4\sqrt{\pi}}e^{-\Omega(t)/2}\right|^2$$
$$= \frac{4\pi\alpha^2 G^4(t)}{|t|^2}$$
$$- \sigma_{tot}\frac{\alpha G^2(t)}{|t|}\left[\rho\cos(\alpha\phi(t)) + \sin(\alpha\phi(t))\right]e^{-\Omega(t)/2}$$
$$+ \sigma_{tot}^2\frac{(\rho^2+1)}{16\pi}e^{-\Omega(t)}\ ,$$

$$\sigma_{tot} = 4\sqrt{\pi}\,\mathrm{Im}F_N(t \to 0)$$

$$\rho \equiv \frac{\mathrm{Re}F_N(t=0)}{\mathrm{Im}F_N(t=0)}$$

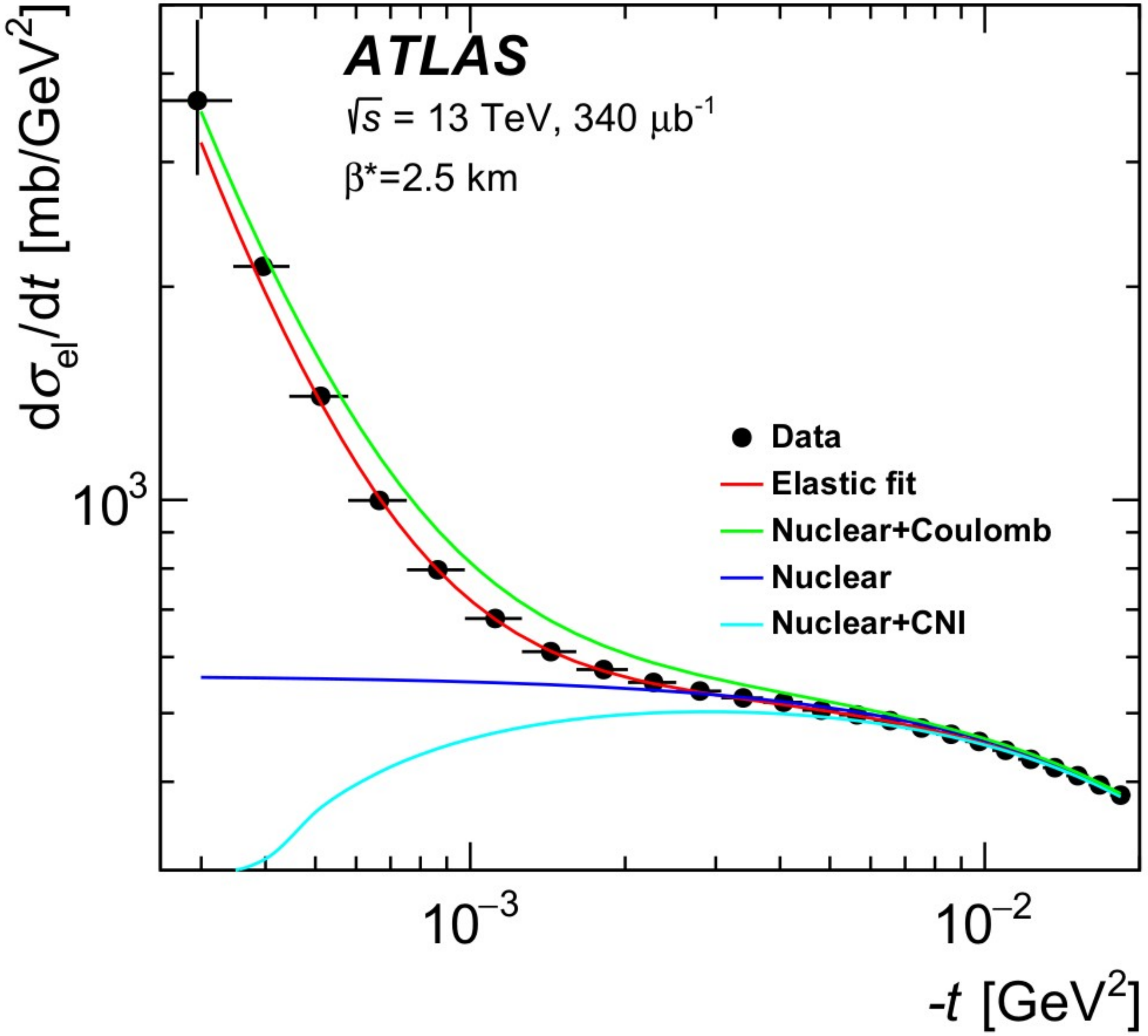
$$G(t) = \left(\frac{\Lambda}{|t| + \Lambda}\right)^2\ , \quad \Lambda = 0.71\ \mathrm{GeV}^2$$

$$\Omega(t) = B|t|$$

$$\phi(t) = -\gamma_E - \ln\left(\frac{B|t|}{2}\right)$$

Differential cross section

$$\frac{\mathrm{d}\sigma_{\mathrm{el}}}{\mathrm{d}t} = \left|F_C(t)e^{i\alpha\phi(t)} + F_N(t)\right|^2$$



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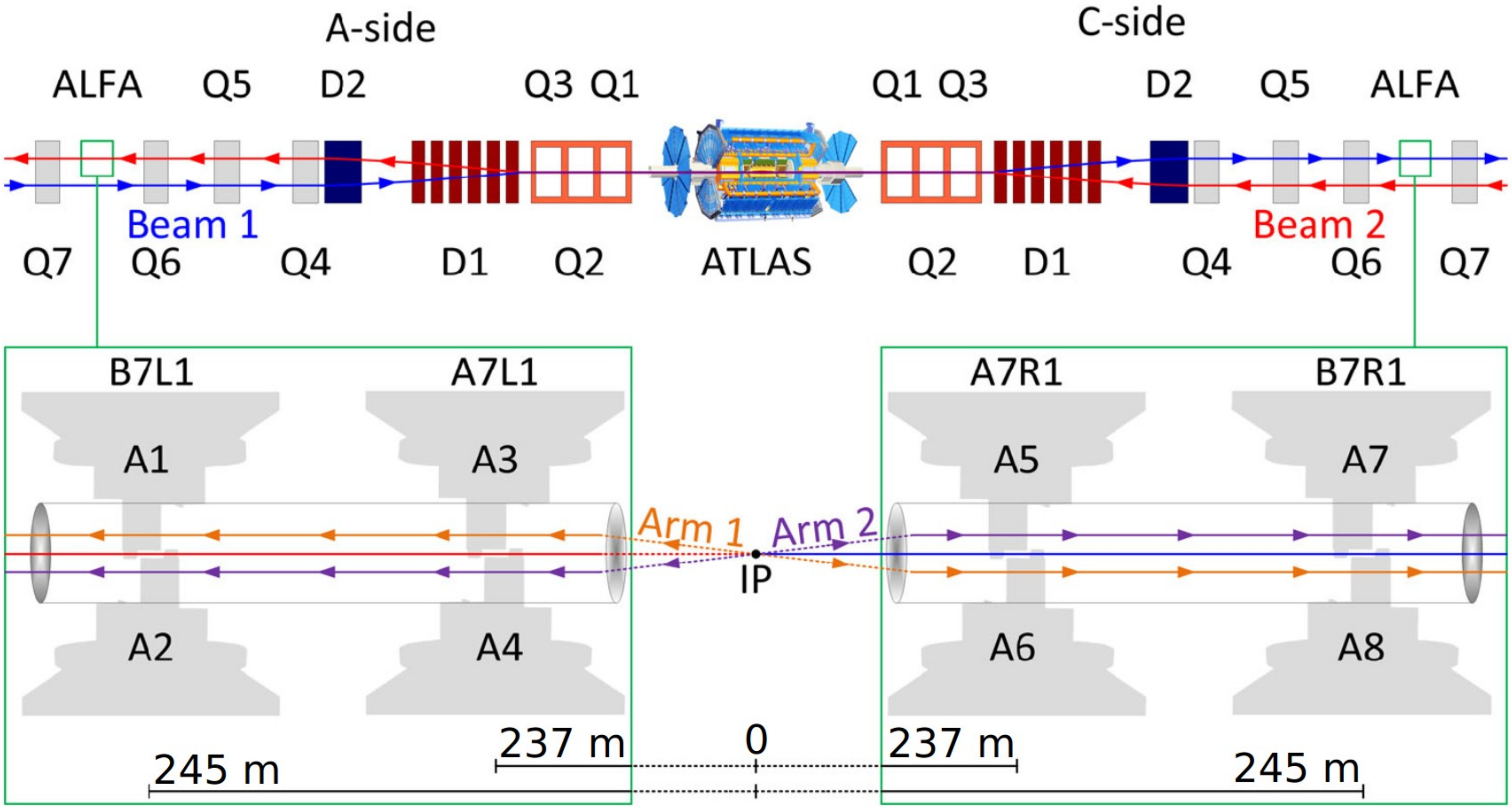
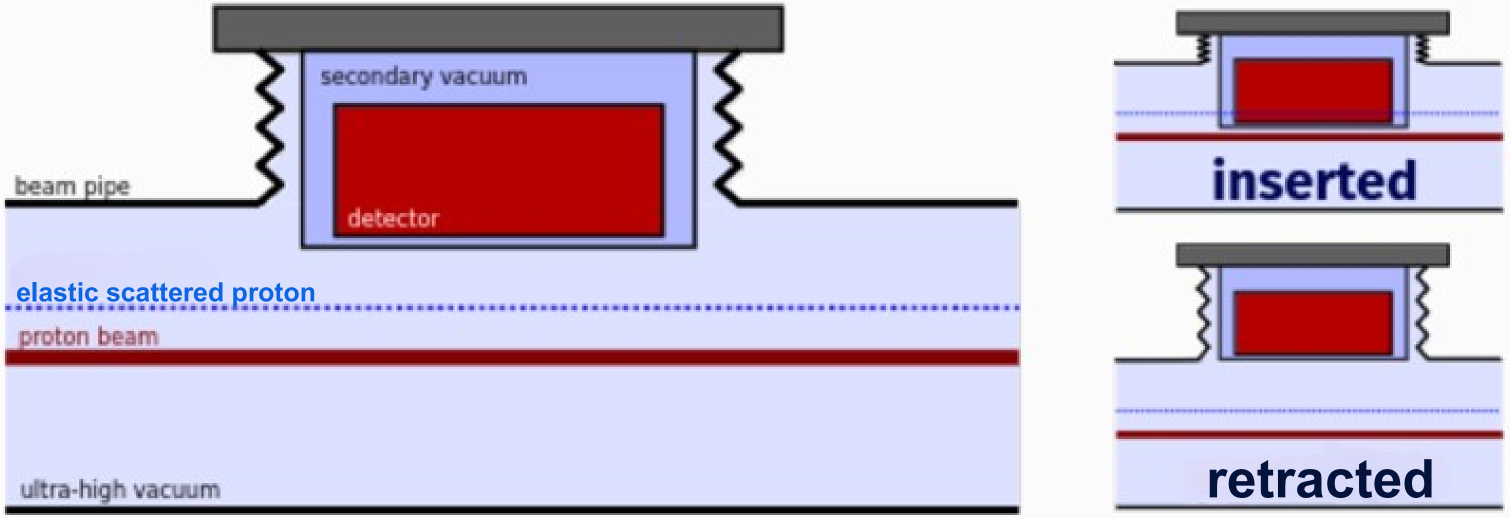
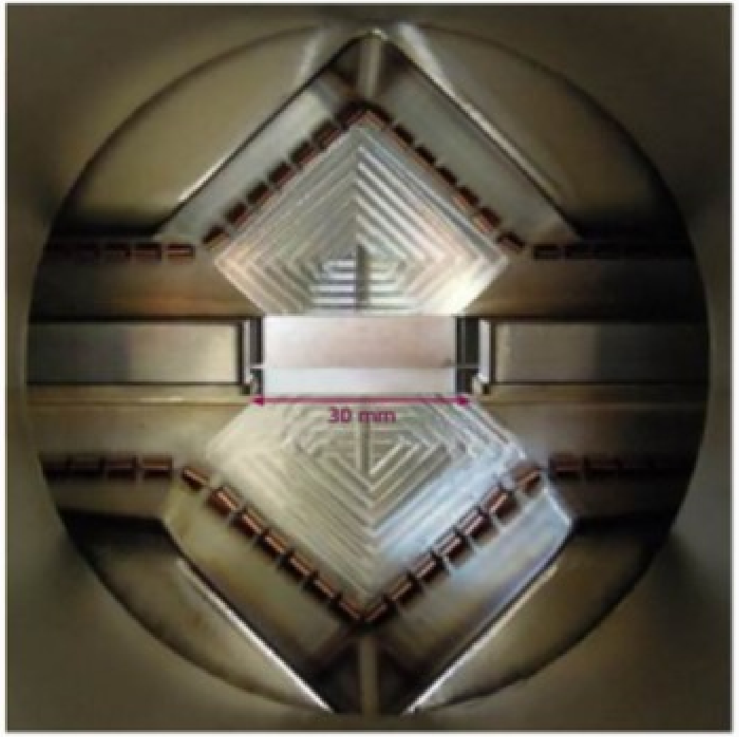
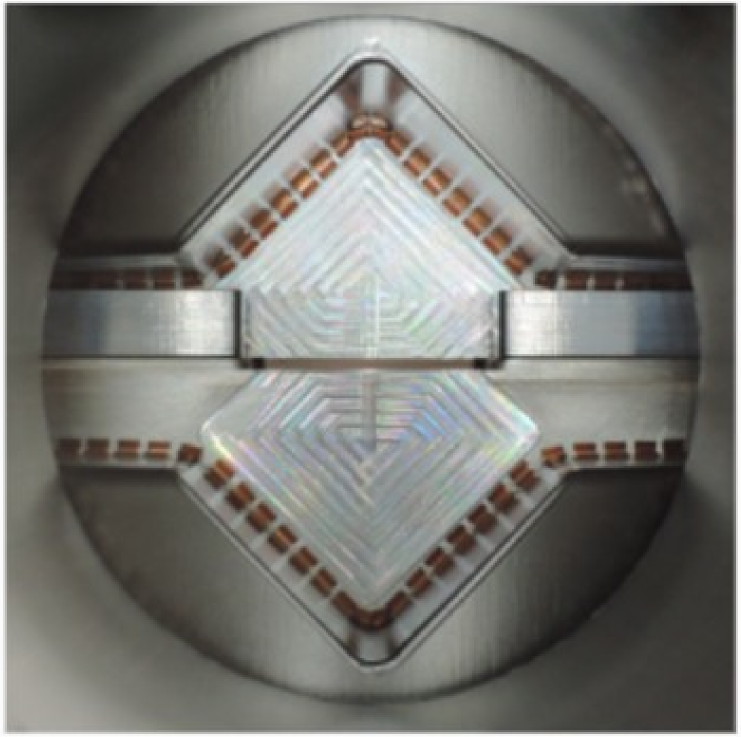
ALFA detector



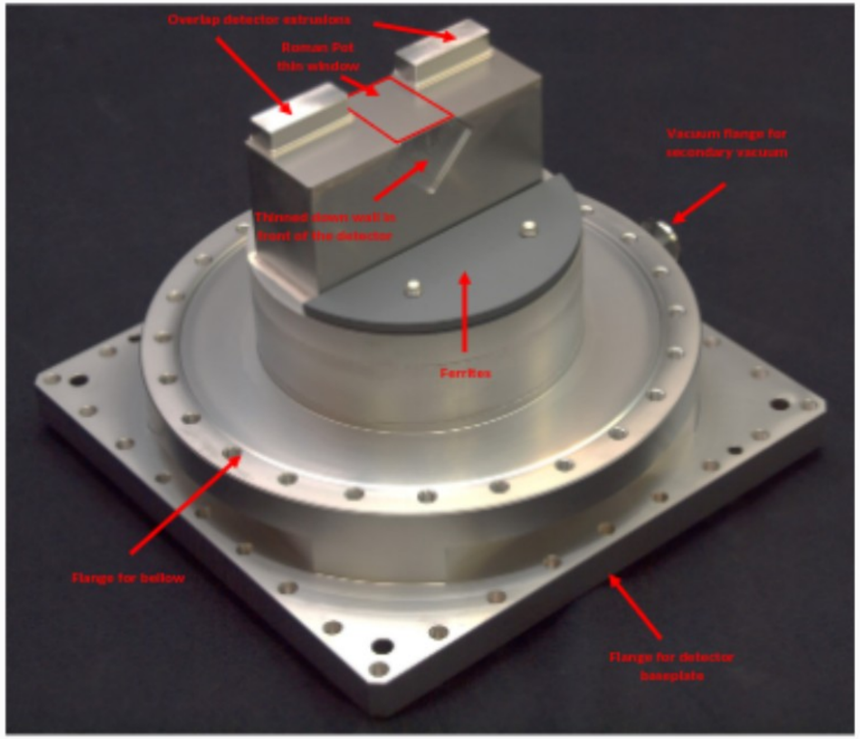
Roman pot mechanism

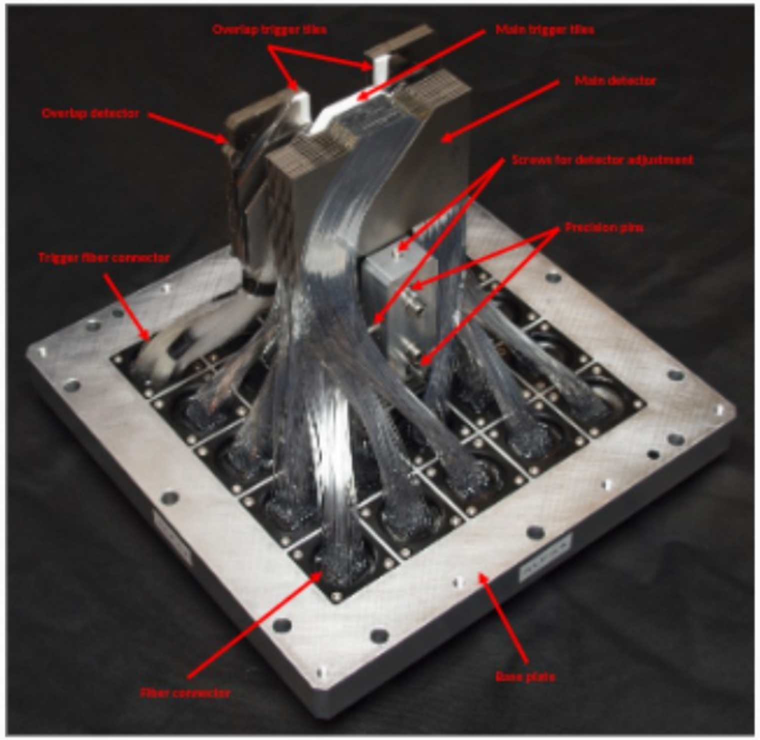


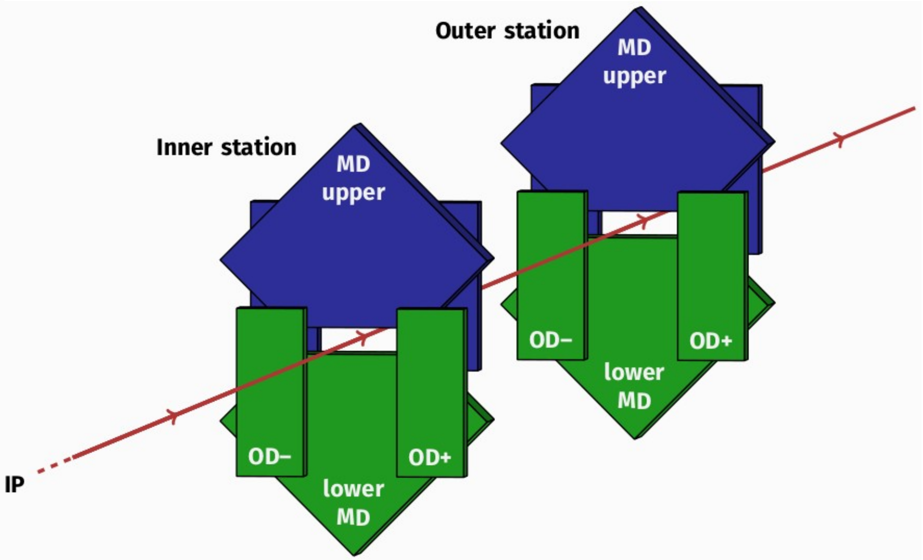




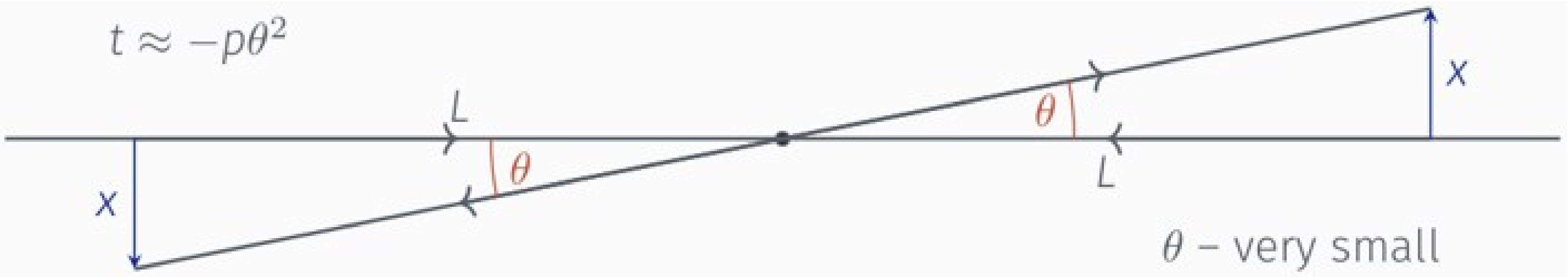
ALFA Roman pot







Measurement principle



No magnetic fields:

$$x = L\theta \qquad \theta_{\text{local}} = \theta^*$$

With magnetic fields

$$x = L_{\text{eff}}\theta \qquad \theta_{\text{local}} \propto \theta^*$$

Finite beam size:

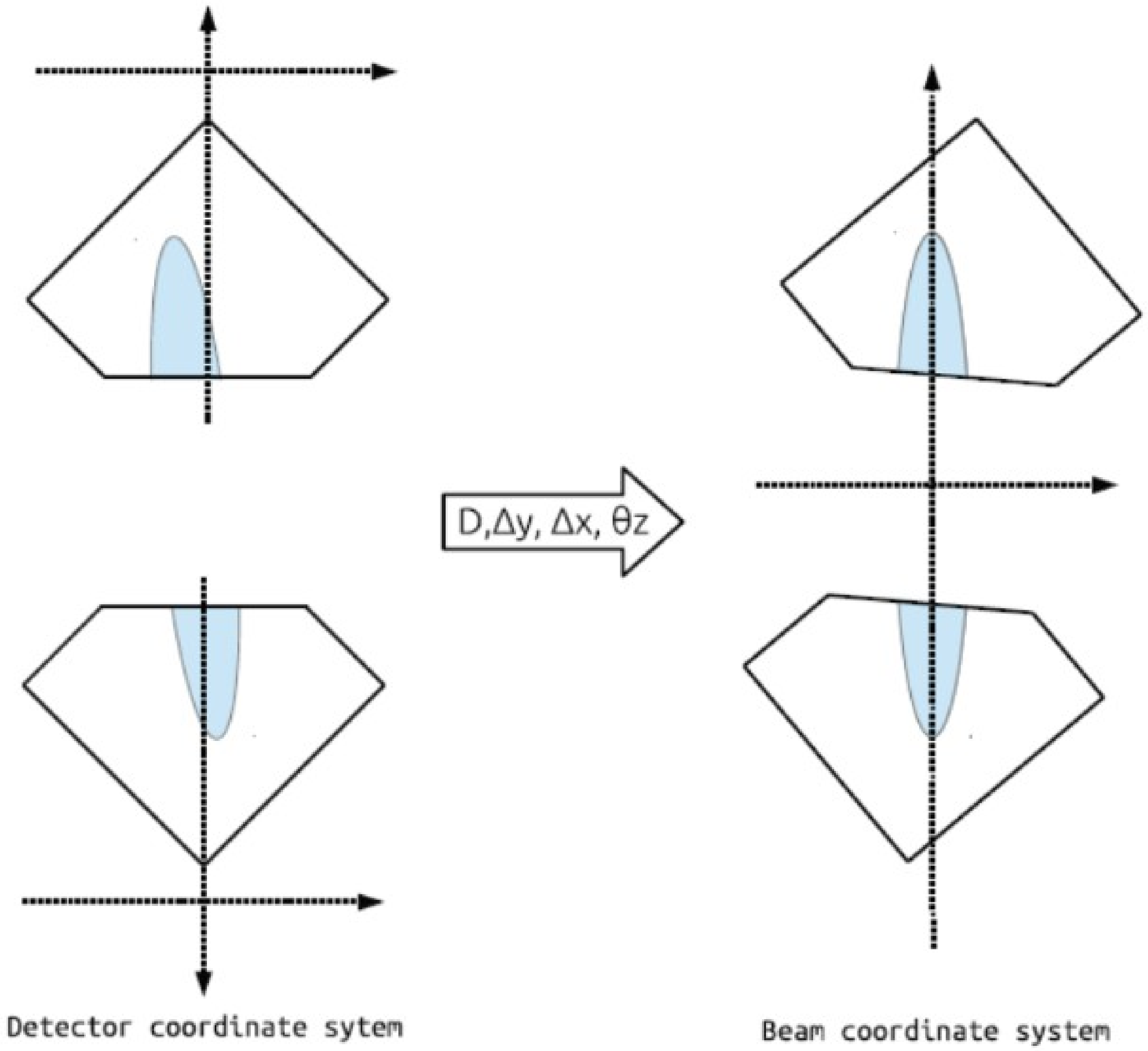
$$\begin{pmatrix} x \\ \theta_x \end{pmatrix} = \begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix} \begin{pmatrix} x_0 \\ \theta_x^* \end{pmatrix}$$

$$(\theta, \varphi) \leftrightarrow (\theta_x, \theta_y)$$

$$\begin{pmatrix} x \\ \theta_x \end{pmatrix} = \begin{pmatrix} M_{11}^x & M_{12}^x \\ M_{21}^x & M_{22}^x \end{pmatrix} \begin{pmatrix} x_0 \\ \theta_x^* \end{pmatrix}$$

$$\begin{pmatrix} y \\ \theta_y \end{pmatrix} = \begin{pmatrix} M_{11}^y & M_{12}^y \\ M_{21}^y & M_{22}^y \end{pmatrix} \begin{pmatrix} y_0 \\ \theta_y^* \end{pmatrix}$$

ALFA alignment parameters



D : Distance between upper and lower detectors

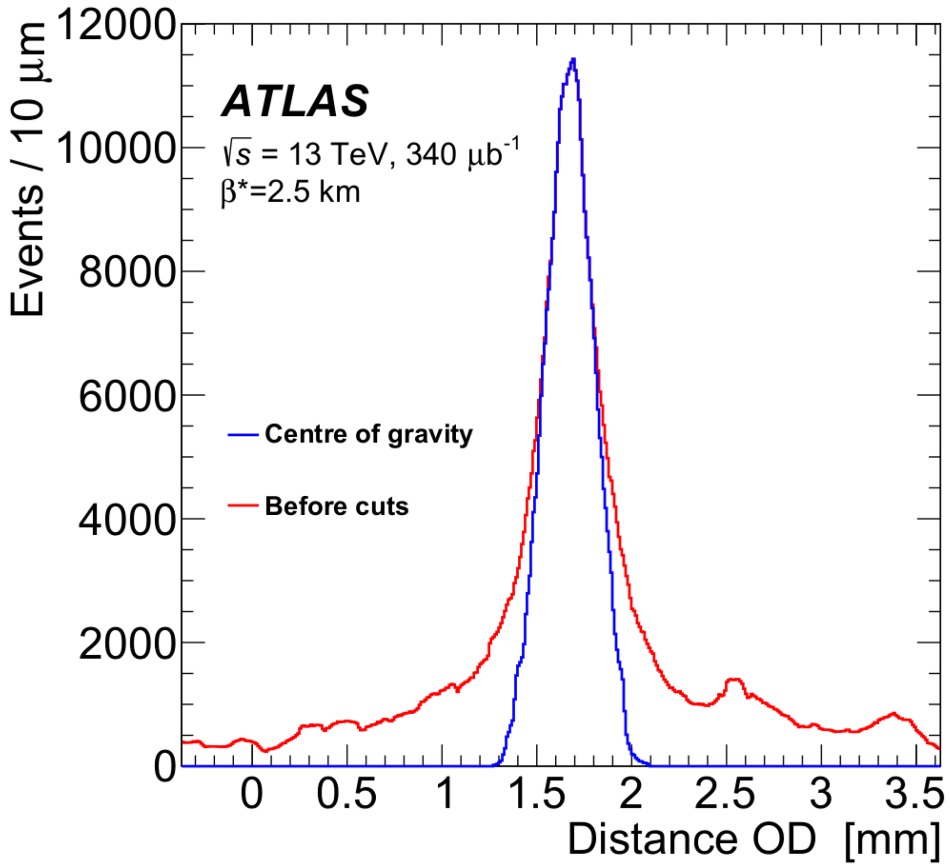
Δy : Vertical offset

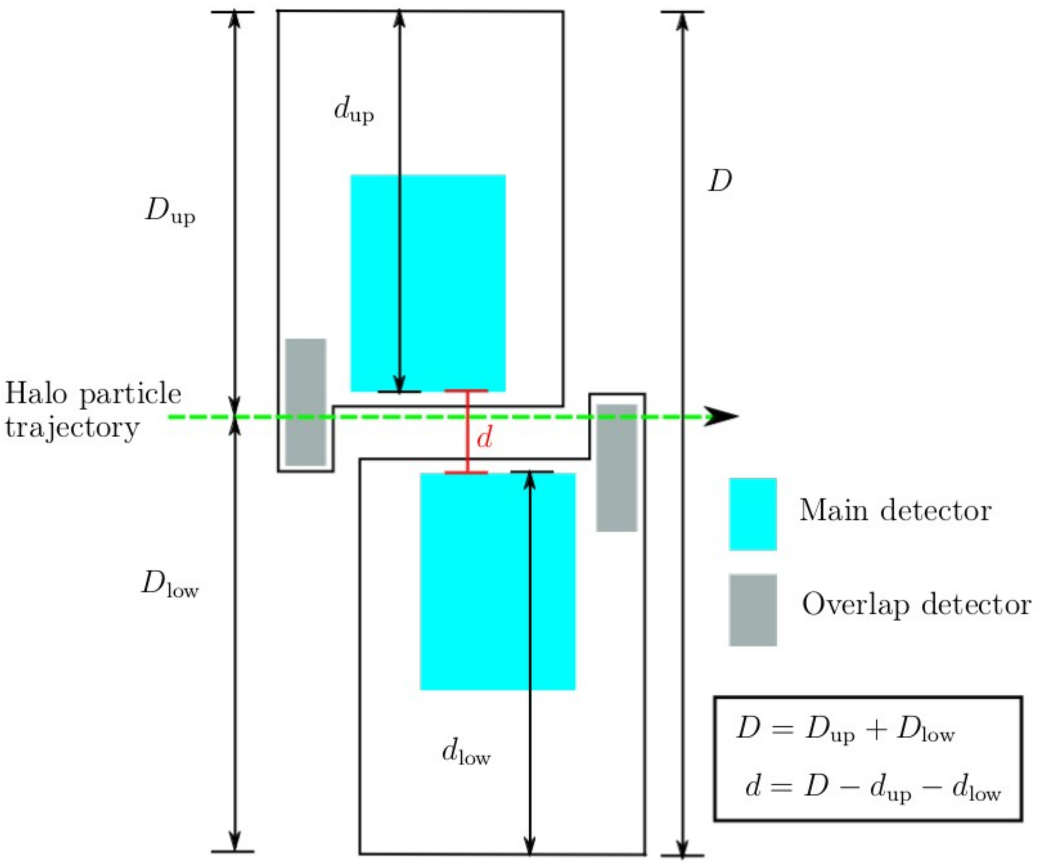
Δx : Horizontal offset

θz : Rotation around z axis

Distance measurement

- The OD is designed to measure the vertical coordinate of traversing beam-halo particles or shower fragments.
- Halo particles originate from beam particles which left the bunch structure of the beam but still circulate in the beam pipe.
- These halo particles hit fibers in upper and lower OD in the ALFA station with the same vertical position. The measured positions can be used to determine the distance "d" between upper and lower MD.





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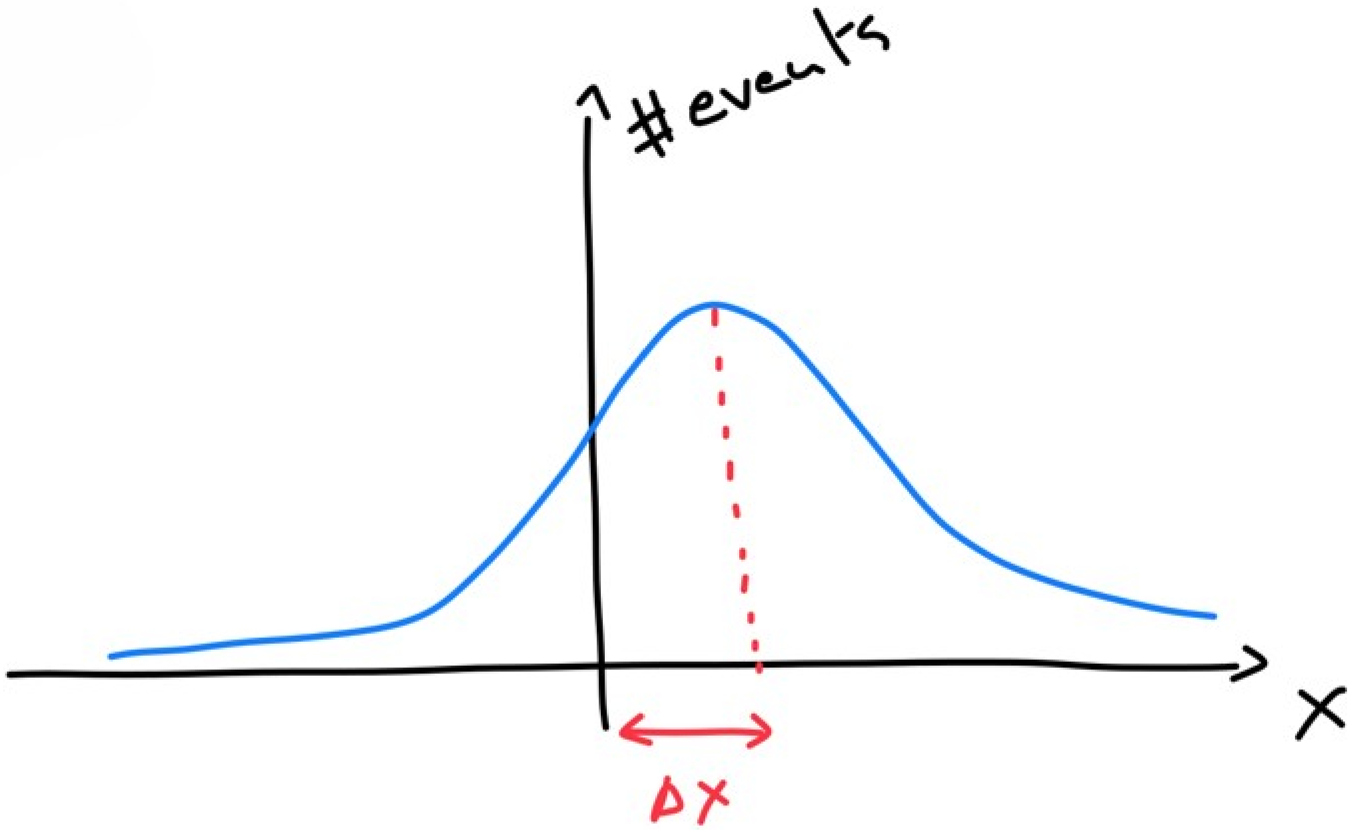
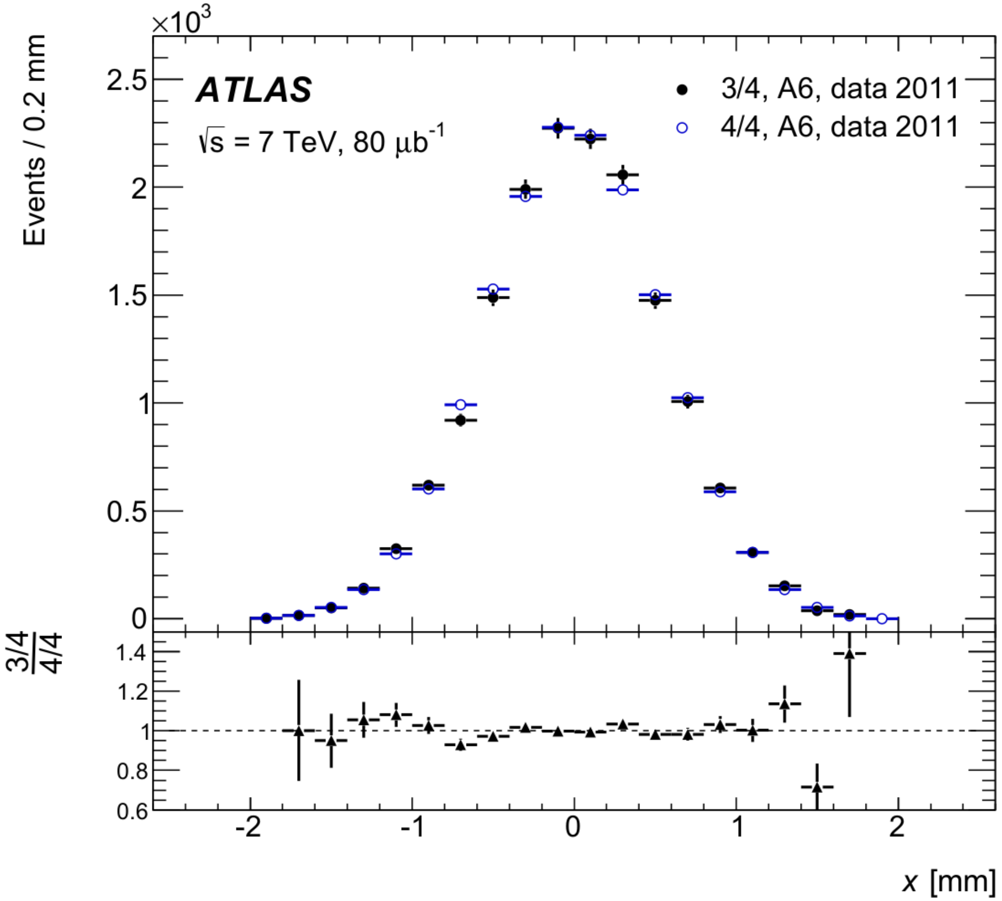
Horizontal alignment

- The mean value of the distribution of horizontal position of elastic protons is used for horizontal offset estimation.
- In this method, the mean value considered as a correction, and added to the previous ones.
- After a few iterations, when for different detectors these corrections became so small or the values of horizontal offset converged to a fix number, the procedure would stop.





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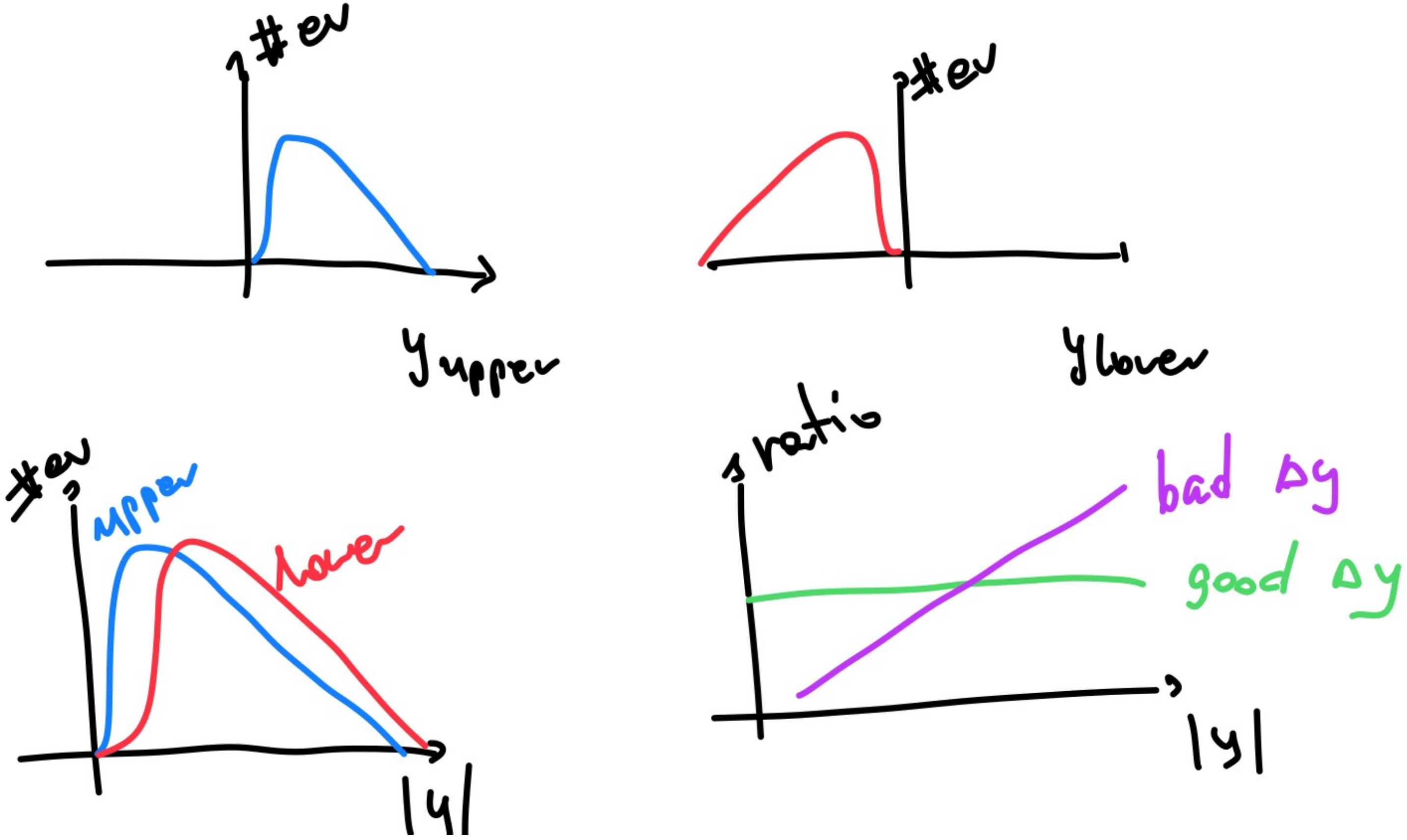
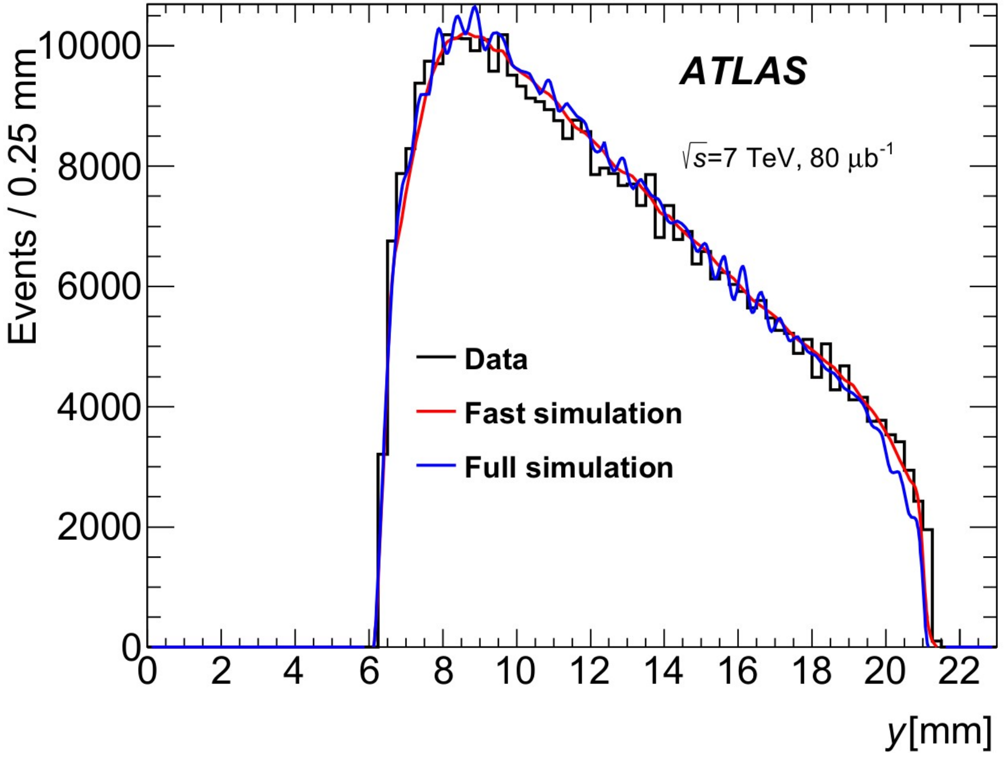
Vertical alignment

- In each station, the detectors are aligned if both of the distributions of vertical position of elastic protons are overlapping in the selected range.
- For this, the lower detector is shifted to the left or right while the upper detector is fixed as to achieve a constant ratio between distributions, because inclination indicates misaligned detectors.
- The shift is a measure of vertical offset between the center of the ALFA station with respect to the actual beam position.
- For implementation, the slope of fitting line to the ratio between vertical distribution of upper detector and vertical distribution of lower detector with a negative sign is considered, while the vertical distribution of lower detector could shift to the left or right completely as much as size of a bin times number of shifts.





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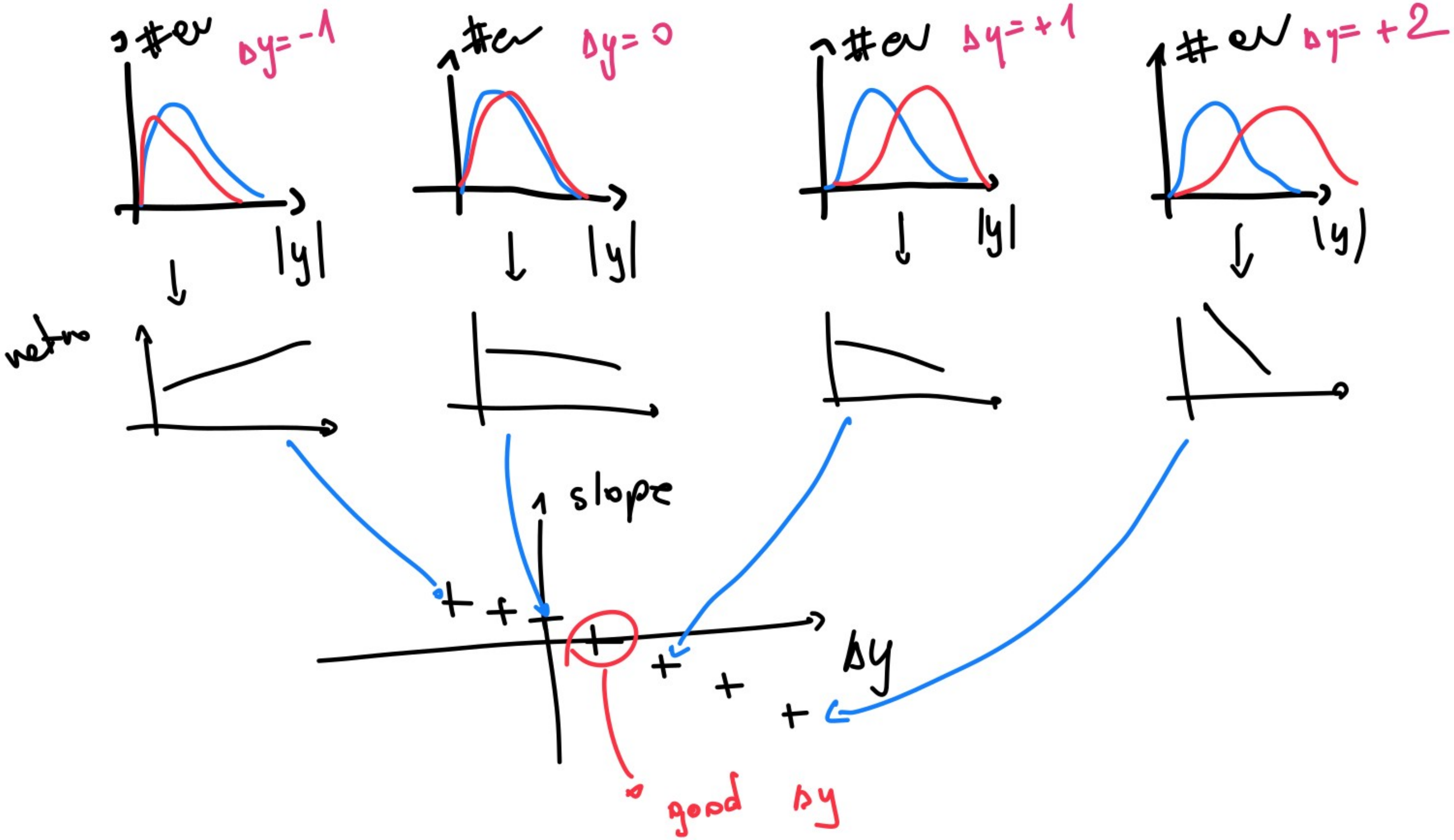
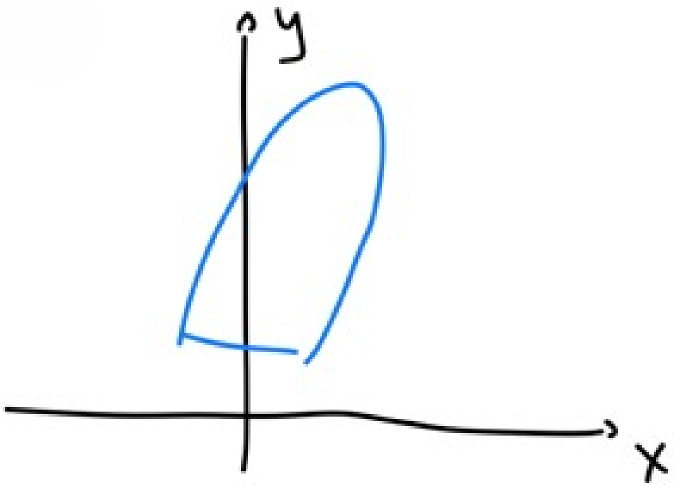
Vertical alignment

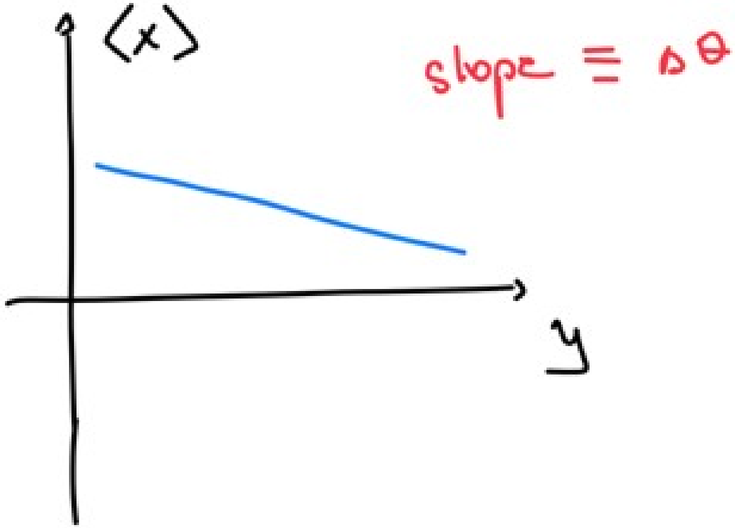
- So, we can have plot of slopes in terms of shifts.
- In the next step, the slope of fitting line to the plot of slope vs shift is considered as a correction, and added to the previous one, after multiplying to the half of size of bin with negative sign.
- After a few iterations, when for different stations these corrections became small and alternating, or the value of vertical offset converged to a fix number, the procedure would stop.

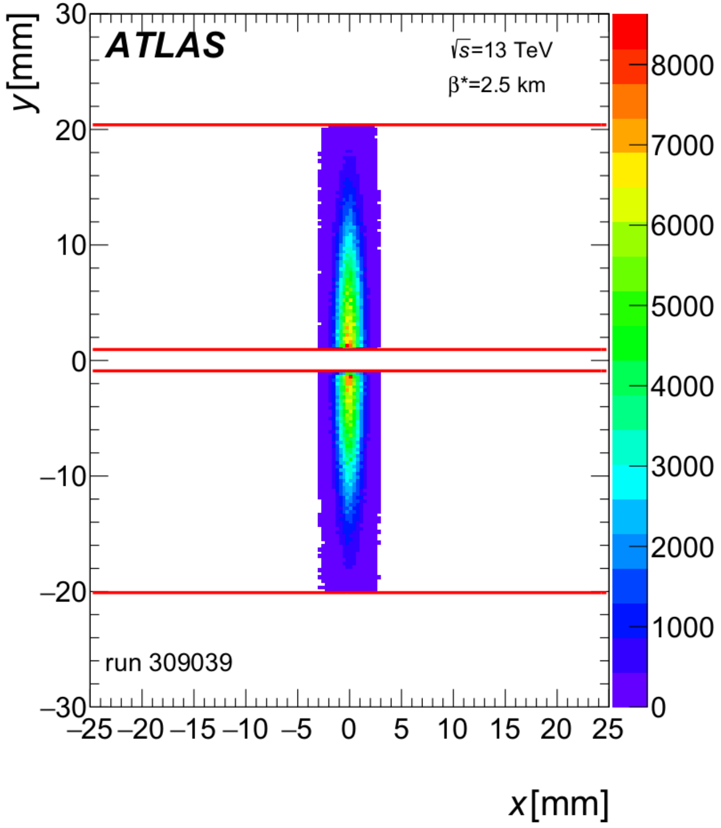


Rotational alignment

- Tangent inverse of the slope of linear fit to the correlations between the vertical position and average horizontal position indicates the rotation angle θz of the detector.
- In this method, the rotation angle θz considered as a correction, and added to the previous ones.
- After a few iterations, when for different detectors these corrections became so small or the values of the rotation angle θz converged to a fix number, the procedure would stop.







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Summary

- The physics behind elastic proton-proton scattering was explained.
- The experimental set-up of the ATLAS-ALFA detector system was presented.
- The concepts of distance measurement, horizontal and vertical alignments, as well as rotational alignment, were investigated.
- In my analysis, I am working on the alignment of the data from $\sqrt{(s)} = 900$ GeV and $\beta^* = 11$ m campaign.


Thank You
Vinaka
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Asante
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감사합니다
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Manana
Dankon
Dank Je
Mauruuru
Biyan
Diolch i Chi
Terima Kasih
Matondo
Taiku
Tack
Blagodaram
Dziekuje
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Grazie
Juspaxar
Arigato
Mochchakkeram
நன்றி
धन्यवाद
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谢谢
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Go Raibh Maith Agat
Eskerrik Asko
Salamat
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