

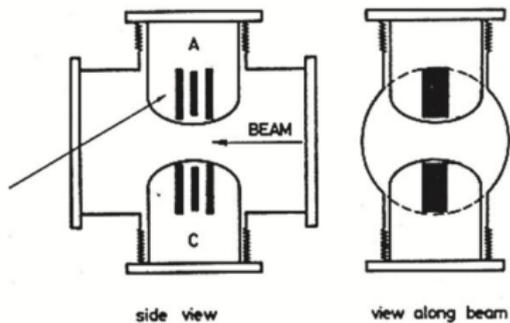
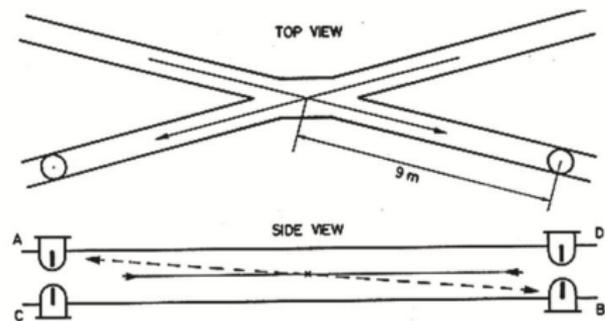
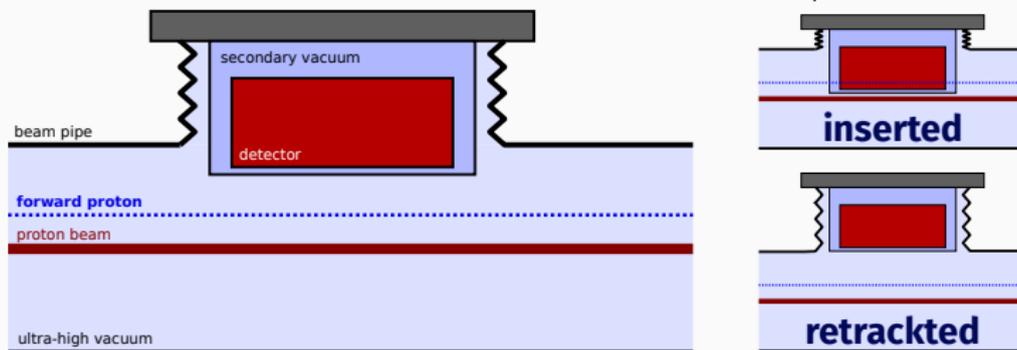
Forward proton physics at LHC

Rafał Staszewski (IFJ PAN Cracow)

supported in part by Polish National Science Centre NCN project no 2021/42/E/ST2/00350

DIS 2023, 27 March – 1 April 2023, MSU

Roman pots



Roman pot insertion



Adapted from Maciej Trzebiński, CERN Detector Seminar, 1 December 2017

Roman pot insertion



Adapted from Maciej Trzebiński, CERN Detector Seminar, 1 December 2017

Roman pot insertion



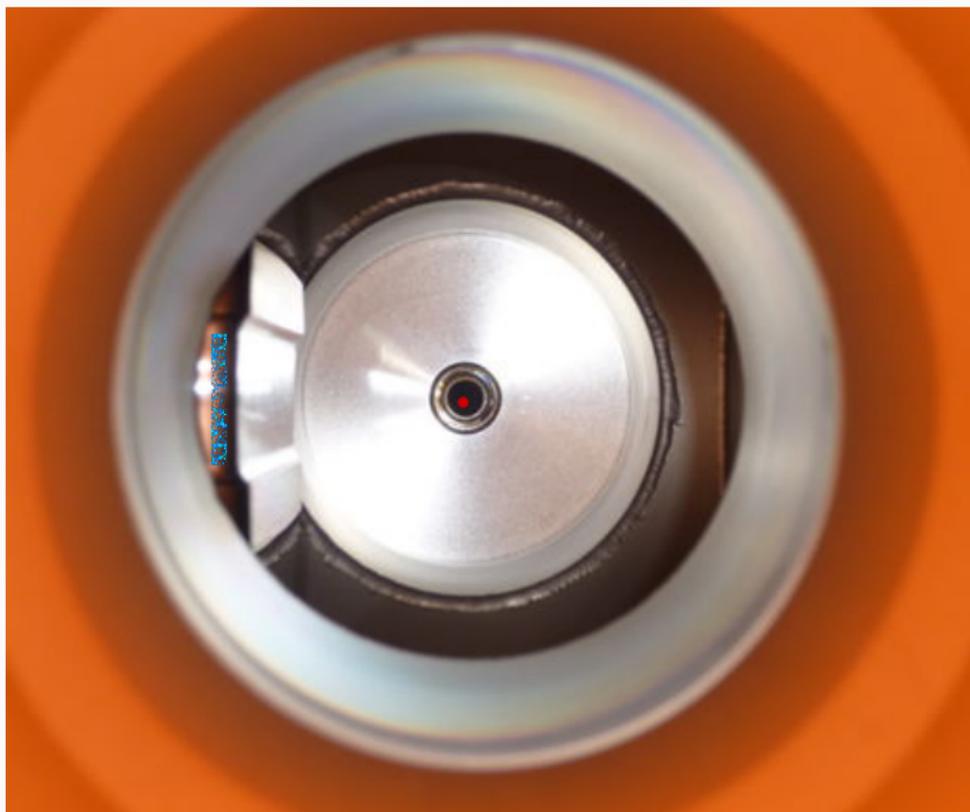
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Roman pot insertion



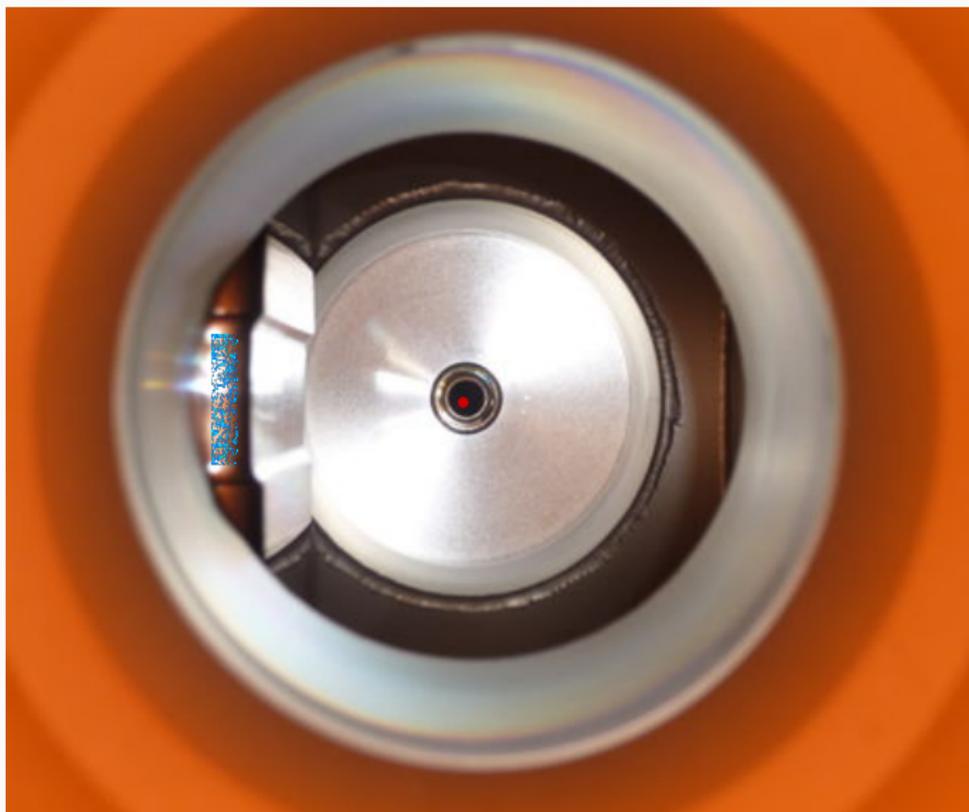
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Roman pot insertion



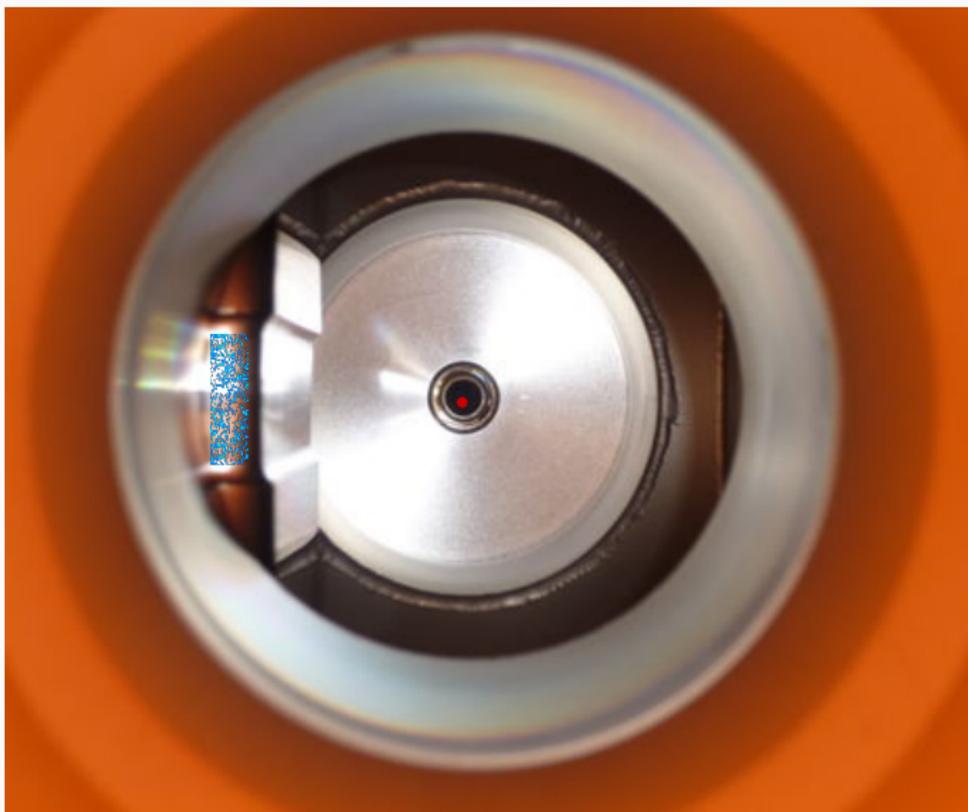
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Roman pot insertion



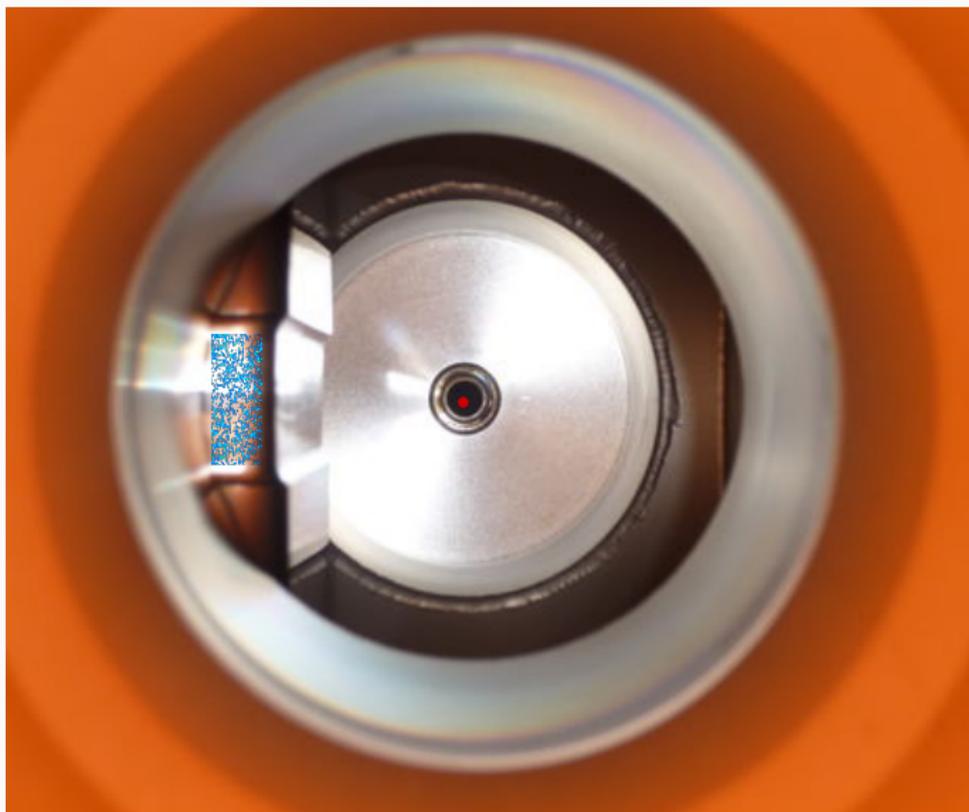
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Roman pot insertion



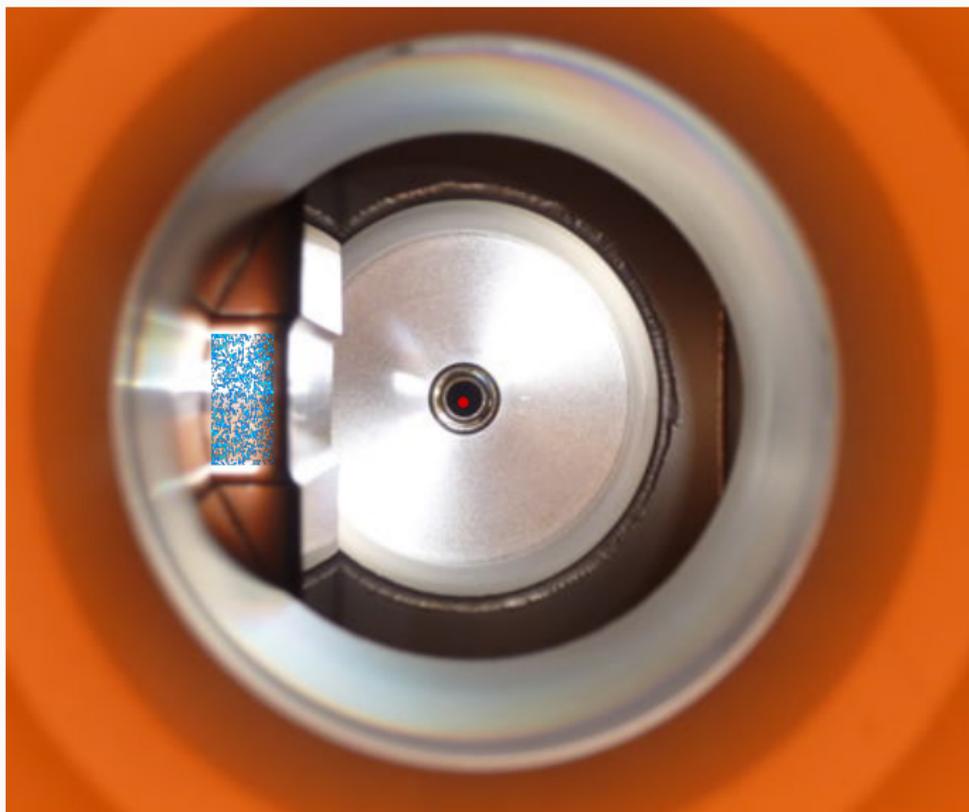
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Roman pot insertion



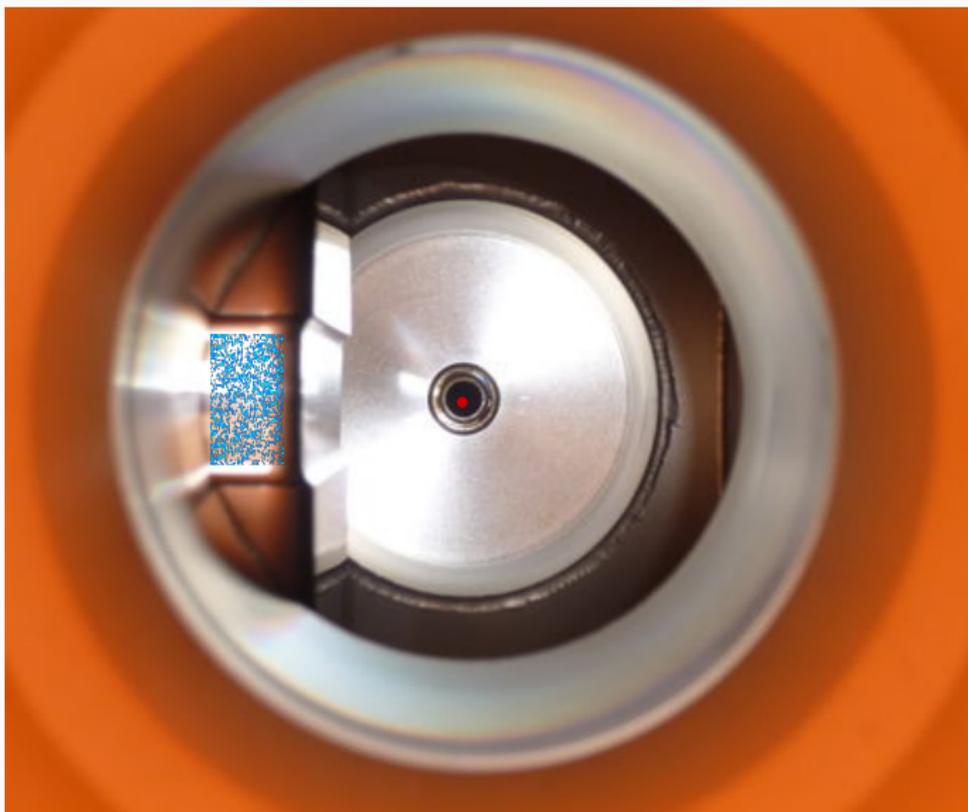
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Roman pot insertion



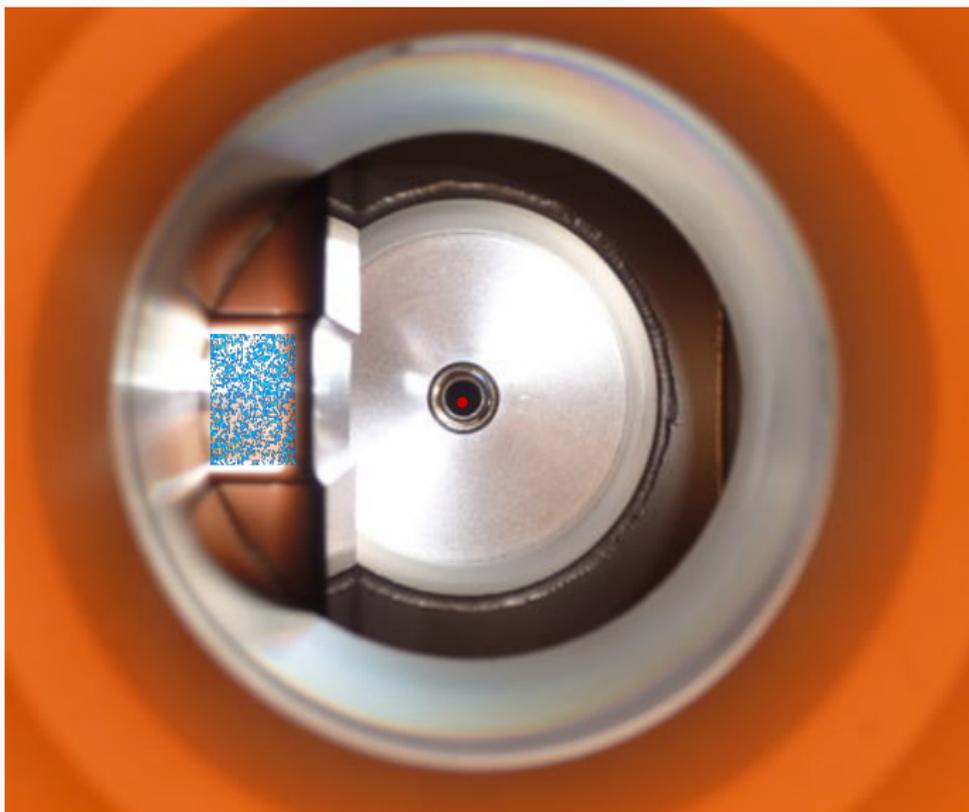
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Roman pot insertion



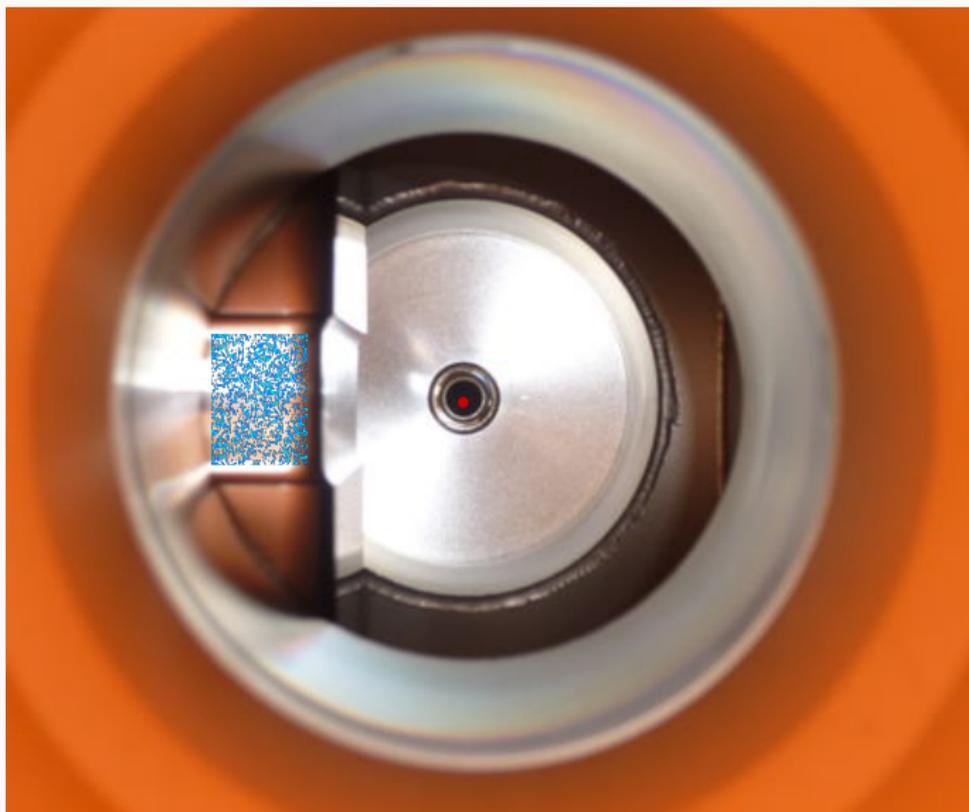
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Roman pot insertion



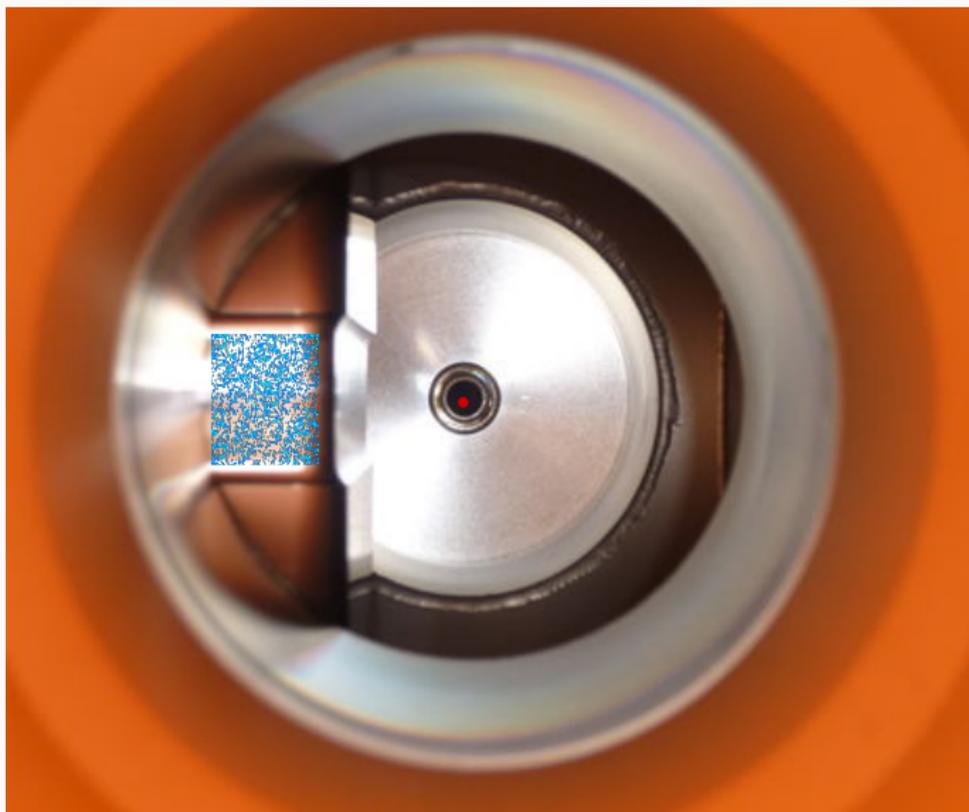
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Roman pot insertion



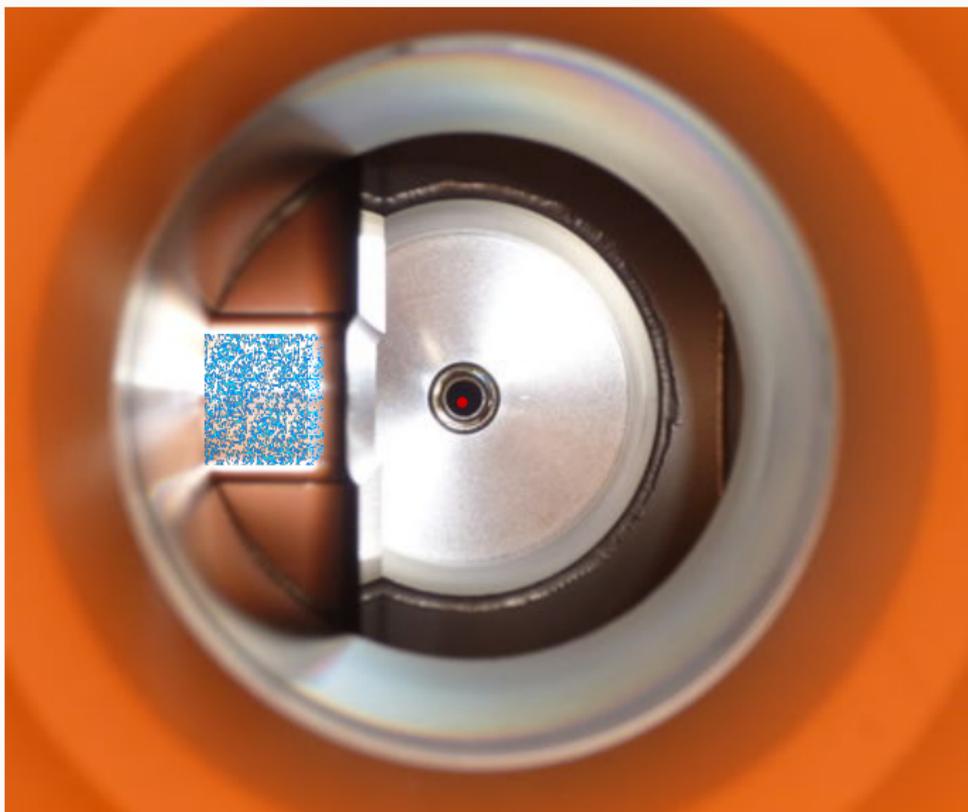
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Roman pot insertion



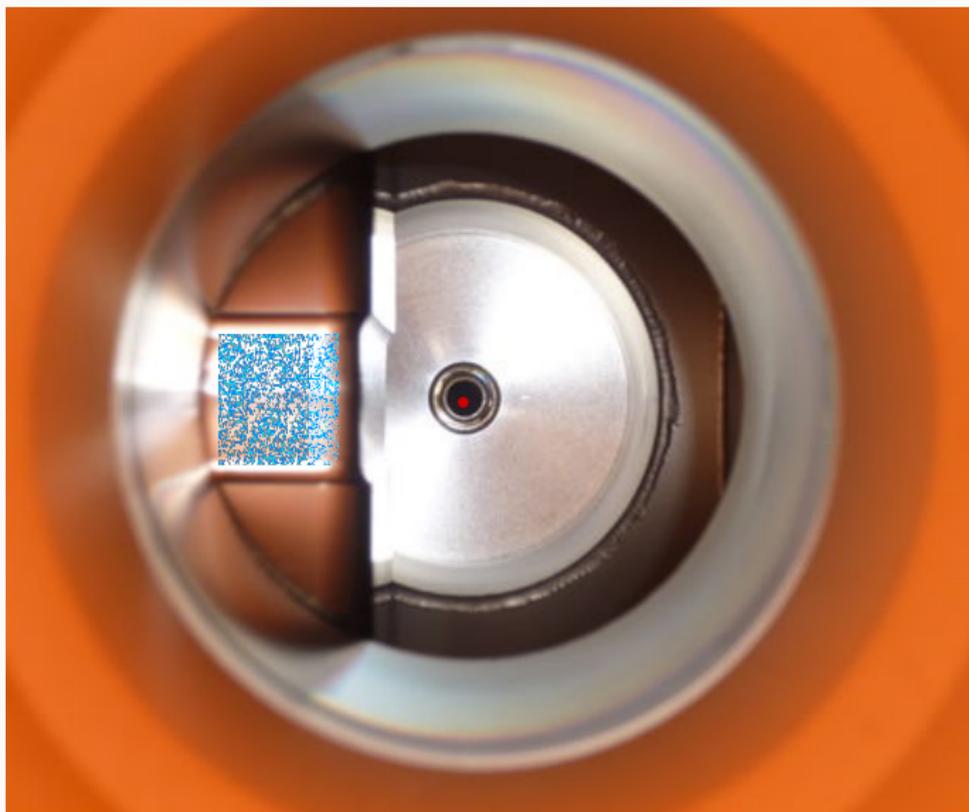
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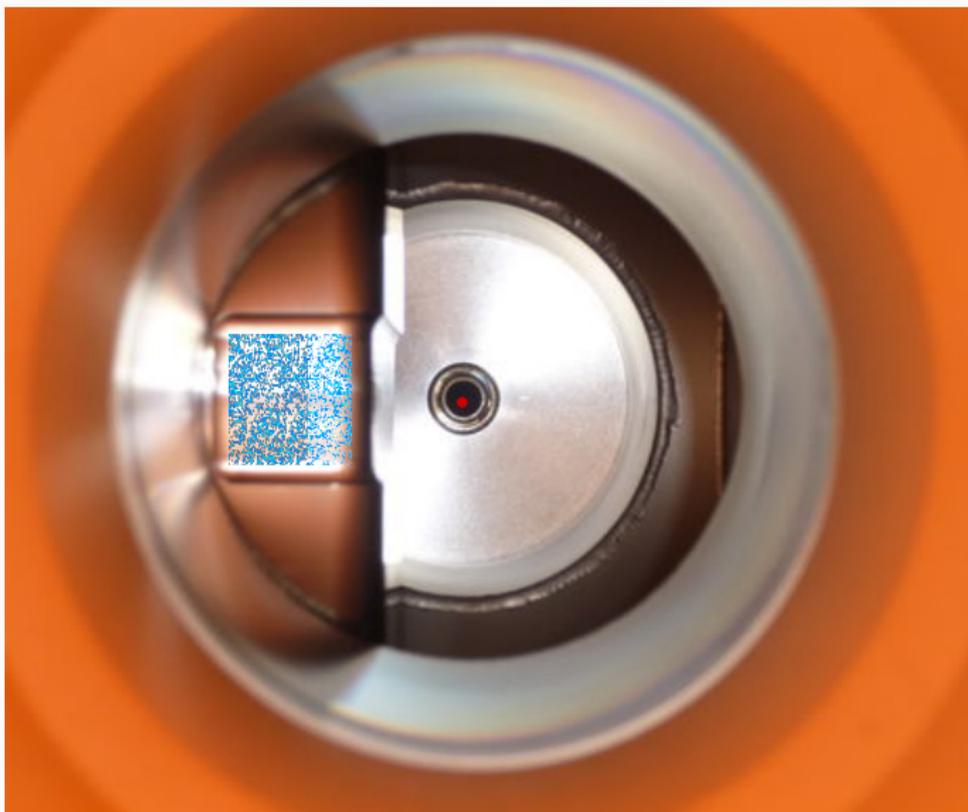
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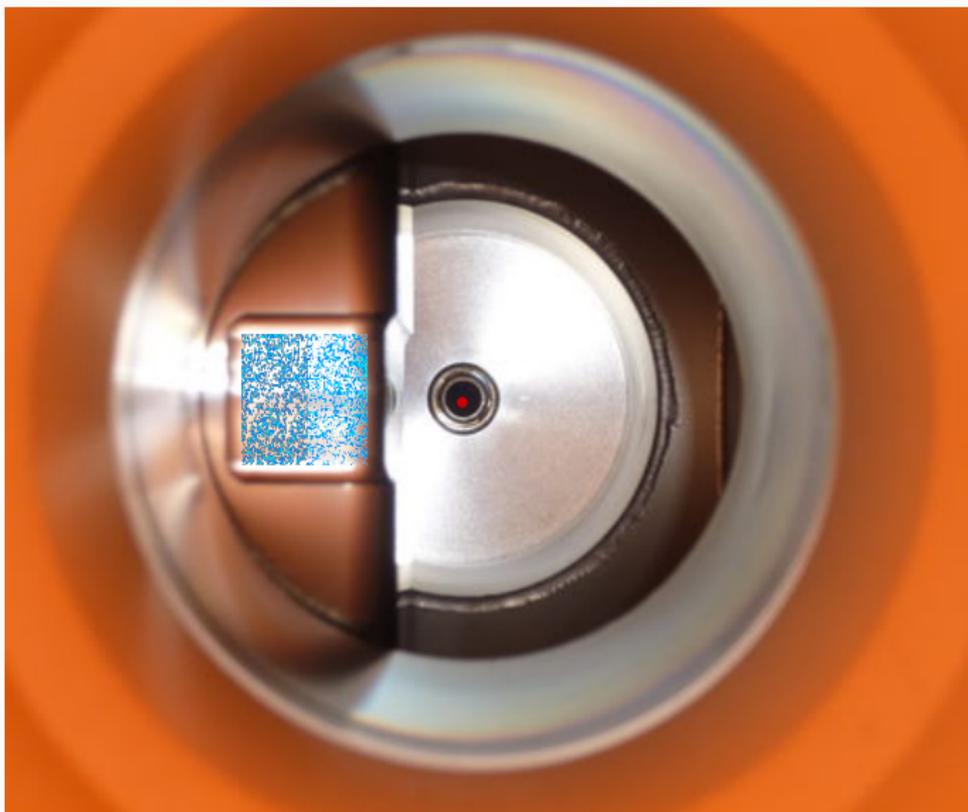
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Roman pot insertion



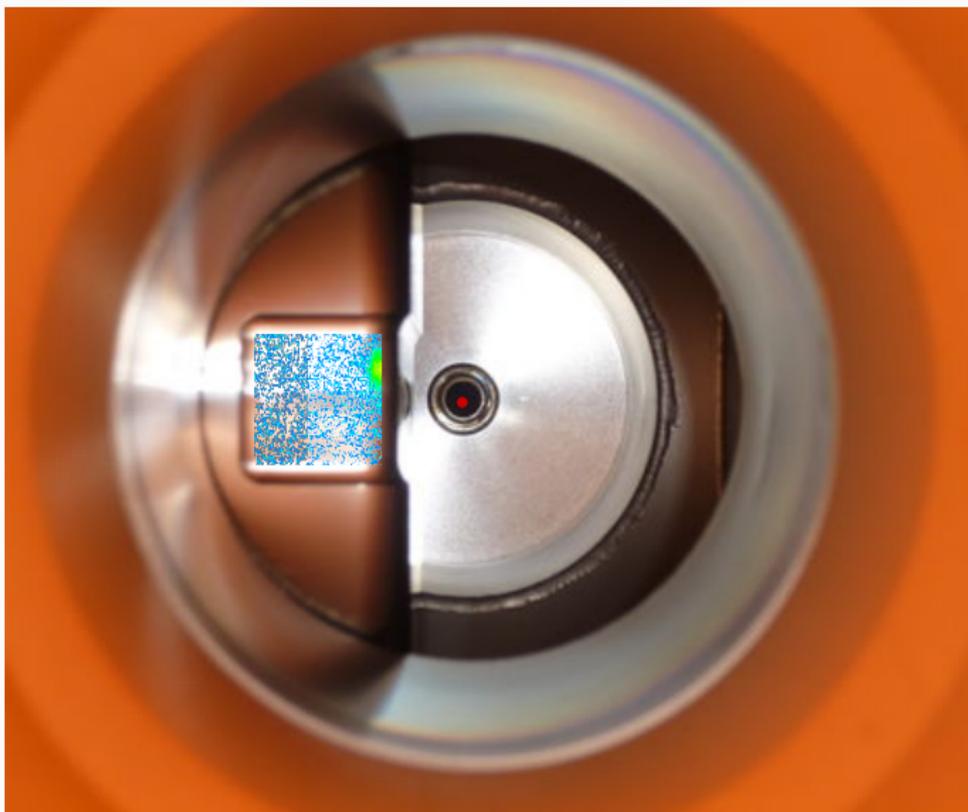
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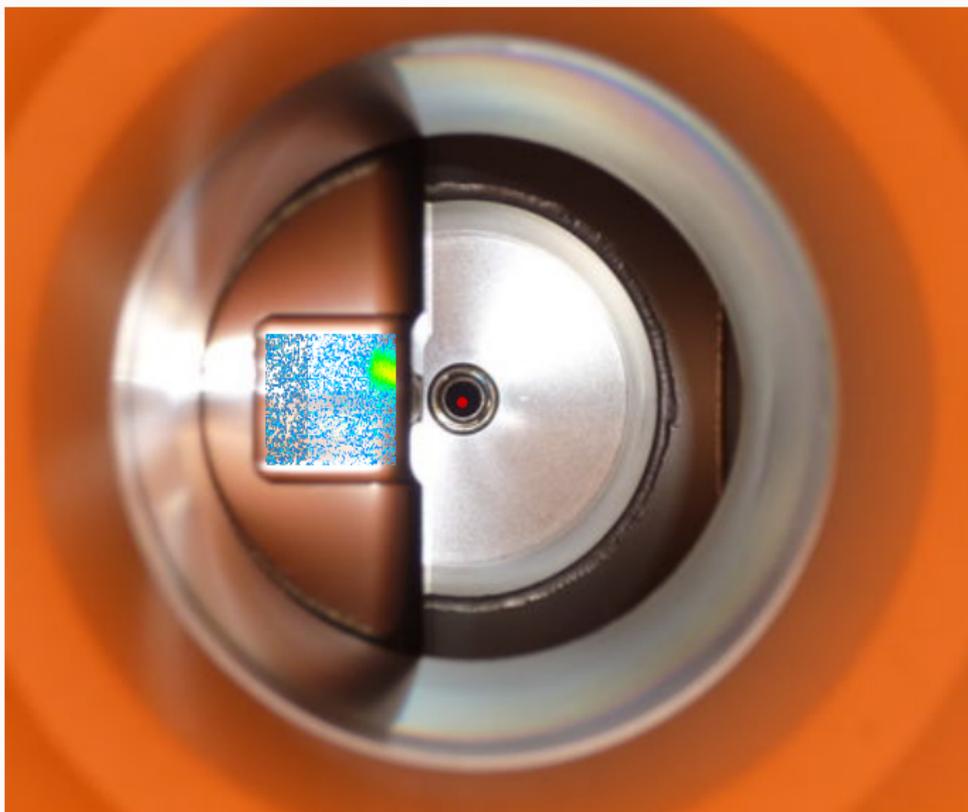
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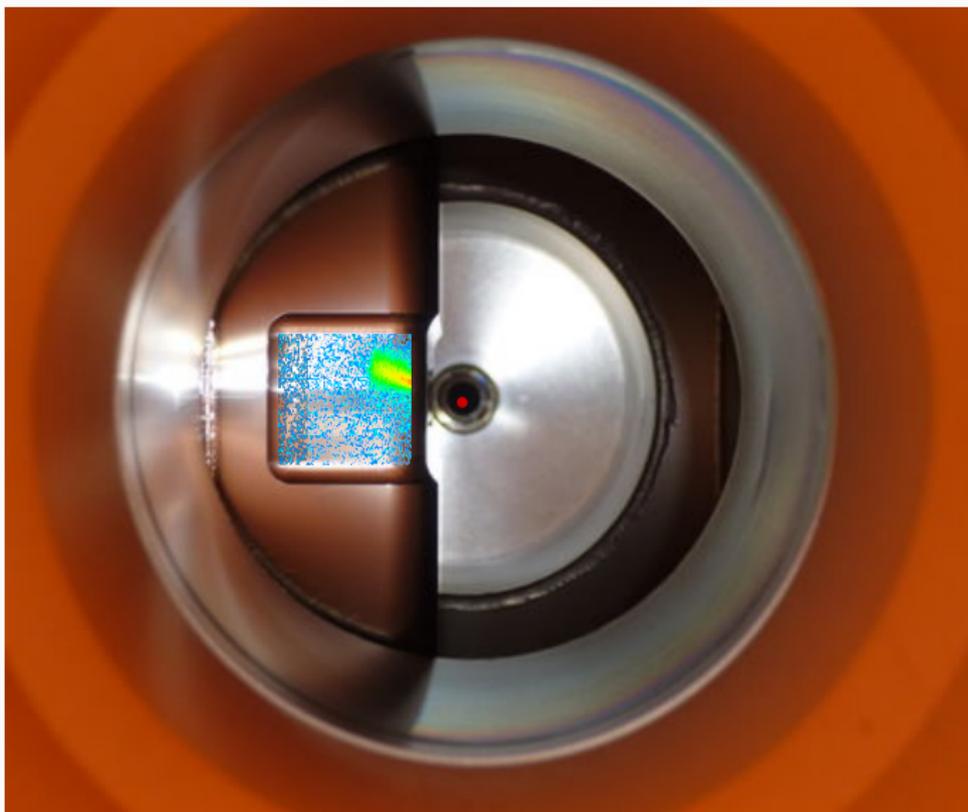
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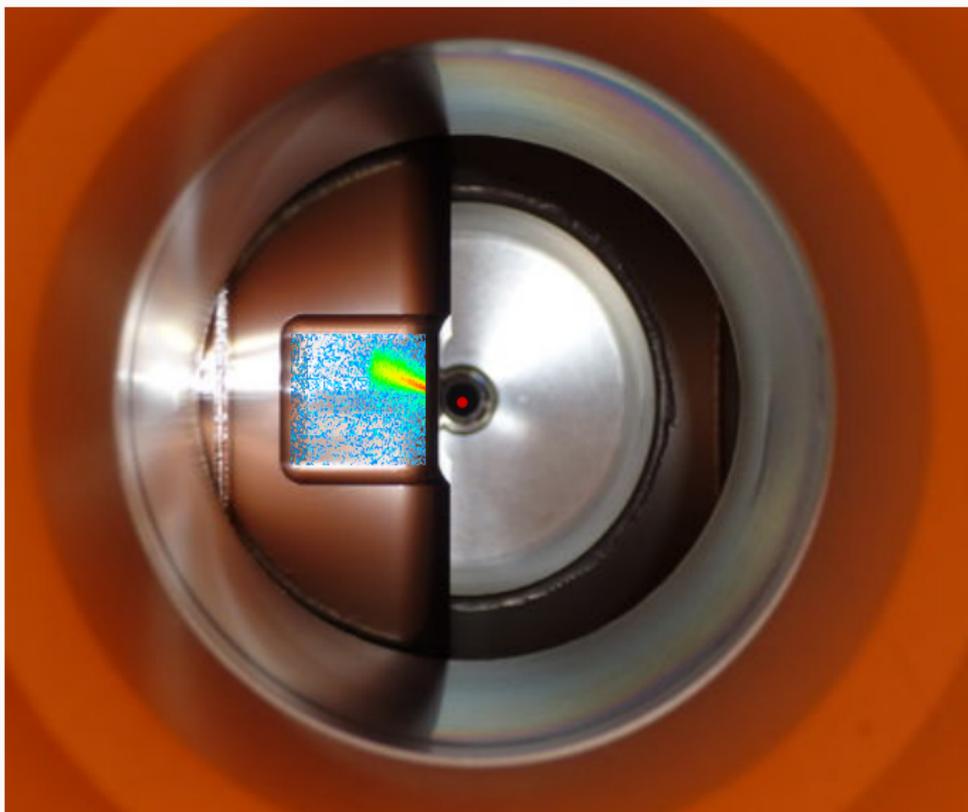
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Roman pot insertion



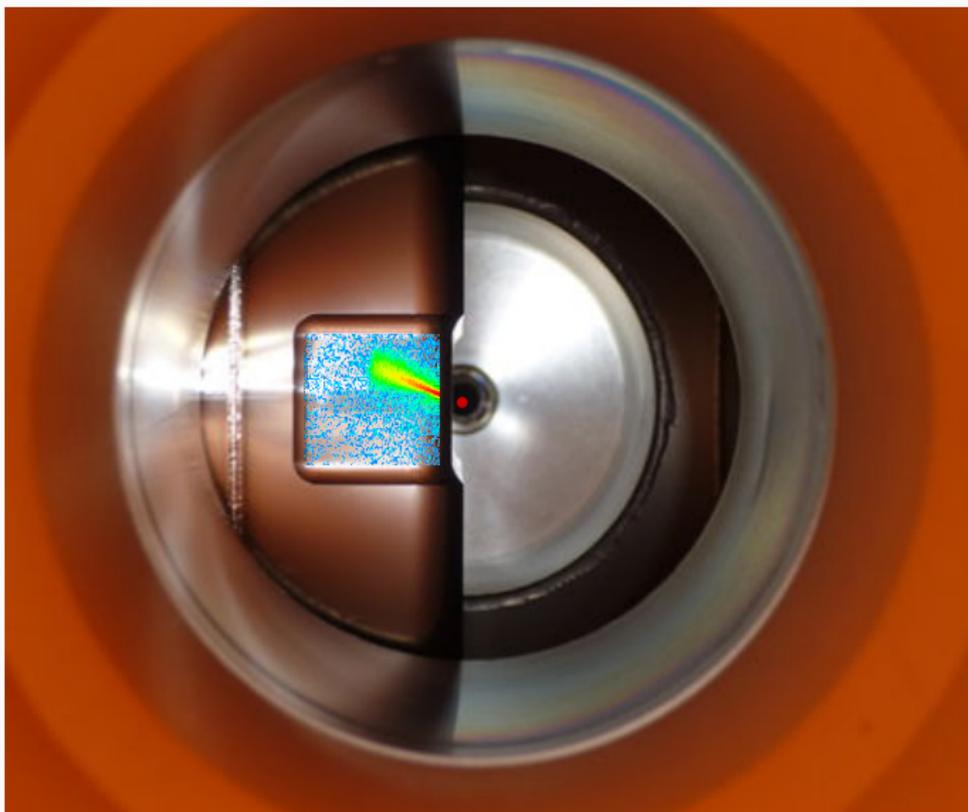
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Roman pot insertion

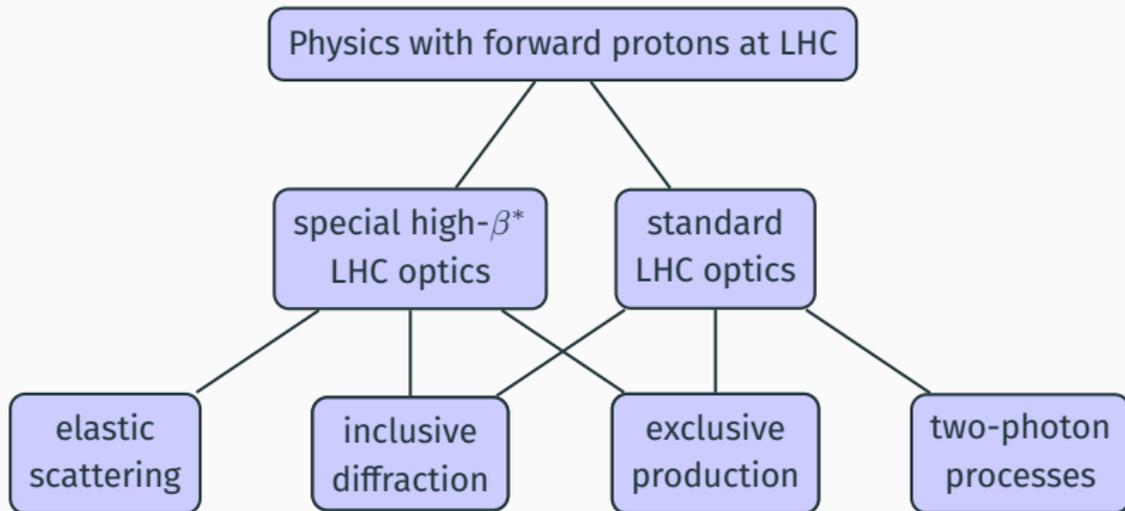


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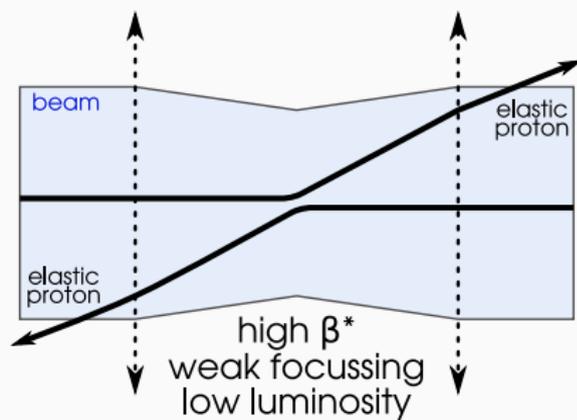
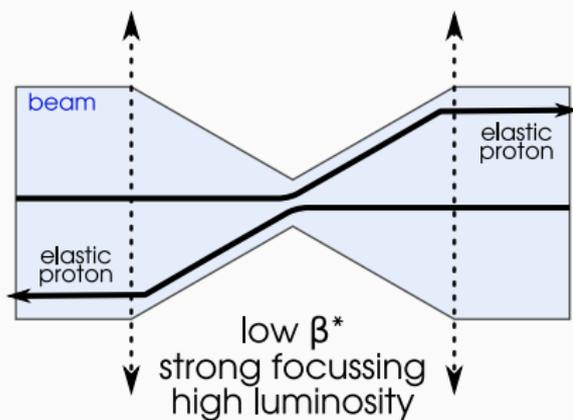
Roman pot insertion



Adapted from Maciej Trzebiński, CERN Detector Seminar, 1 December 2017



High- β^* optics



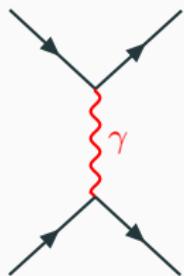
Typical values at LHC:

$$\beta^* < 1 \text{ m}$$

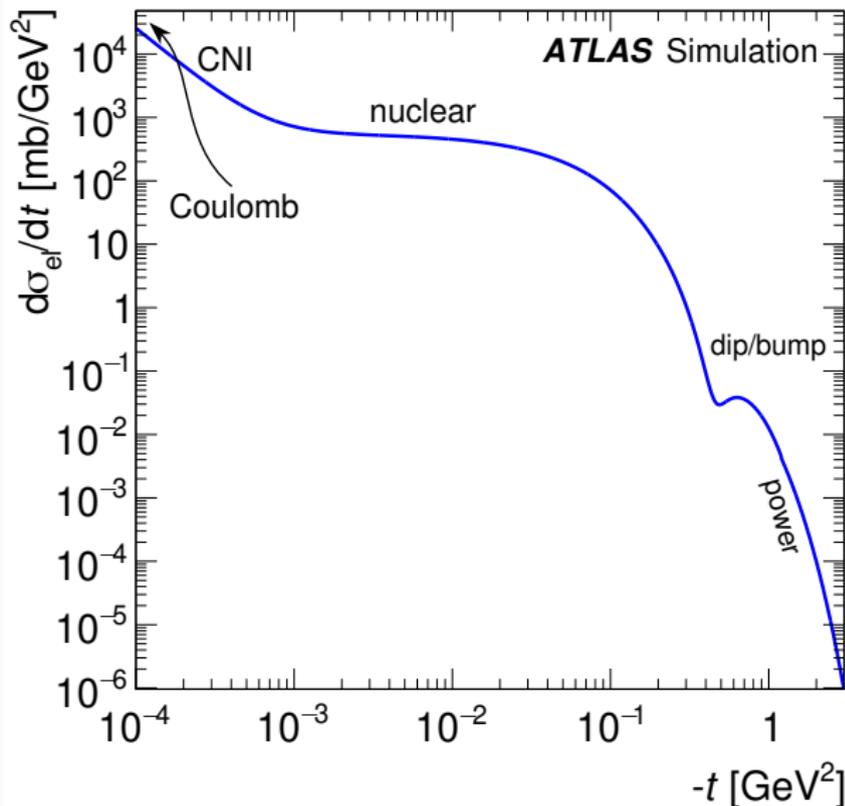
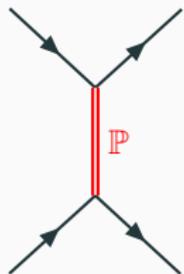
$$\beta^* \geq 90 \text{ m}$$

Elastic scattering

Coulomb
(electromagnetic)

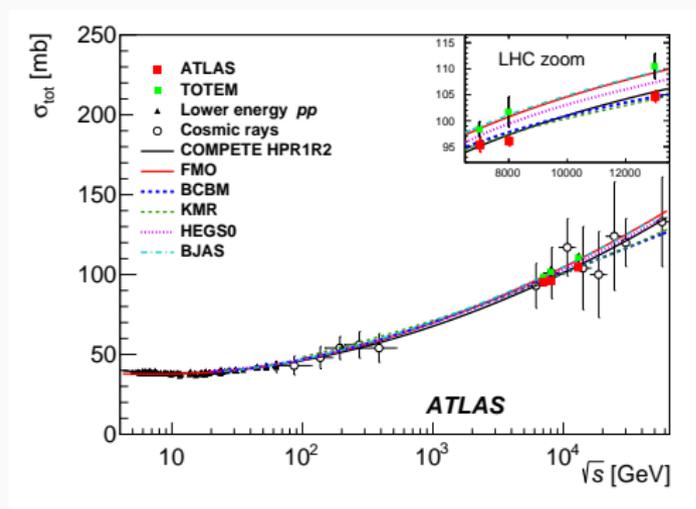


Nuclear (strong)



Optical theorem

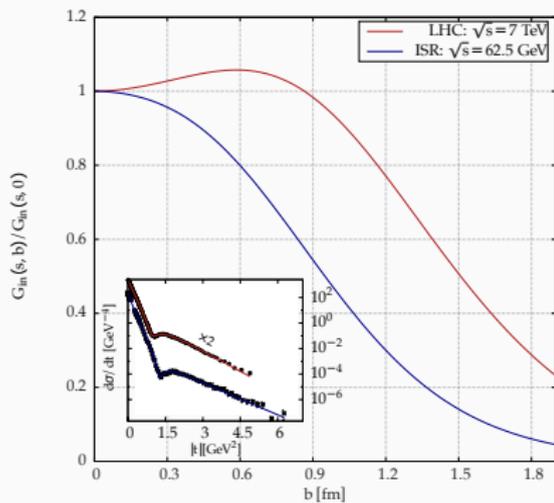
$$\sigma_{\text{tot}} = 4\pi \text{Im} T_{\text{el}}(t=0)$$



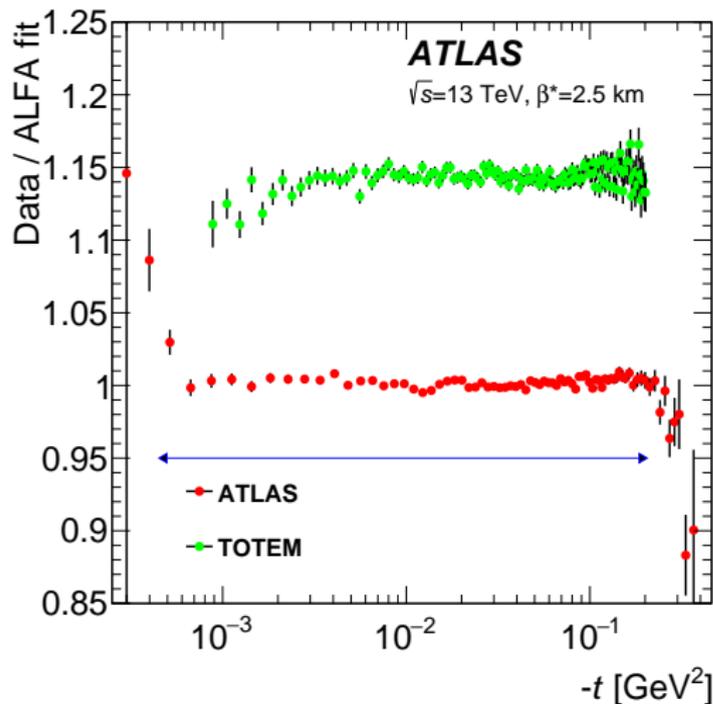
arXiv:2207.12246 [hep-ex]

Impact parameter space

$$G_{\text{in}}(\vec{b}) = 2\text{Im}\tilde{T}_{\text{el}}(\vec{b}) - |\tilde{T}_{\text{el}}(\vec{b})|^2$$



arXiv:1605.09176 [hep-ph]



atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/STDM-2018-08/

Luminosity-independent (TOTEM)

$$\sigma_{\text{tot}} = \frac{16\pi}{1 + \rho^2} \frac{1}{N_{\text{el}} + N_{\text{inel}}} \left. \frac{dN_{\text{el}}}{dt} \right|_{t \rightarrow 0}$$

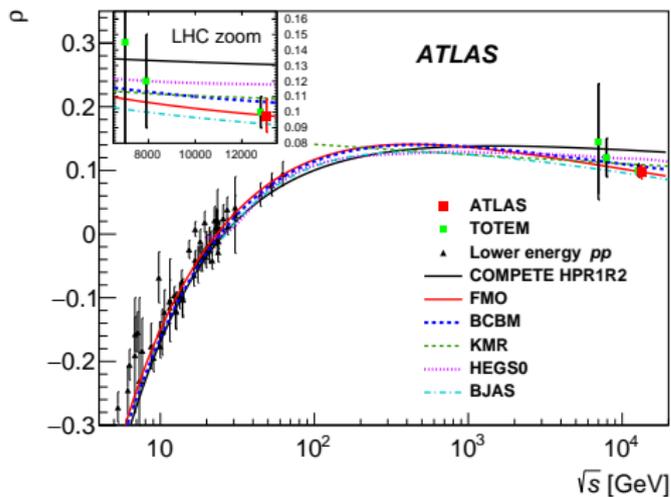
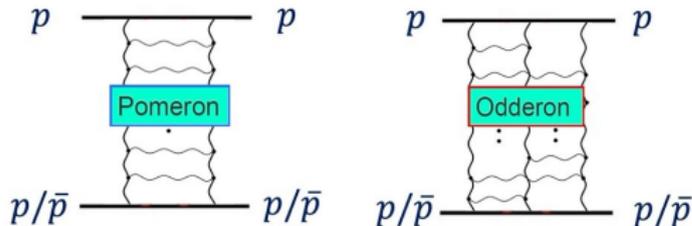
Requires correction for not measured small-mass diffraction

Luminosity-dependent (ATLAS)

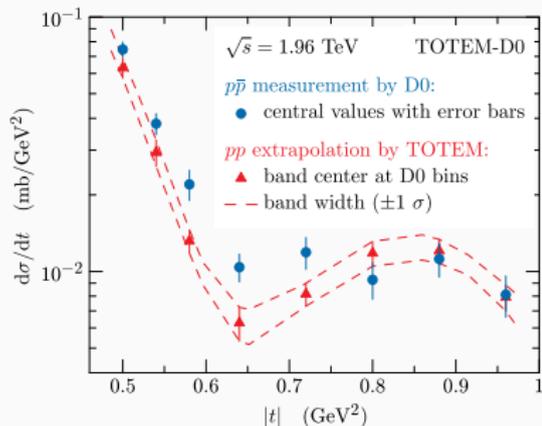
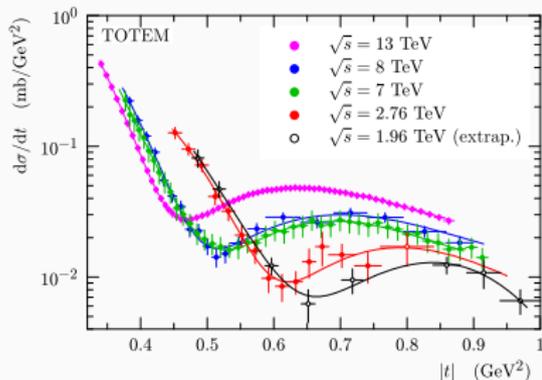
$$\sigma_{\text{tot}}^2 = \frac{16\pi}{1 + \rho^2} \frac{1}{L} \left. \frac{dN_{\text{el}}}{dt} \right|_{t \rightarrow 0}$$

Requires a dedicated luminosity measurement

Elastic scattering – Odderon

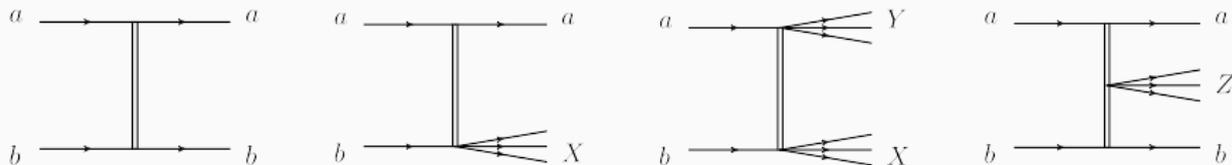


arXiv:2207.12246 [hep-ex]



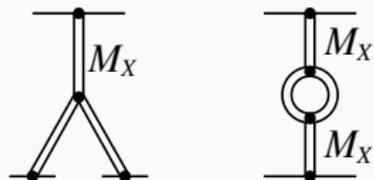
arXiv:2012.03981 [hep-ex]

Inclusive diffraction



Regge theory

Triple pomeron vertex



Resolved pomeron

- Ingelman-Schlein model
- pomeron has partonic structure
- absorptive corrections (survival probability)

Soft colour interactions

- QCD-inspired model
- additional gluon exchanges screen the color flow

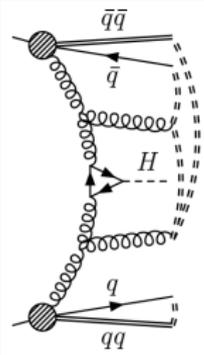
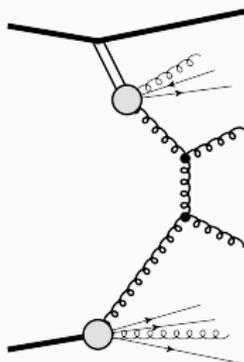
Good-Walker

Ψ_k – mass eigenstates

Φ_n – diffractive eigenstates

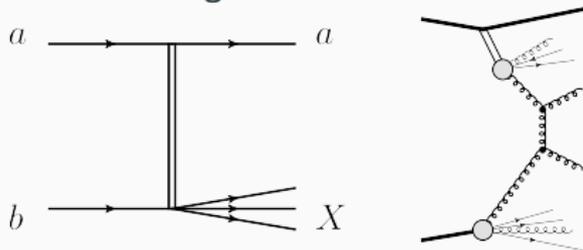
$$\Psi_k = \sum C_{kn} \Phi_n$$

$$d\sigma_{\text{diss}}/d^2b = \langle T^2 \rangle - \langle T \rangle^2$$

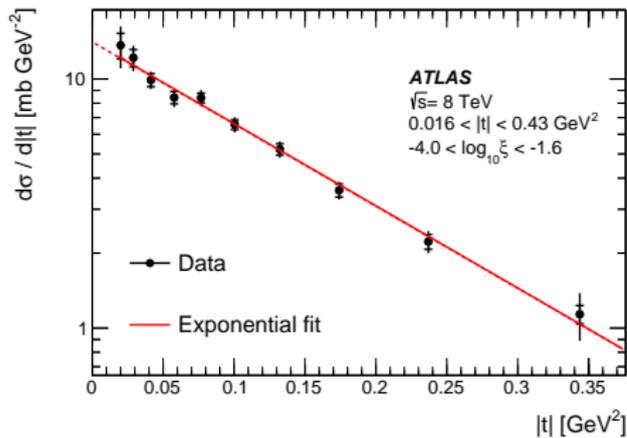
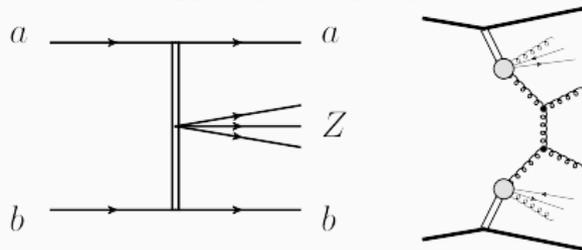


Inclusive diffraction

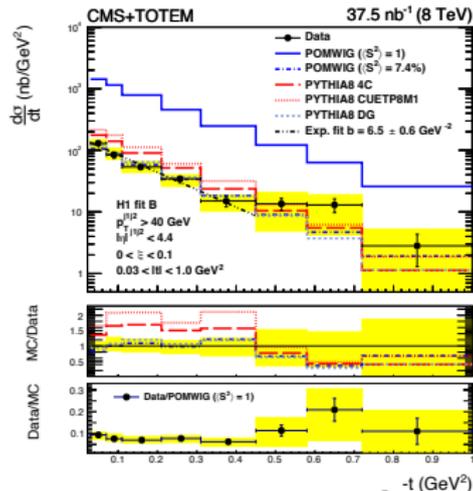
Single diffraction



Central diffraction

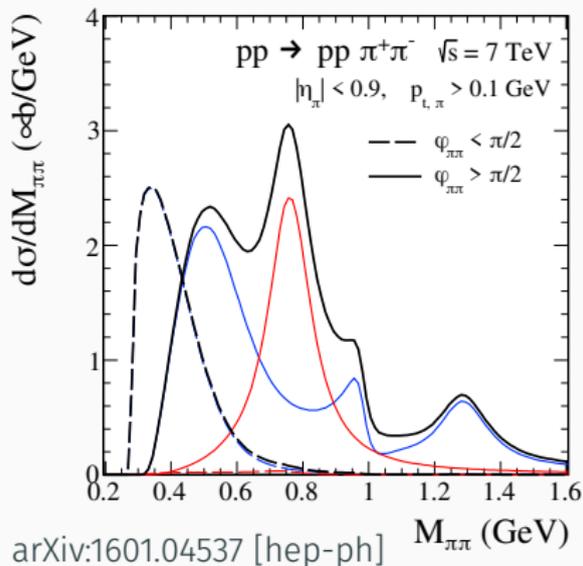
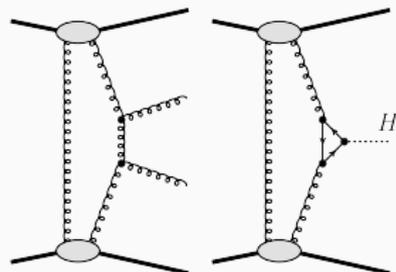
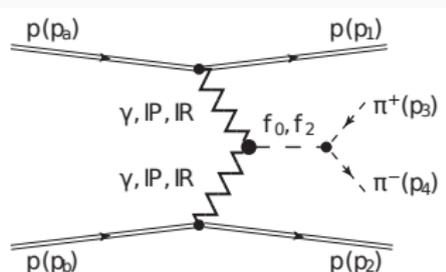
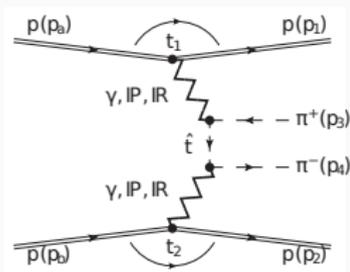


Soft SD, arXiv:1911.00453 [hep-ex]



Hard SD, arXiv:2002.12146 [hep-ex]

Exclusive diffraction (central exclusive production)



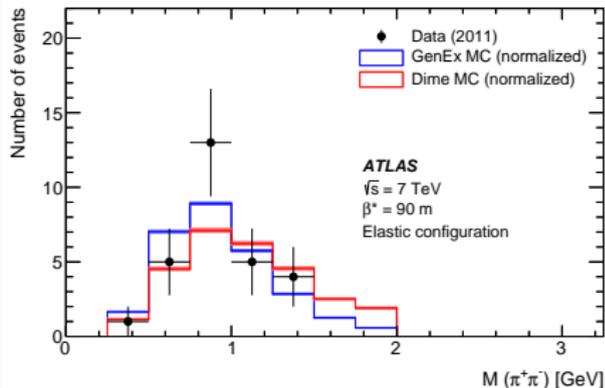
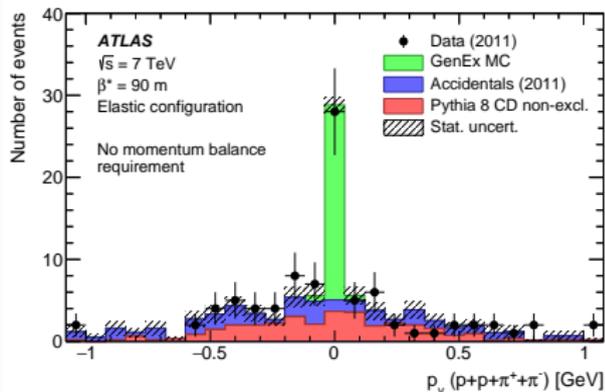
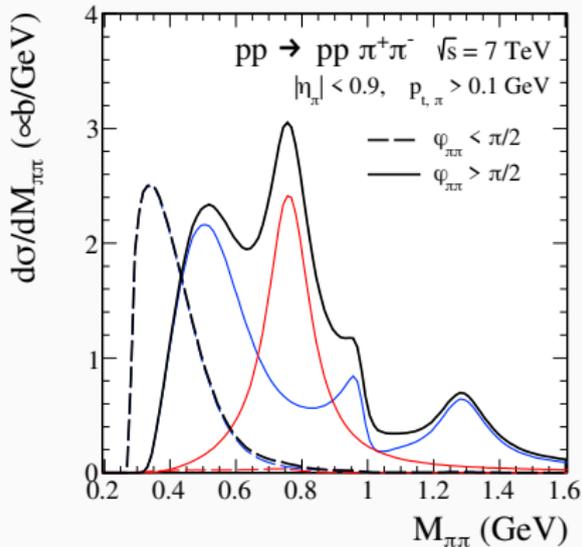
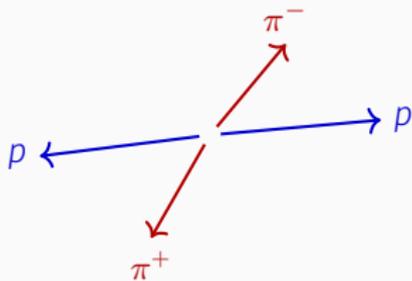
Soft exclusive diffraction

- interesting and complex mechanism
- non-trivial interplay of continuous and resonant production
- important absorptive corrections

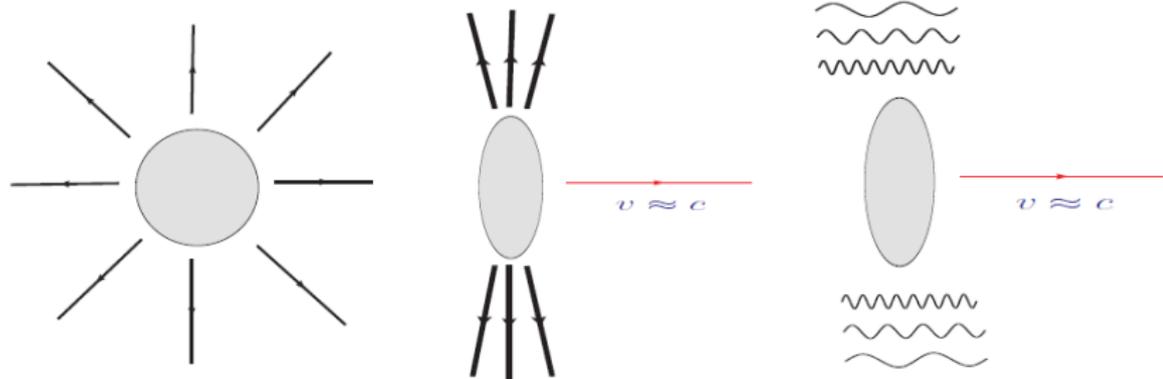
Hard exclusive diffraction

- interesting pQCD mechanism
- constraints on spin of the produced system
- important absorptive corrections
- difficulty with triggering

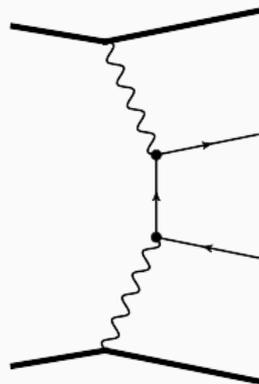
Exclusive pion pair production



Two-photon processes

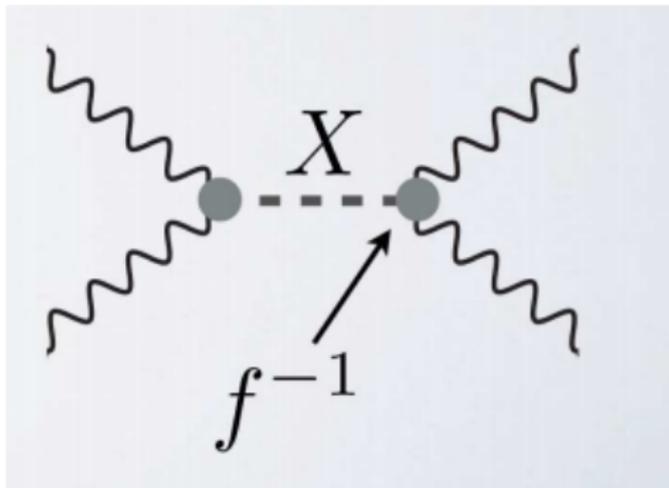
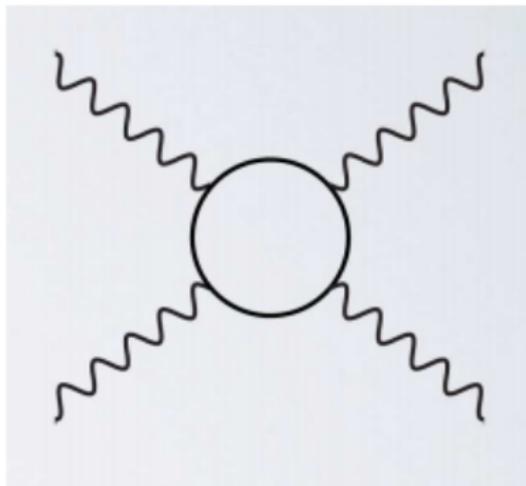


- Accelerated charged particles surrounded by photons
- Equivalent photon approximation
- Two-photon processes can be computed within QED

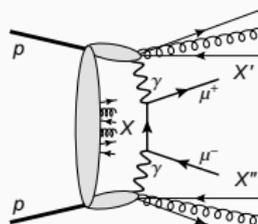
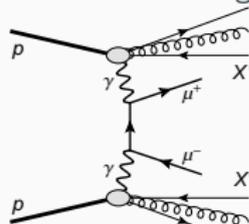
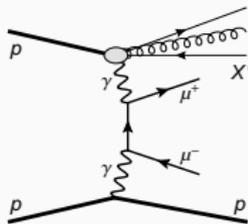
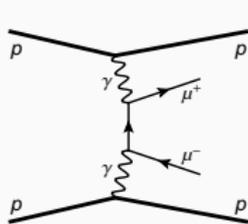


Motivation for research

EWK motivation – possible new particles:

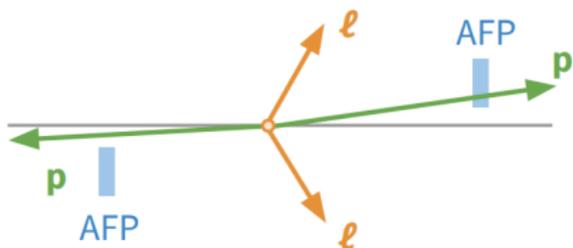


QCD motivation – proton dissociation and additional exchanges:



Kinematic matching

Signal:



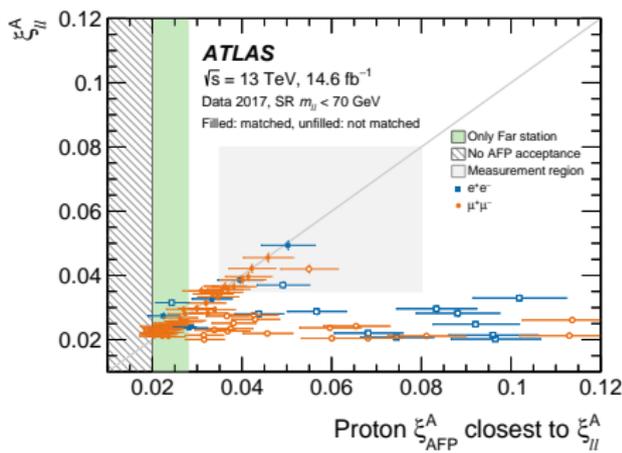
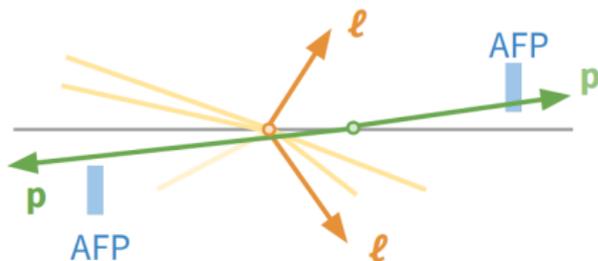
- ξ – fraction of proton energy carried by the photon
- ξ from proton measurement

$$\xi = 1 - E_p/E_{\text{beam}}$$

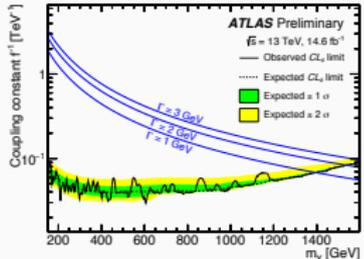
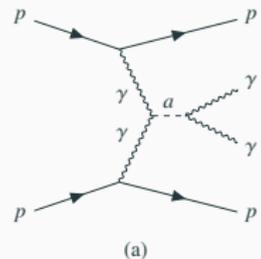
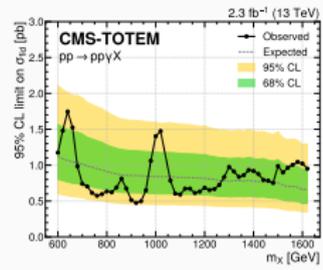
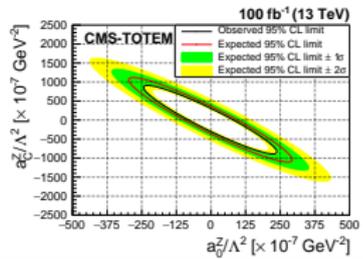
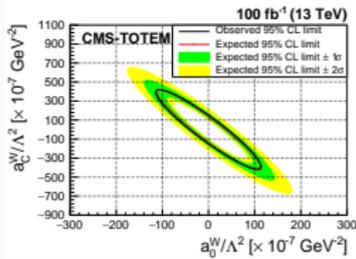
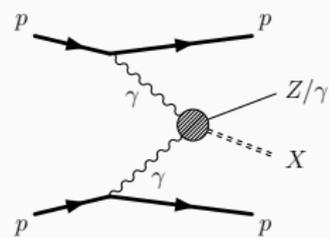
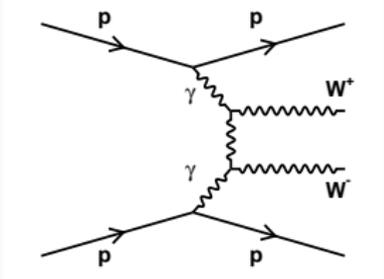
- ξ from central system measurement

$$\xi_{\pm} = \frac{M_{\ell\bar{\ell}}}{\sqrt{s}} \cdot e^{\pm y_{\ell\bar{\ell}}}$$

Background:



Sensitivity to new physics



Time-of-Flight detector

