Lmd Offline Software

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The Goal & Concept

Goal: measure luminosity L with highest possible accuracy and precision

$$N = L \times \sigma$$

Idea: pick well known cross section σ and measure number of events N $\rightarrow$ obtain luminosity L

- cross section: **elastic $\bar{p}p$ scattering** $\rightarrow$ measure at small angles (close to beampipe far behind IP)
- **measure tracks** @ lmd to **reduce systematic** effects (background and $\bar{p}p$ beam imperfections)
- **fit 2D** track angle distribution N(θ,ϕ) to cross section model $\sigma(\theta,\phi)$
- **But:** because N includes for example the detector acceptance and resolution, either N or σ have to be modified for direct comparison $\rightarrow$ **here: mostly modify $\boldsymbol{\sigma}$!**

Track Reconstruction

1st part of the Lmd offline software

(most code written by
A. Karavdina)

Input: Lmd detector digis (event based)

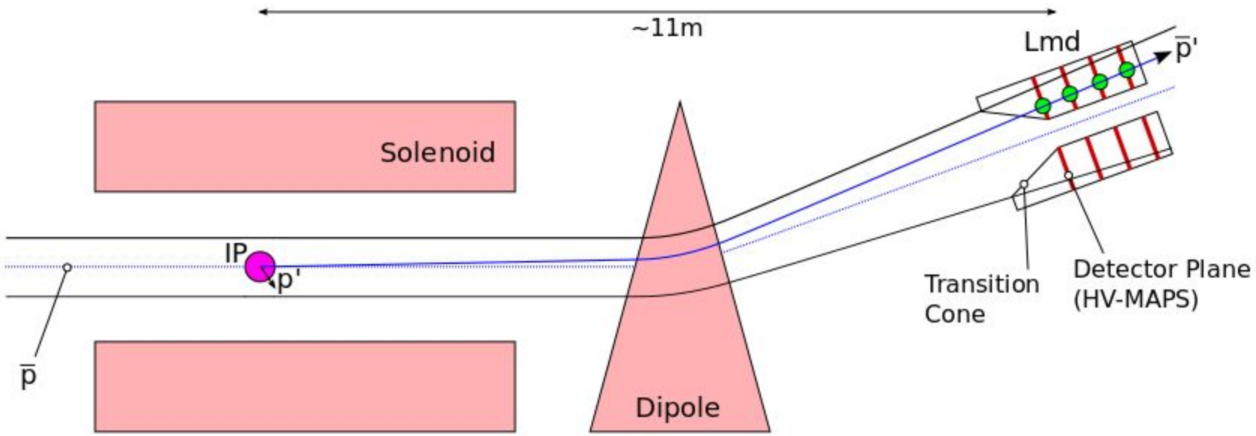
Output/Goal: lmd track parameters

Notes:

- Fairroot/Pandaroot can simulate input (using Geant+ROOT)
- Detector alignment is a separate module
  (see Roman's talk afterwards)

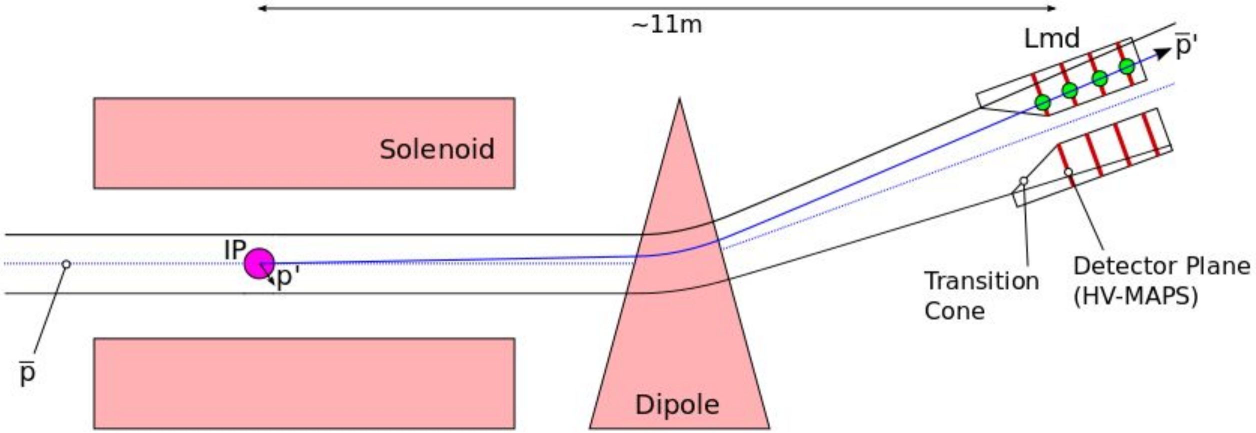
Track Reconstruction Steps

1. **Hit Reconstruction**
   - convert digi info to 3D point
   - hit clustering
   - optional: merging hits from different sides of planes



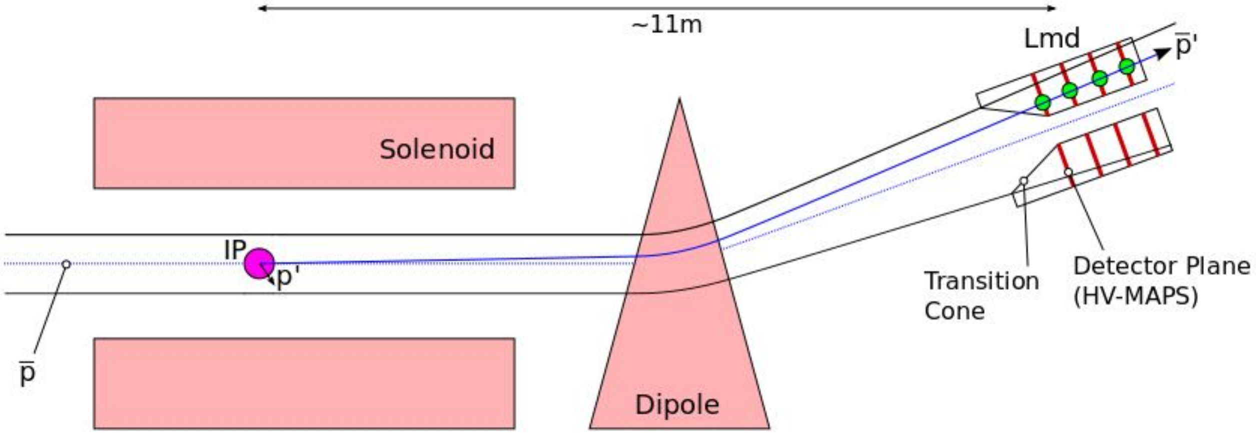
Track Reconstruction Steps

1. Hit Reconstruction
2. **Track Search**
    - find hits that make a meaningful track candidate
    - two methods available: cellular automaton (CA) track following



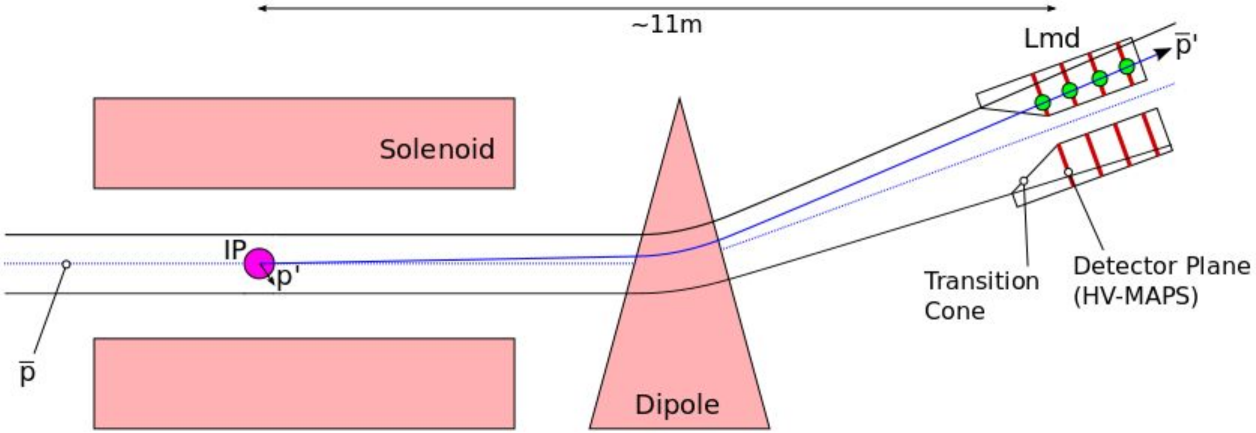
Track Reconstruction Steps

1. Hit Reconstruction
2. Track Search
3. **Track Fit**
    - fit track candidate to obtain precise track parameters + errors
    - using broken line model



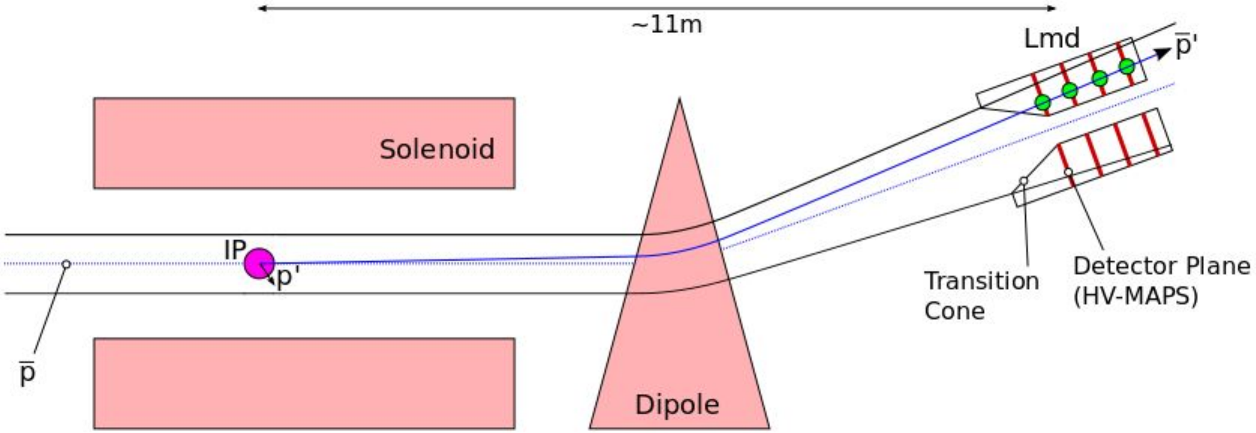
Track Reconstruction Steps

1. Hit Reconstruction
2. Track Search
3. Track Fit
4. **Track Filtering (1st)**
    - filter out "good" $\bar{p}$ tracks based on characteristic track parameters
    - using multivariate analysis (MVA)



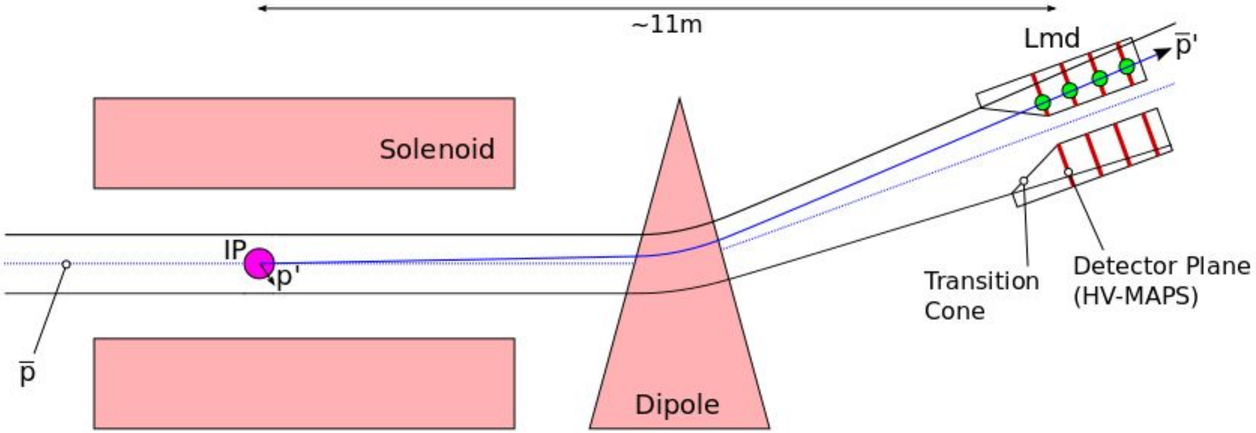
Track Reconstruction Steps

1. Hit Reconstruction
2. Track Search
3. Track Fit
4. Track Filtering (1st)
5. **IP Backtracking**
   - propagate tracks to IP to avoid difficult modification of σ (magnetic fields)
   - using Geane (Geant3) and point of closest approach (PCA) to IP



Track Reconstruction Steps

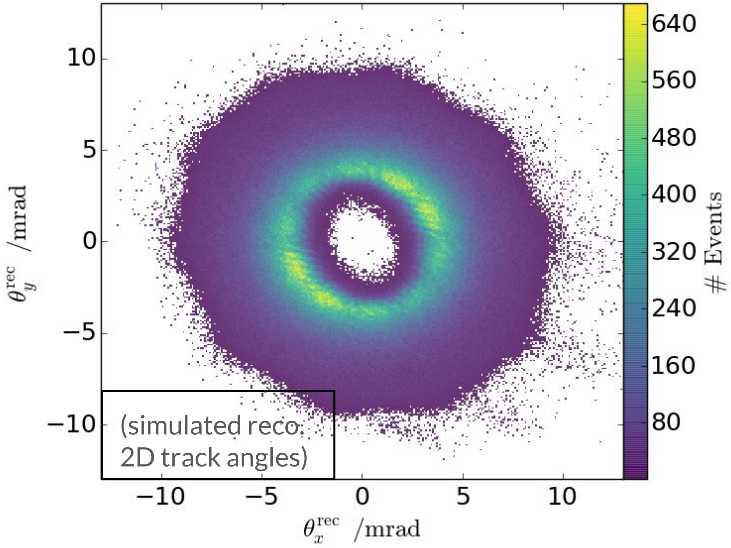
1. Hit Reconstruction
2. Track Search
3. Track Fit
4. Track Filtering (1st)
5. IP Backtracking
6. **Track Filtering (2nd)**
   - filter out “good” $\bar{p}$ tracks mainly based on track position info
   - deviation for background tracks, due to “wrong” momentum assumption



Luminosity Fit

2nd part of the lmd offline software

(by Stefan Pflüger)



Input: Track parameters (event based)

Output: time-integrated luminosity

Notes:

- modification of the cross section is necessary
- separate framework (https://github.com/spflueger/LuminosityFit)

For all plots in this section: 1.5 GeV/c antiproton beam momentum

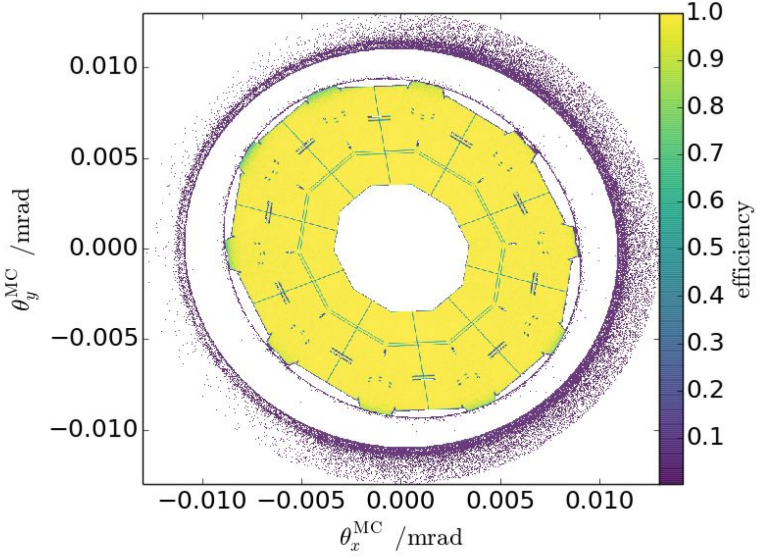
Luminosity Fit

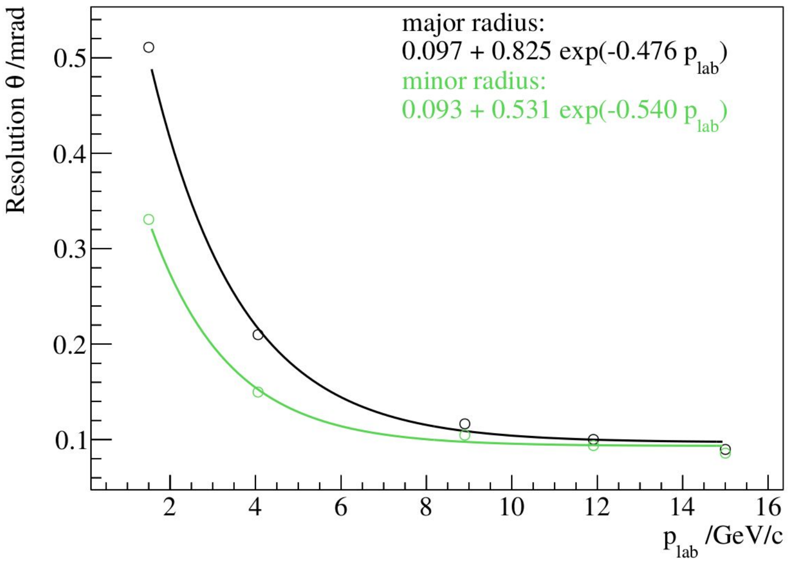
Steps of Basic Workflow:

1. coordinate transformations from $t \rightarrow \theta \rightarrow \theta_{x,y}$ (is special coordinate system simplifying
2. detector acceptance correction
3. detector resolution correction

fit uses binned extended log likelihood estimator (typical binning 300x300)

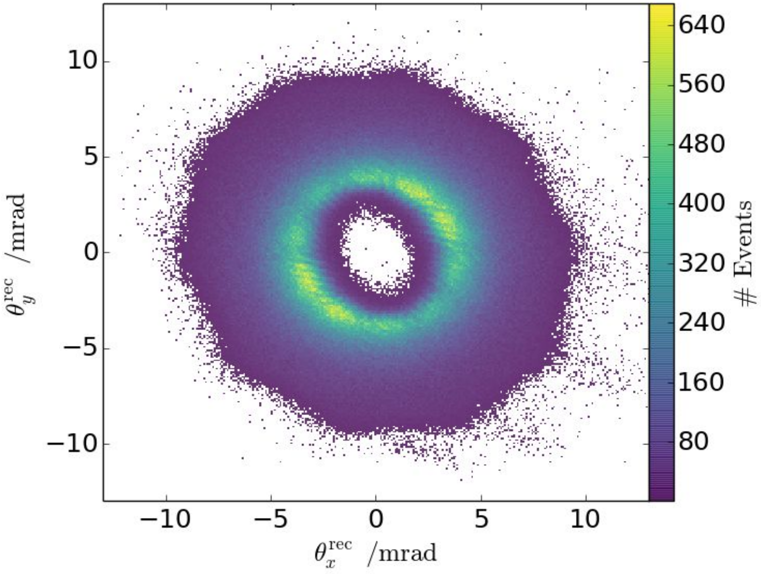
Lmd Acceptance & Resolution



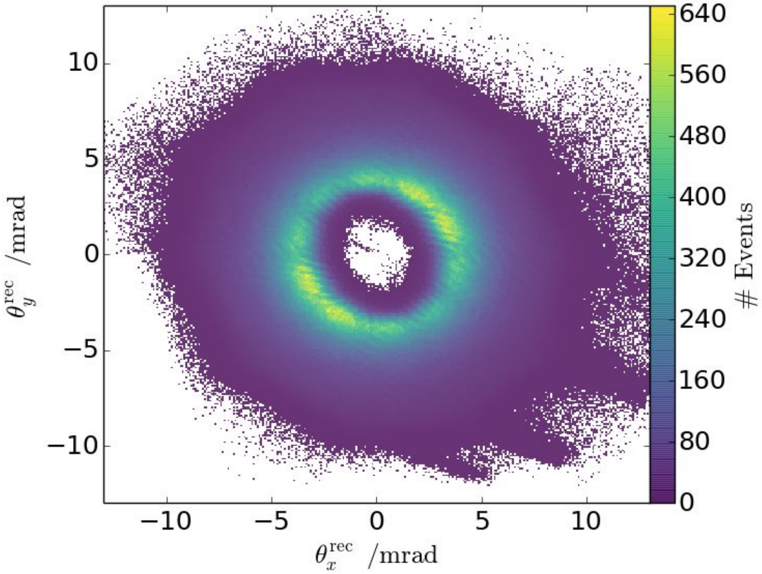


Exemplary Fit Result

Luminosity accuracy below 0.1%

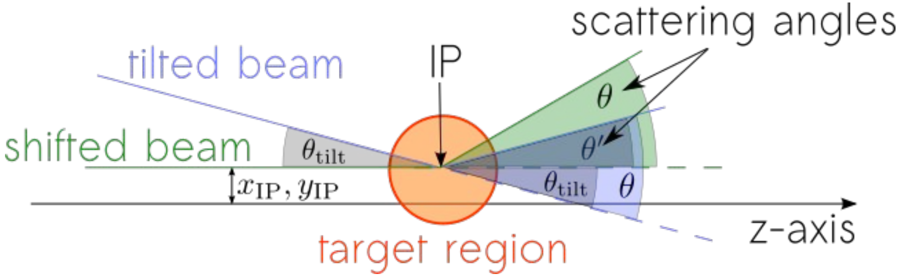


simulated 2d track angles



corrected cross-section model

Luminosity Fit Revisited

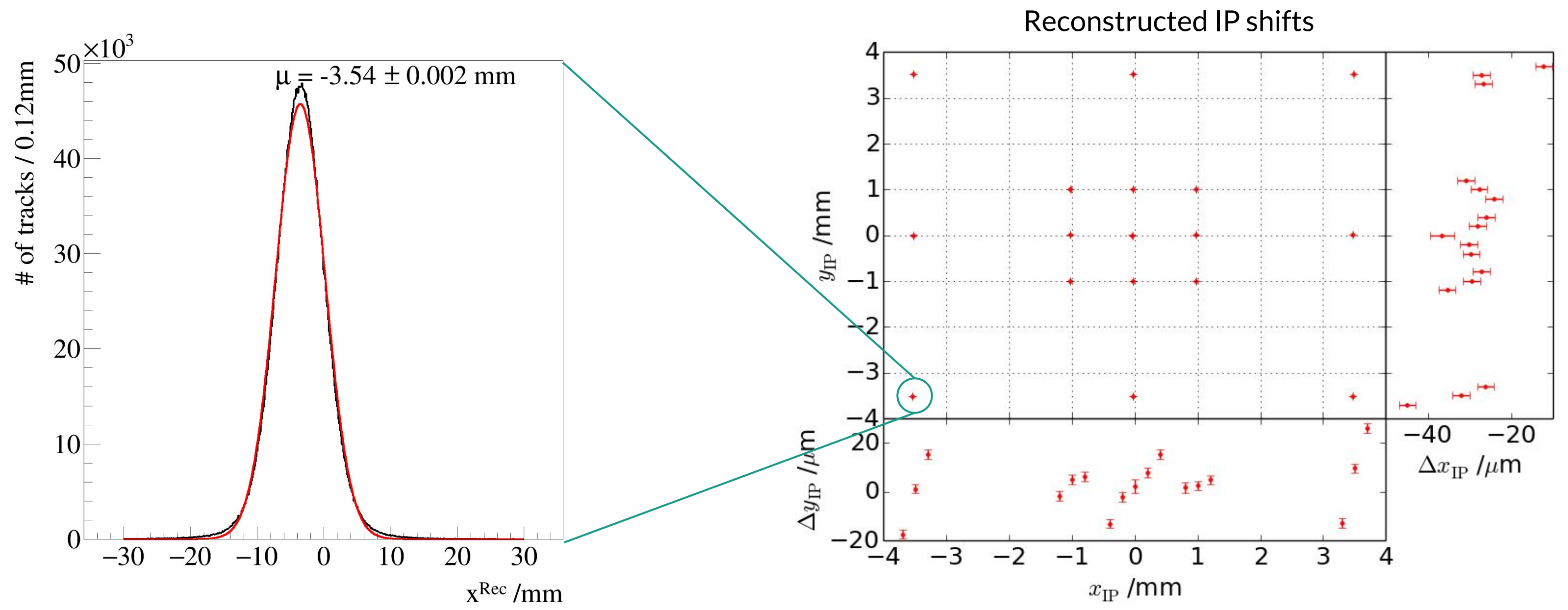


1. determine IP distribution (used in acceptance correction later on)
    a. IP mean determined from track position parameters
    b. IP distribution shape is assumed (normal distribution)
2. coordinate transformations from $t \longrightarrow \theta \longrightarrow \theta_{x,y}$
3. $\bar{p}$ beam corrections
    a. beam distribution shape (divergence) is assumed (here normal distribution, but width is used in fit)
    b. beam tilt is additional transformation: $\theta'_{x,y} \longrightarrow \theta_{x,y} + \text{tilt}_{x,y}$ ($\text{tilt}_{x,y}$ are fit parameters)
4. detector acceptance correction
5. detector resolution correction

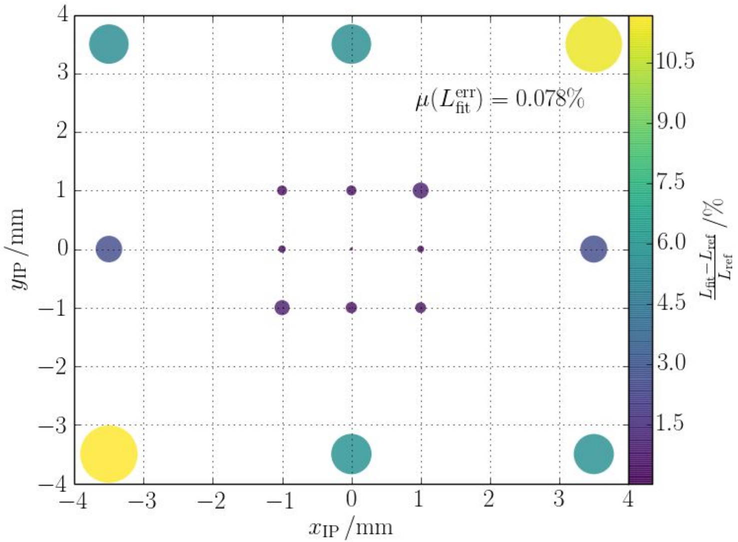
Measurement of IP shift

Simulation: IP shifts of 0, 1, 3.5 mm

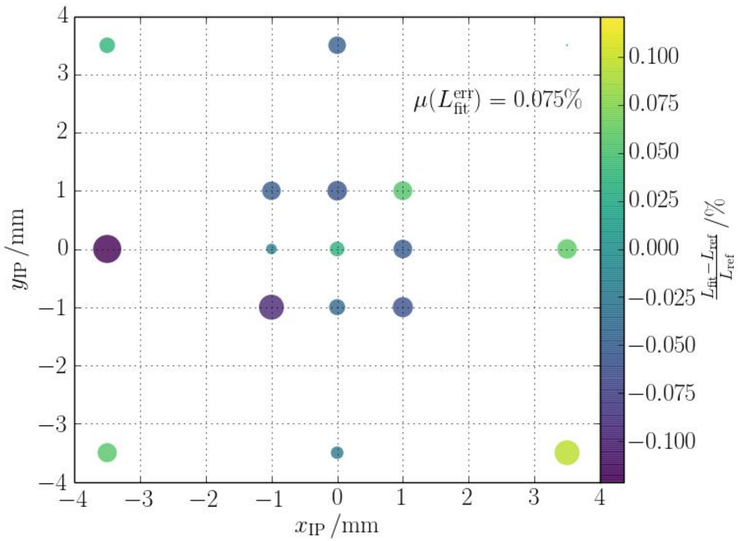
IP shift reconstruction accuracy below 50 μm



Influence of IP shift on Luminosity



w/o correction



with correction

Realistic Scenarios

The Luminosity Fit software is able to:

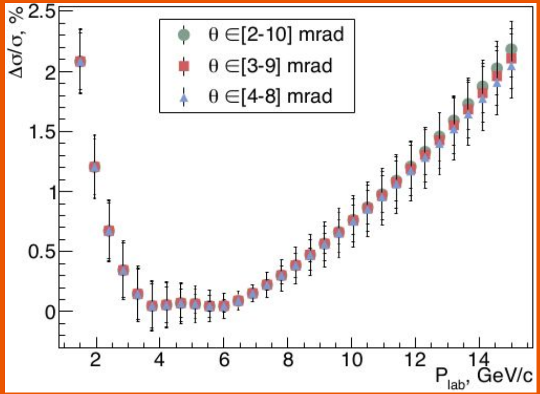
- extract IP shifts with accuracy 50 µm
- extract antiproton beam tilts with accuracy 3-30 µrad (for p_{lab} 1.5 - 15 GeV/c)*
- extract antiproton beam divergence with accuracy ~20 µrad*
  (BUT: only works for divergences above 200µrad and low energies)
- Includes most systematic effects
  - remaining systematic effects: hadronic elastic scattering cross section, misalignments, (inelastic background)**, geometry model and magnetic field maps in the simulation
- And most importantly, the luminosity is extracted with ....

* when the accuracy decreases the influence on the extracted luminosity decreases likewise
**background is generally reduced to approx. 0.2%

Relative Systematic Uncertainty of Luminosity*:

~ 0.5%

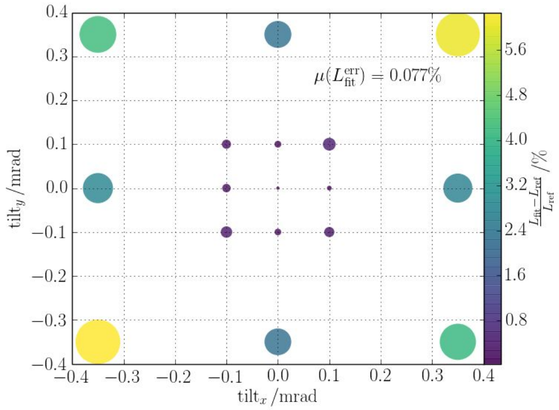
* excludes huge uncertainty of several % for the hadronic part of elastic cross section
(improvement from KOALA experiment to be expected)

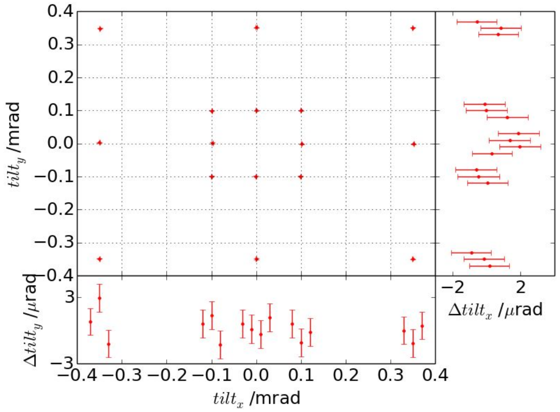


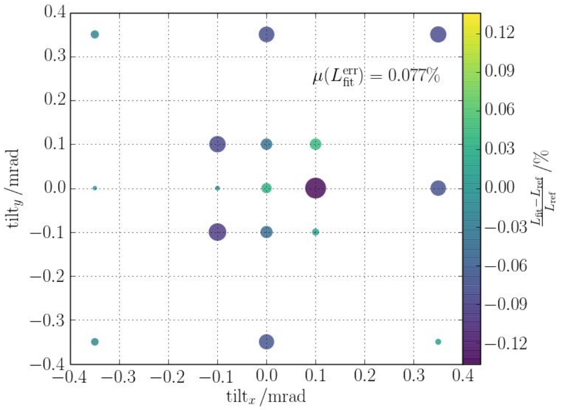
The End

Thanks for your attention!

Antiproton Beam Tilt







Antiproton Beam Divergence