Forward Detectors for the LHC

Detector Workshop, Karlsruhe , 03.04.2008

- LHC Beam-line detectors:
- Roman Pots for ATLAS:
  principle of measurement
  purpose, construction and prospects

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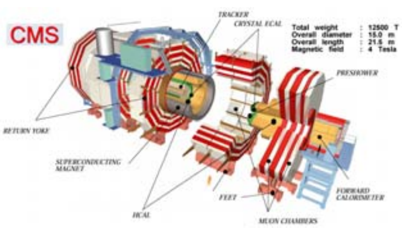
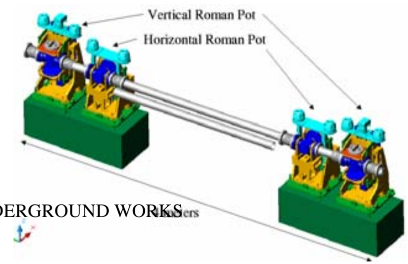
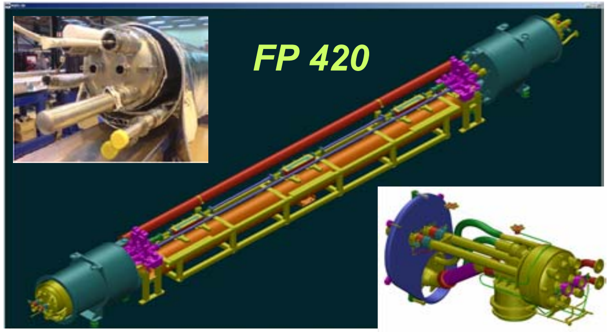
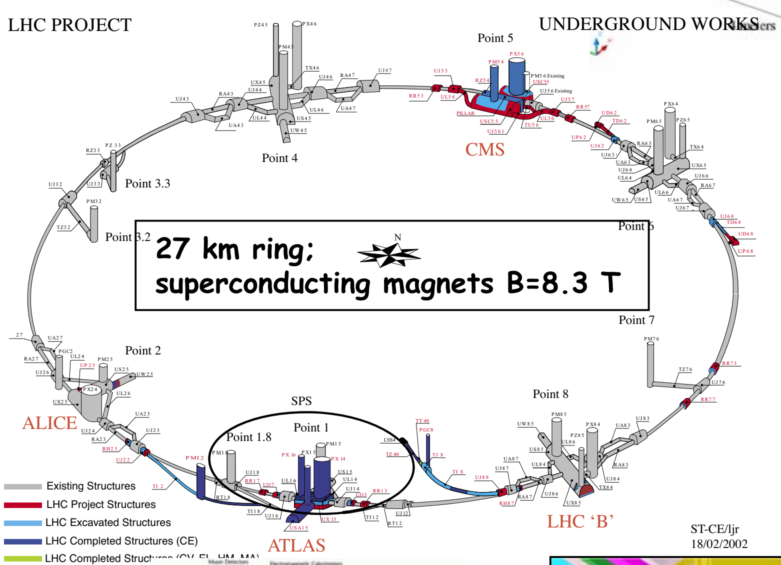
Forward detectors near ATLAS and CMS



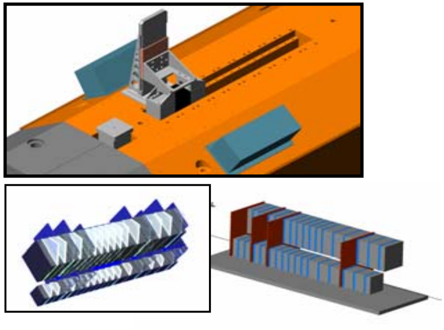
Totem, RP 150-220

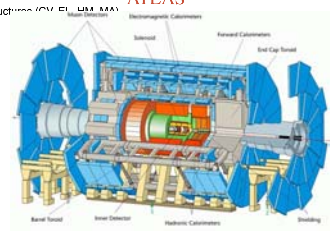


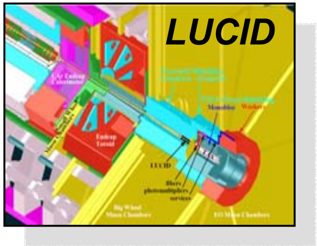




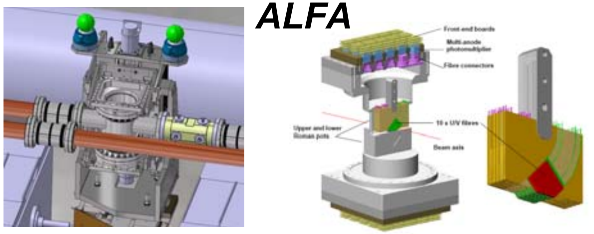
TAN: ***LHCf, ZDC***







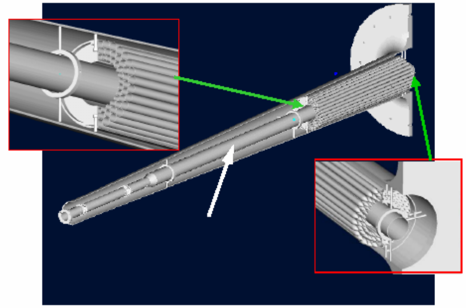
ALFA

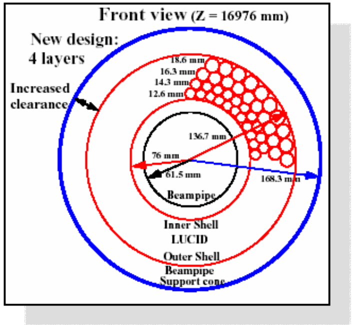


LHC Beam-line Detectors

LUCID

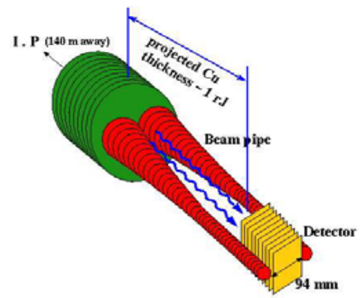
Čerenkov light tubes connected to quartz fibers placed around the beam pipe at ~17 m from IP. for ATLAS Luminosity monitoring

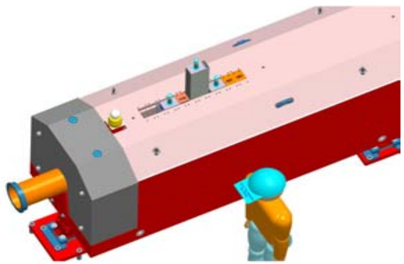




TAN: LHCf, ZDC

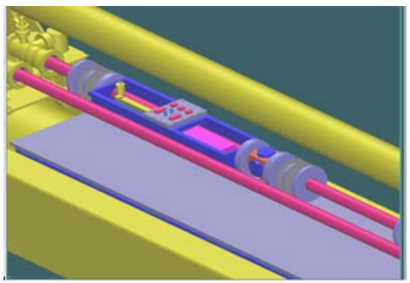
Tungsten/Si/Scintillators/Quartz calorimeters placed in the beam-pipes junction point at 0° to IP to mesaure neutral particles in forward region

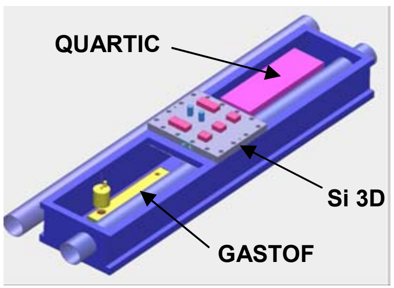




FP420

GasTof, Č-Quartz and Si trackers inside the cold moving beam pipe ("Hamburg pipe") at 420 m from IP. Main physics aim: pp → p+X+p

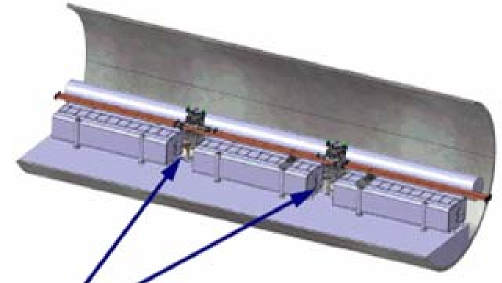


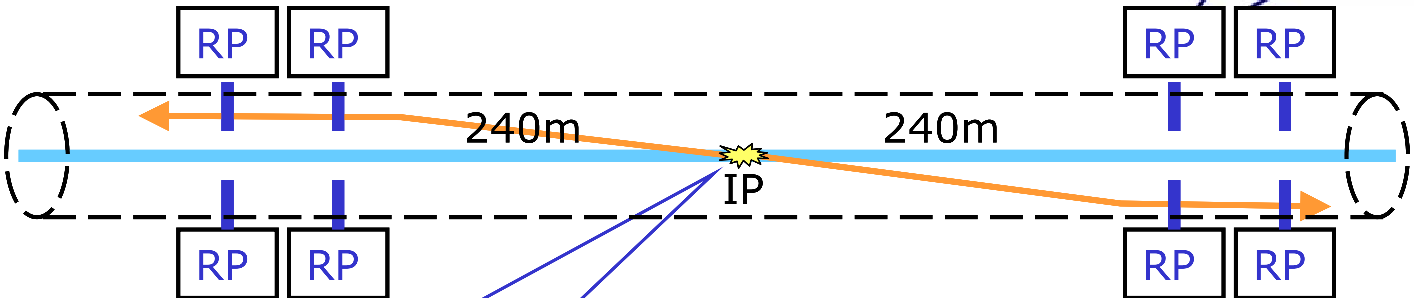


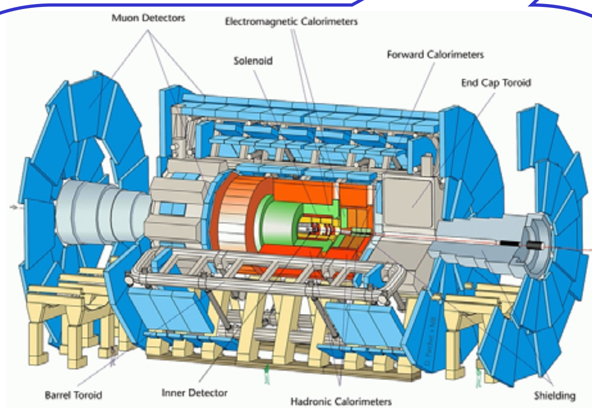
Roman Pot Detectors: RP150-220, ALFA

ALFA: Roman Pots for ATLAS

ALFA detector: Absolute Luminosity For ATLAS

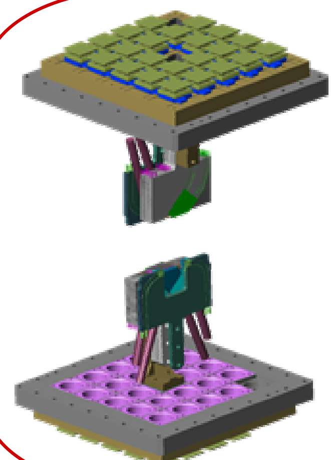


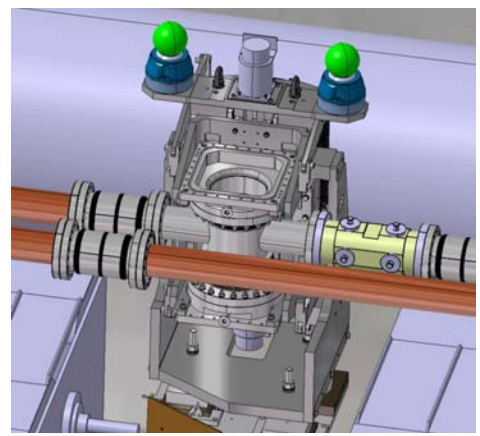




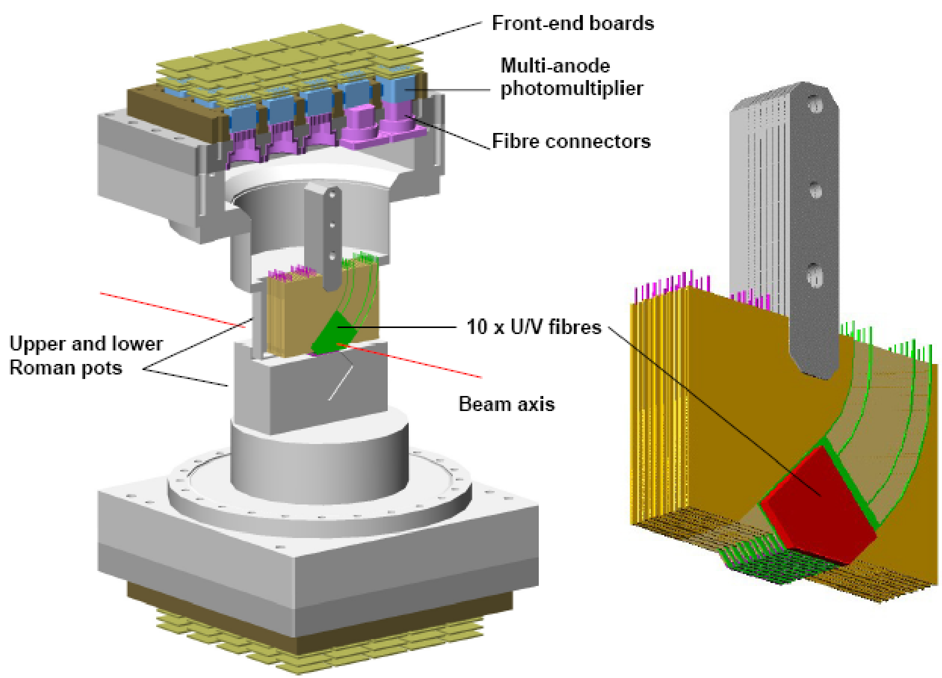
ATLAS Detector at LHC

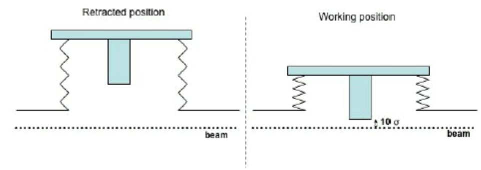
ALFA detector + Roman Pot

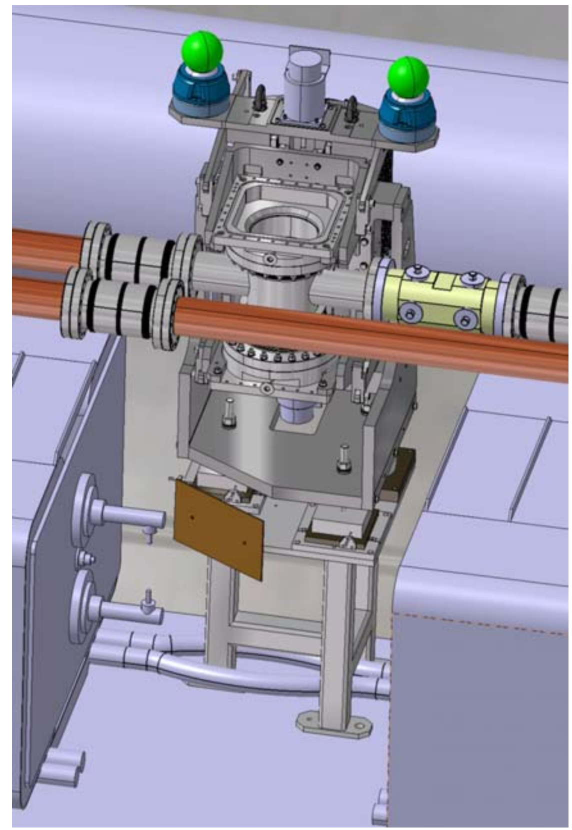




ALFA detector design







- square scintillating fibres 0.5x0.5 mm^2
- U/V planes: ±45° layers. U+V = 1 module
- 64 fibers per plane.
- 10 modules per pot
- covered with two trigger scintillator tiles

German Groups Involved in ALFA

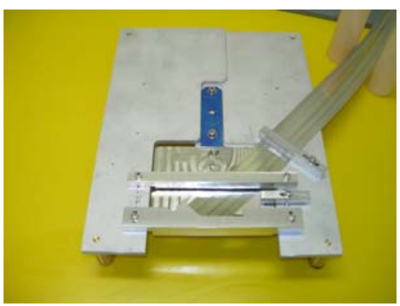
HU Berlin: titanium machining

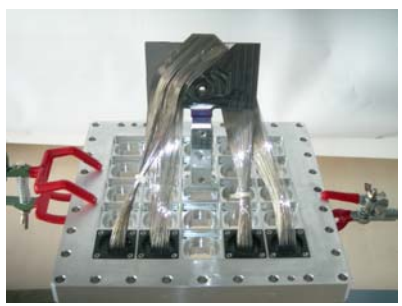
DESY-Hamburg: photomultipliers, test-stand, metrology, software

DESY-Zeuthen: trigger counters

JLU Gießen: ALFA assembly, MC simulation

ALFA production in Gießen



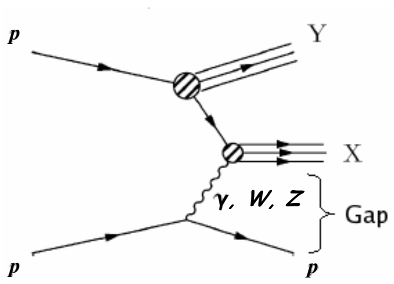


Why ALFA ?

1) Get luminosity from the forward elastic rate

2) Calibrate Čerenkov detector (LUCID) for relative luminosity measurement

3) Involve ALFA in physics analysis:



- to measure cross sections for elastic proton-proton interaction and for W/Z production
- to measure σ_{tot} through elastic scattering parameters
- to tag proton for single diffraction **p p → X p**

ALFA may be able to reach the Coulomb scattering region

$|t| \sim 6 \times 10^{-4}$ GeV^2 or **$\Theta \sim 3.5\ \mu$ rad**

- **detector position ~1.5 mm from the beam axis**
- **spatial resolution < 50 μm**
- good and stable beam and vacuum conditions

ALFA Acceptance

Global ALFA acceptance is 67% at:

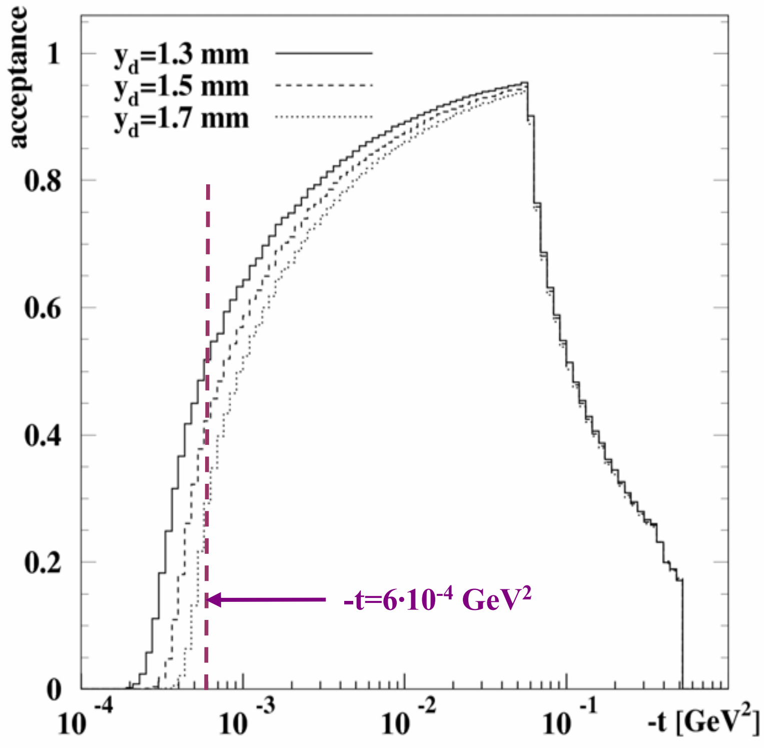
1) y_d=1.5 mm, including losses in the LHC aperture.
2) require tracks 2(R)+2(L) RP's.

Move-in detectors as close as possible to the beam in order to reach the Coulomb scattering region!

Coulomb Region : $|f_C| = |f_N|$

$$t \approx \frac{8\pi a_{EM}}{\sigma_{TOT}} \approx 6\times10^{-4}\ GeV^2 \rightarrow \theta \approx 3.5\,\mu rad$$

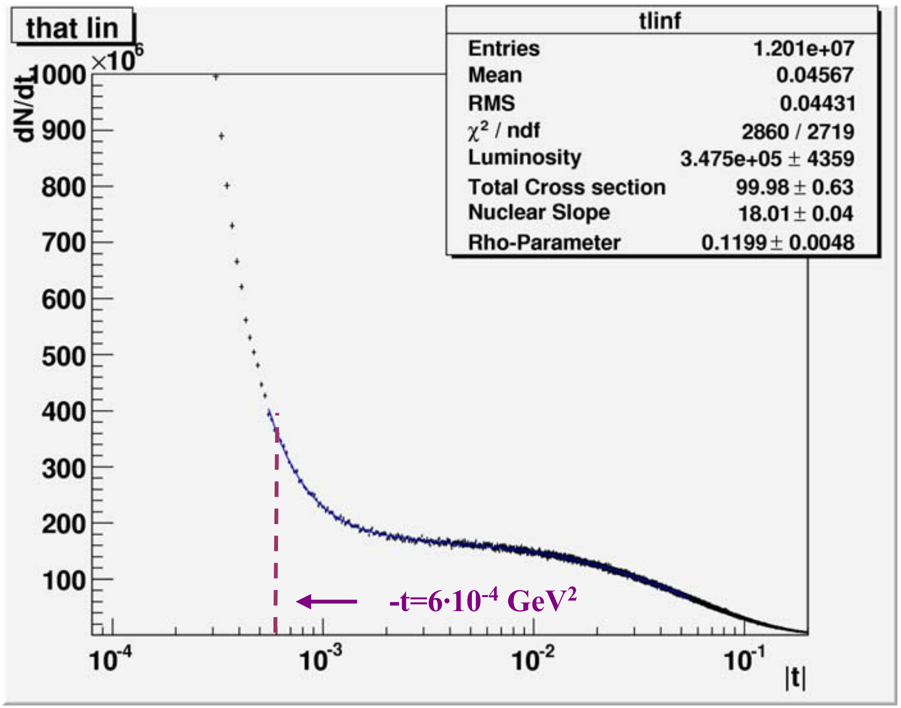
y_d is a closest distance to the beam



Luminosity Fit from t-spectrum

$$\frac{dN}{dt} = L\pi\left|F_C + F_N\right|^2$$

$$= L\left(\frac{4\pi\alpha^2(\hbar c)^2}{|t|^2} - \frac{\alpha\rho\sigma_{tot}e^{-B|t|/2}}{|t|} + \frac{\sigma_{tot}^2(1+\rho^2)e^{-B|t|}}{16\pi(\hbar c)^2}\right)$$



PYTHIA Simulation,
10 M events

	input	fit	error	corre-lation
L	8.10 10^{26}	8.151 10^{26}	1.77 %	
σ_{tot}	101.5 mb	101.14 mb	0.9%	-99%
B	18 Gev^{-2}	17.93 Gev^{-2}	0.3%	57%
ρ	0.15	0.143	4.3%	89%

Summary

- Forward detectors at LHC: Roman Pots: ALFA and FP220 , beam-line detectors: LUCID, LHCf, ZDC and FP420

- Roman Pots for ATLAS equipped with scintillating fibre detectors like the H1 FPS/VFPS at HERA and TOTEM at SPS to measure scattered beam protons at very small proton momentum transfer ***t***.

- Measurements with ALFA Roman Pots at ATLAS:
  - ✓ luminosity at low beam current on LHC;
  - ✓ calibration of luminosity detector LUCID;
  - ✓ total and differential cross section for elastic and single diffraction processes

BACK UP

- **ALFA Acceptance**
- **Simulated ALFA Resolution**
- **Luminosity Fit from t-spectrum**

Simulated ALFA Resolution

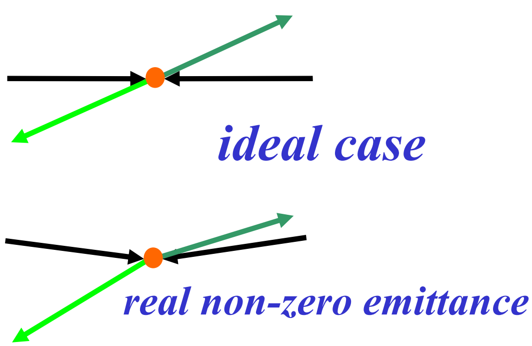
To reach Coulomb region:

emittance $\varepsilon \sim 10^{-6}$ m rad and

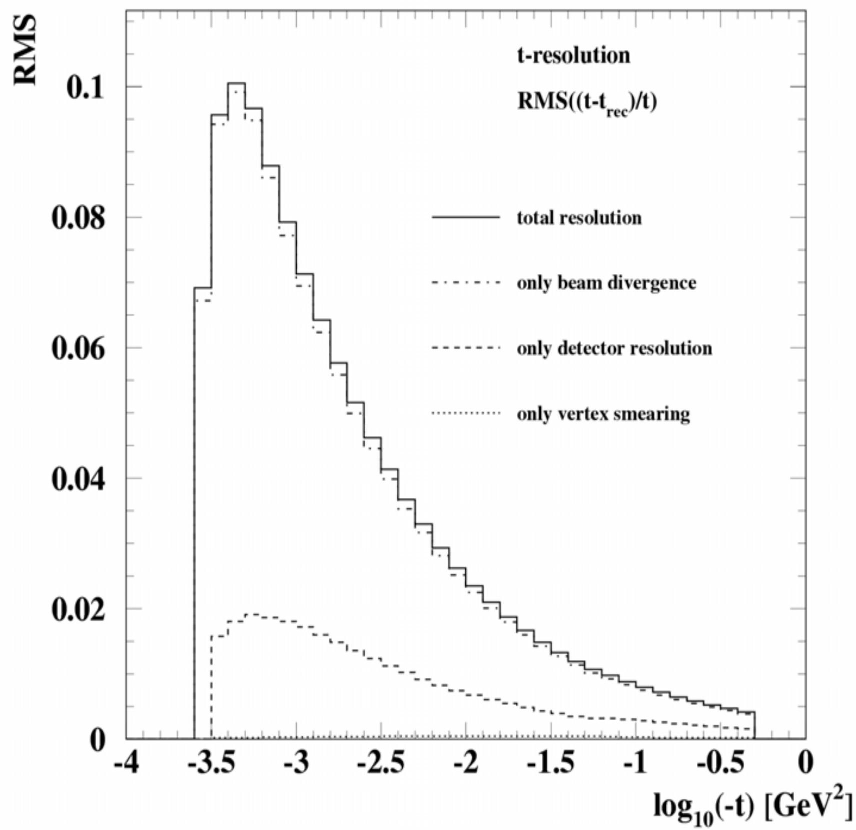
betatron-function in IP $\beta^* \sim 2500$ m

are required

incoming beams divergence: $$\Delta^* = \sqrt{\frac{\varepsilon}{\beta^*}}$$

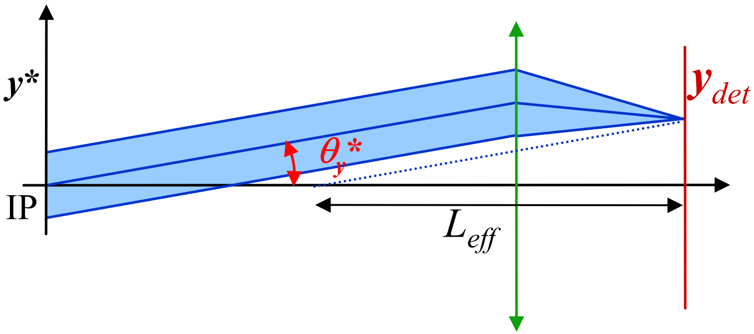


The t-resolution is dominated by the incoming beams divergence



ALFA @ Beam-line

Special optics with high β^* and parallel-to-point focusing:



Transversal displacement in y-projection downstream the interaction point (IP):

$$-t = (p \cdot \Theta^*) = p^2(\overline{\Theta}_x^2 + \overline{\Theta}_y^2) =$$

$$= p^2\left[\left(\frac{\bar{x}}{L_{eff,x}}\right)^2 + \left(\frac{\bar{y}}{L_{eff,y}}\right)^2\right]$$