HARPO:
Analysis of beam and cosmics data

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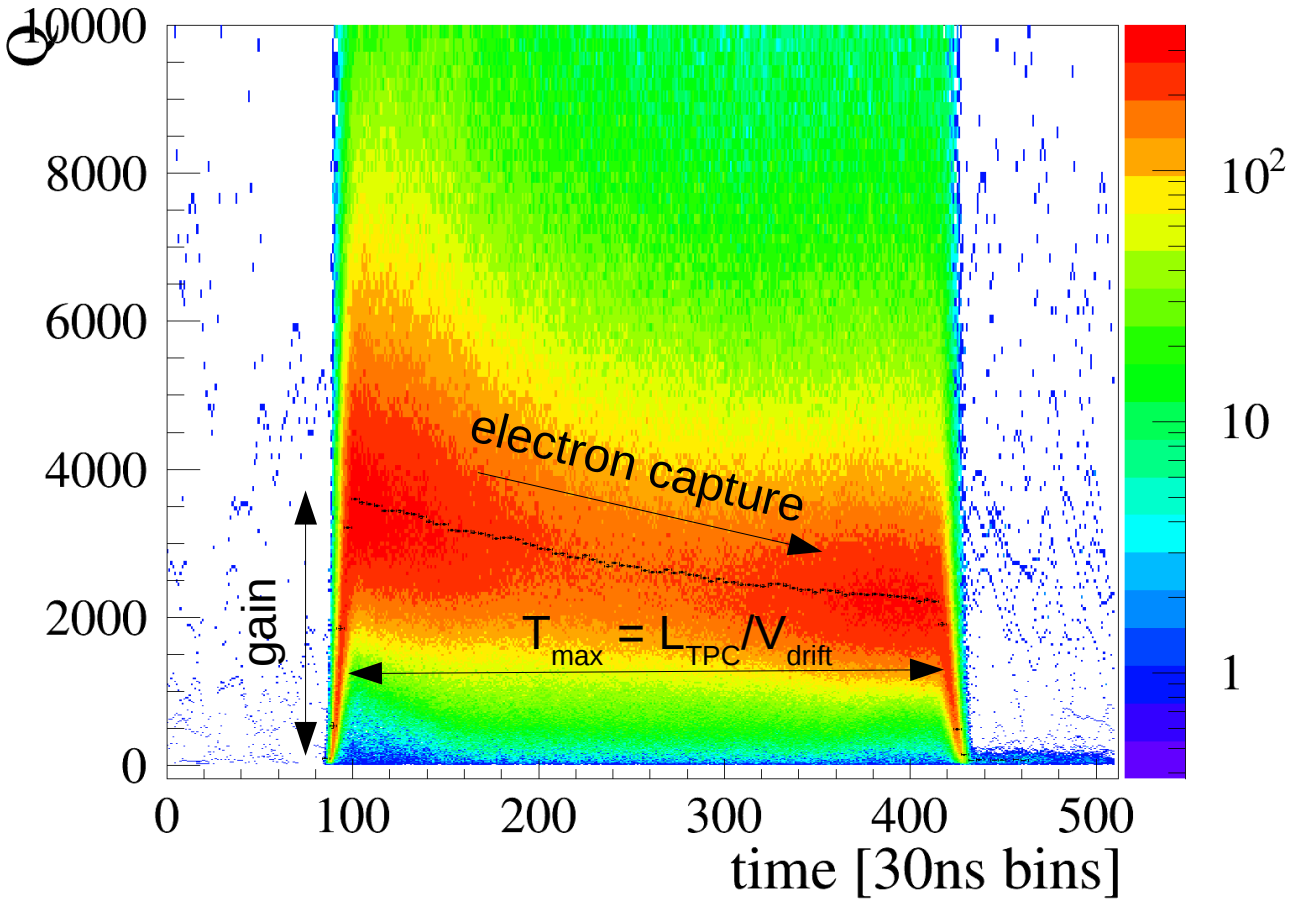
- Detector monitoring using cosmic rays
  - detector/gas stability over several months
- Polarisation measurement in a gamma ray beam
- Simulations
  - pair conversion event generator
  - full detector simulation

Detector monitoring using cosmic rays

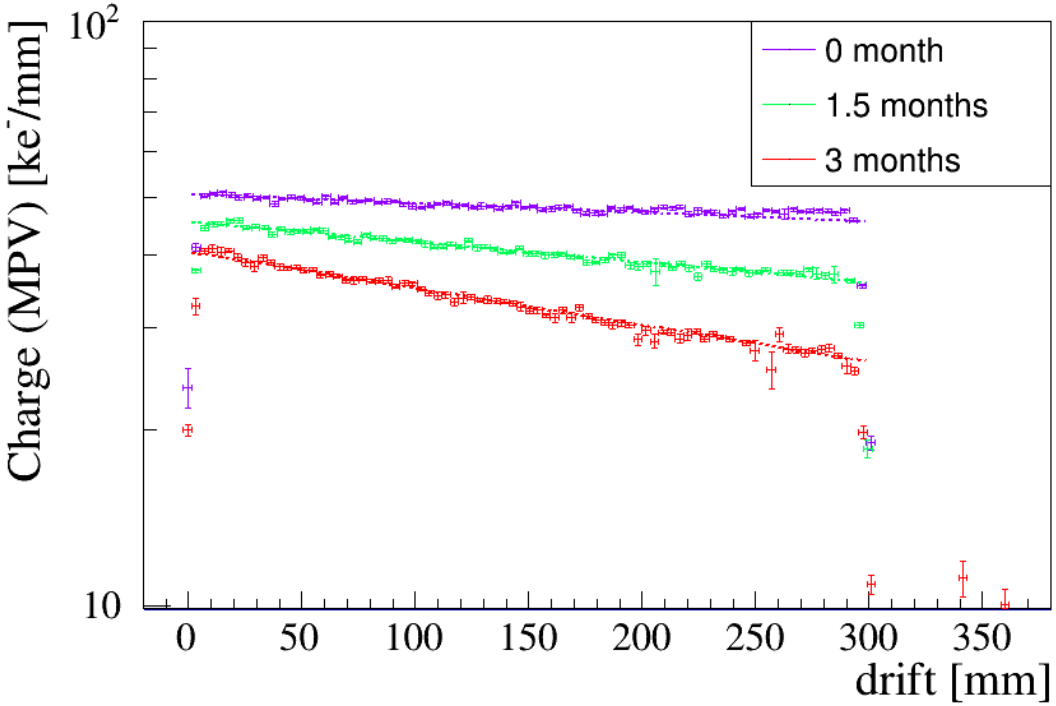
Diagnostics: Q vs T_{drift}



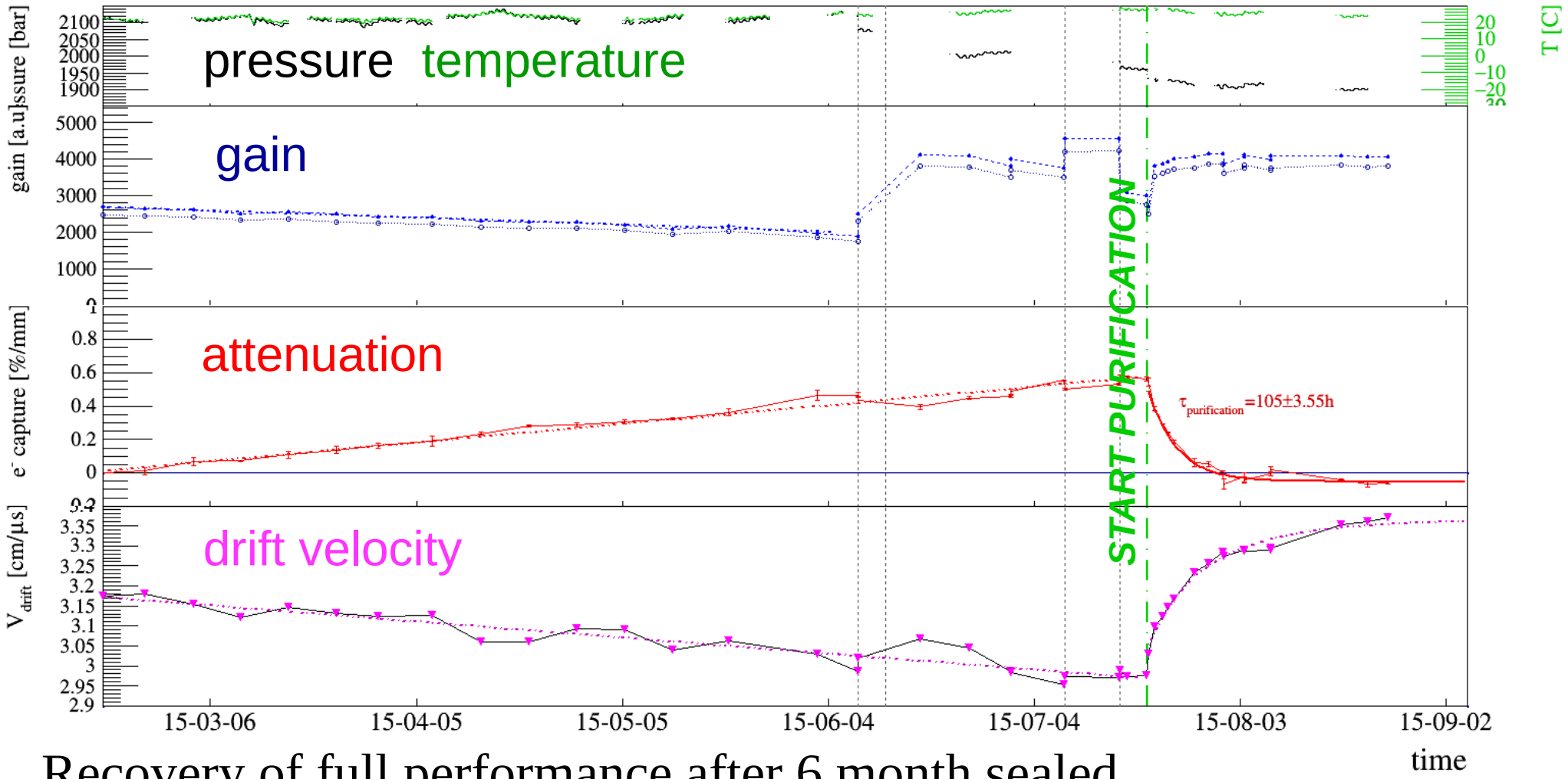
- The charge is normalised with regard to the track angle
- The MPV is obtained from a Landau fit (of slices) (mean value affected by threshold/saturation effects)
- Vdrift is also easily extracted from this plot

Cosmic runs LLR

- Relative measurements
  - First run as reference (“clean gas”)
- Weekly data taking of ~1.5h, for 6 months
- Clear degradation of gain and e- capture



Gas stability

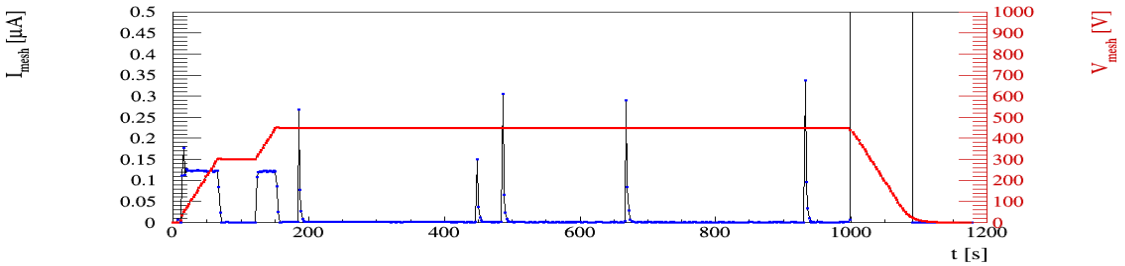


Recovery of full performance after 6 month sealed

Frotin et al., MPGD2015, EPJ Web of Conferences, arXiv:1512.03248

Gas stability

- Test done without HV
  - monitoring necessary: risk of damage on µM
  - HV turned on only for data taking ~1h/day
- **PYRAME** module for HV monitoring and control
  - automatic detection of current spikes
  - emergency shut-down in case of problem
  - successfully tested
  - *thanks to F. Magniette*

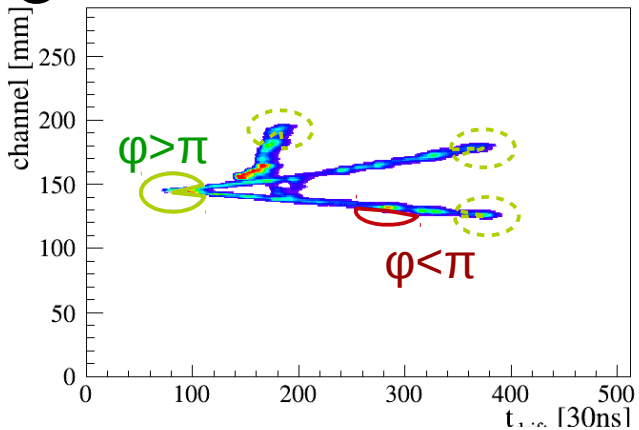


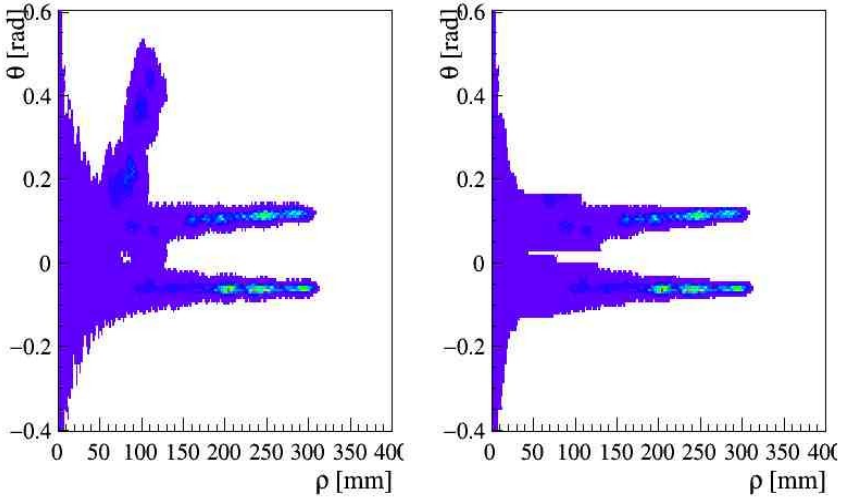
- Planned long term stability test
  - fully automated
  - daily cosmic-ray data taking

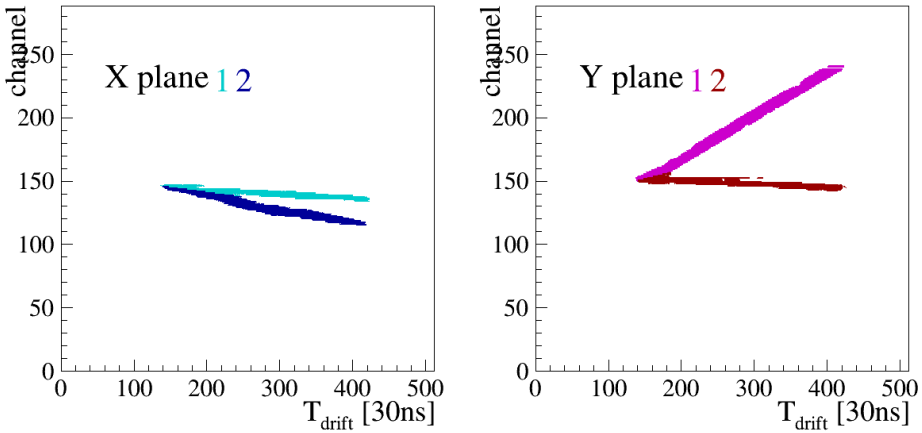
Gamma-ray beam Reconstruction and Analysis

Reconstruction 3.0

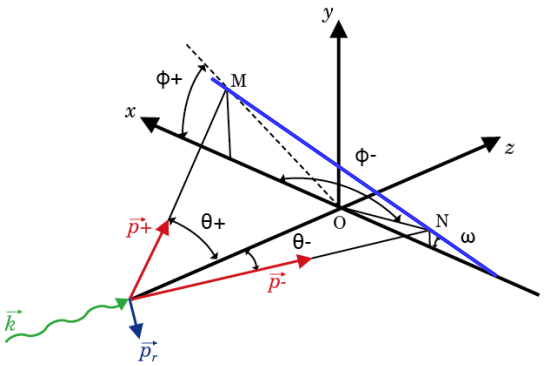
- *No tracking: local vertices*
  - Find ROI
  - Find peaks in polar distribution around point
  - match 2D vertices to get 3D picture



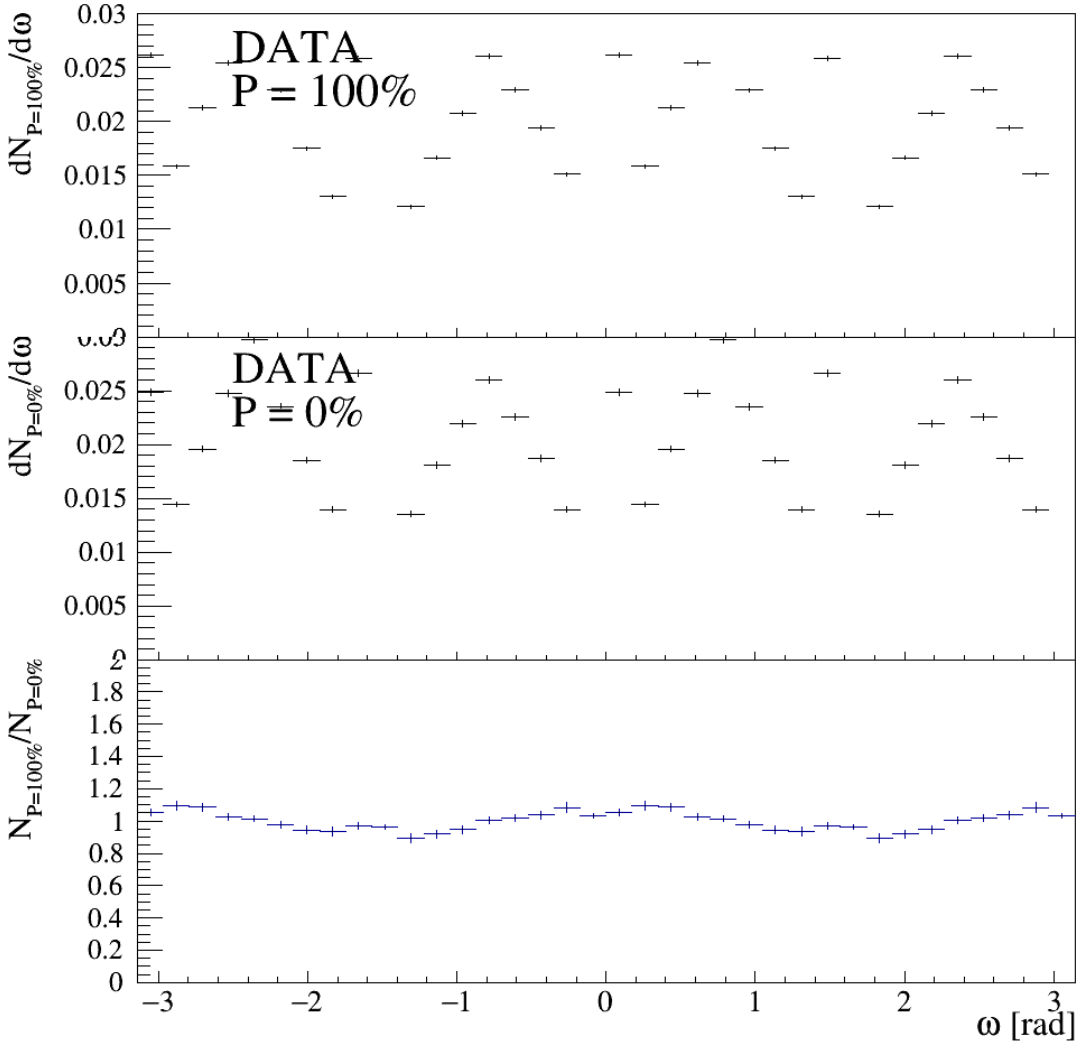




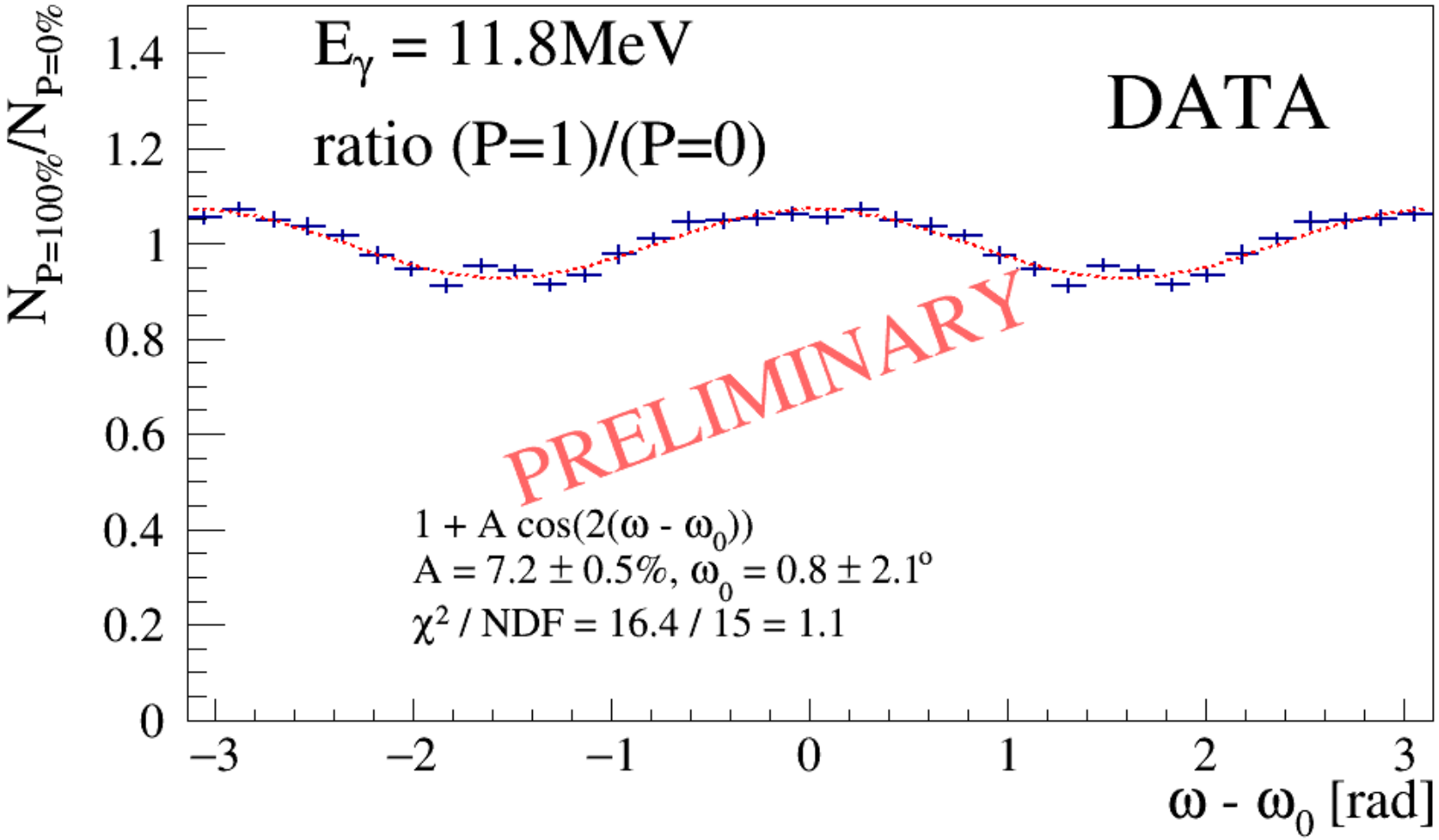
Polarisation



- Large systematics due to cubic geometry
- Cancel systematic bias by taking the ratio between P=100% and P=0%



Polarisation: DATA



Presented at the SPIE conference Space Telescopes and Instrumentation
July 2016, Edimburgh

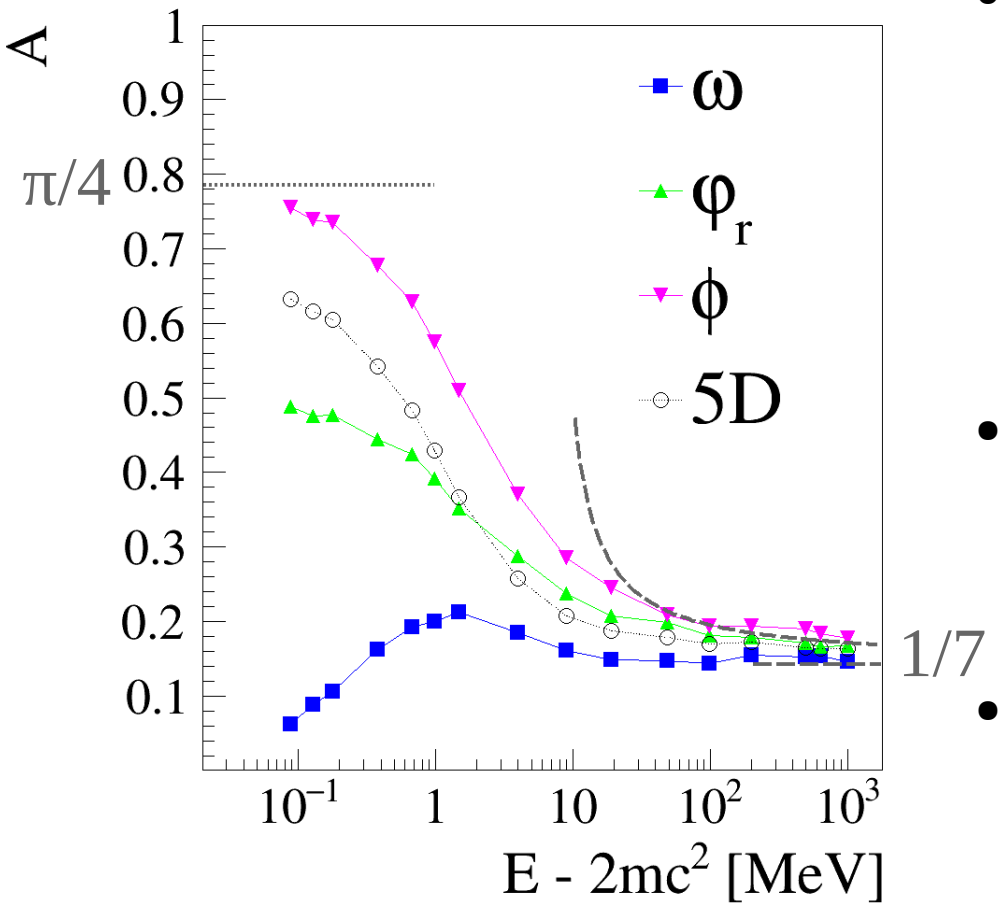
Simulation

Event generator

- Exact pair production event generator developed
  - full 5D differential cross-section
  - photon polarisation
  - first published in NIM A 729 (2013) 765
- Validated and compared
  - cross validation with analytical formulas
  - comparison with other generators
- To be implemented in Geant4

Presented at the SciNeGHE conference, October 2016, Pisa
paper submitted to Astroparticle Physics

Remark on Azimuthal angle



- Azimuthal angle definitions
  - recoil angle φ_r
  - pair plane angle ω
  - pair bisector ϕ
- Angle ω used in previous publications underestimates A at low energy
- ϕ appears in Bethe-Heitler formula, agrees with asymptotic values

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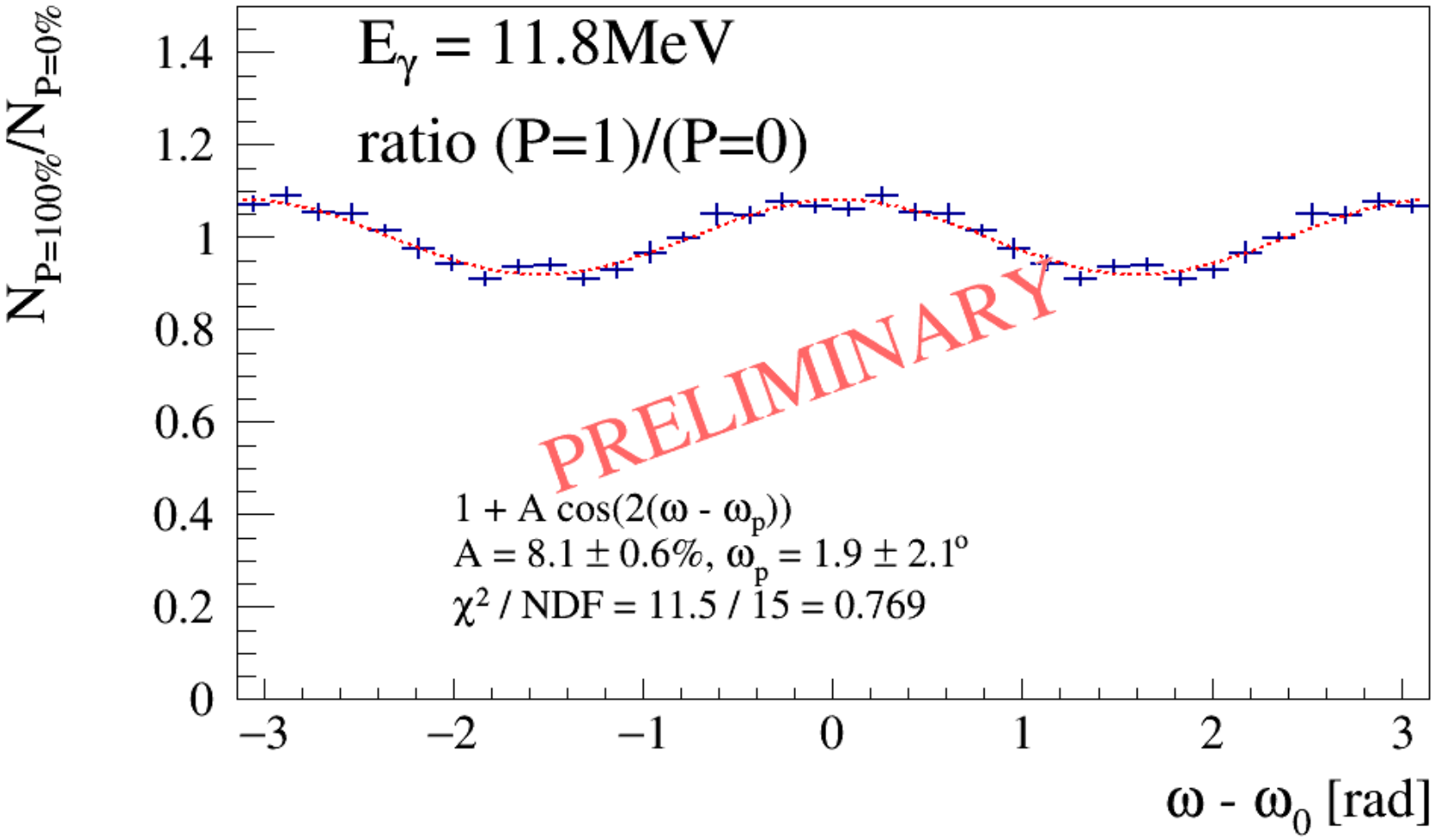
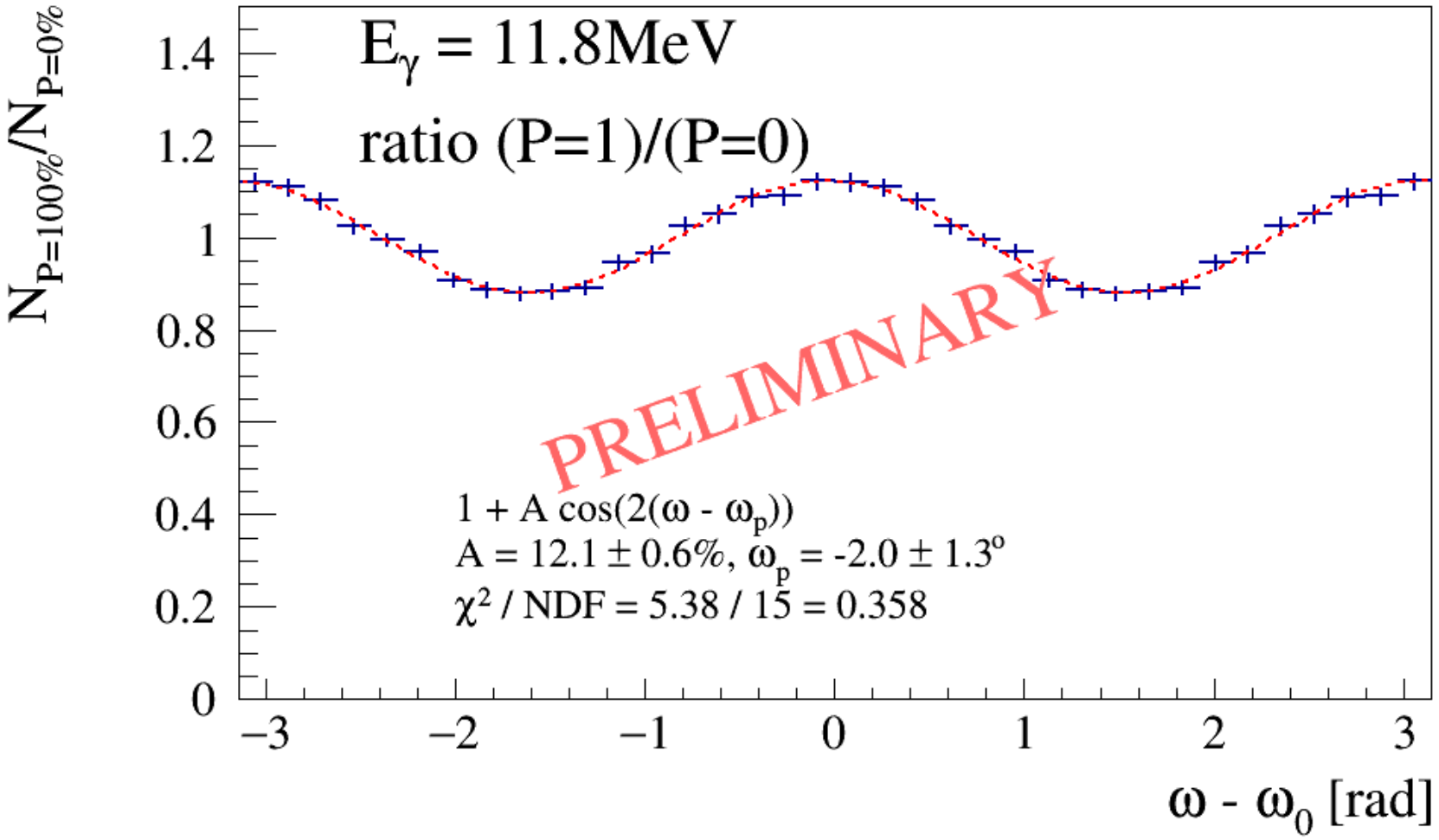
Azimuthal angle ω (old)



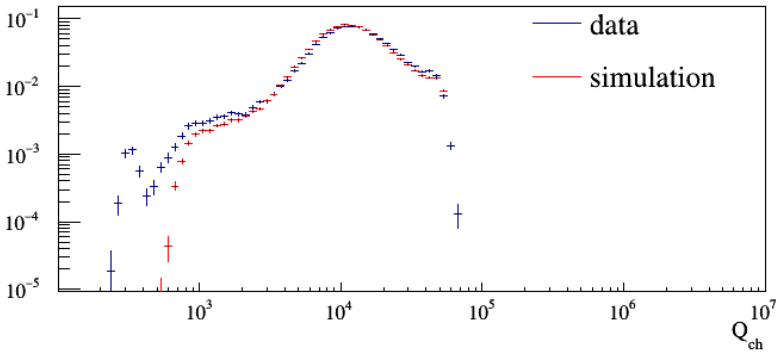
Azimuthal angle ϕ (new)

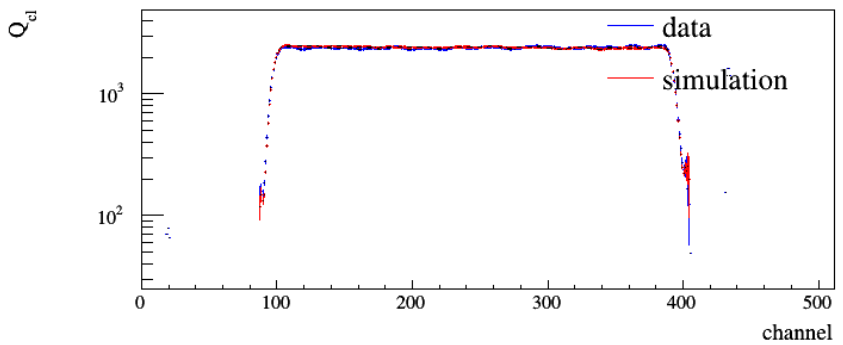


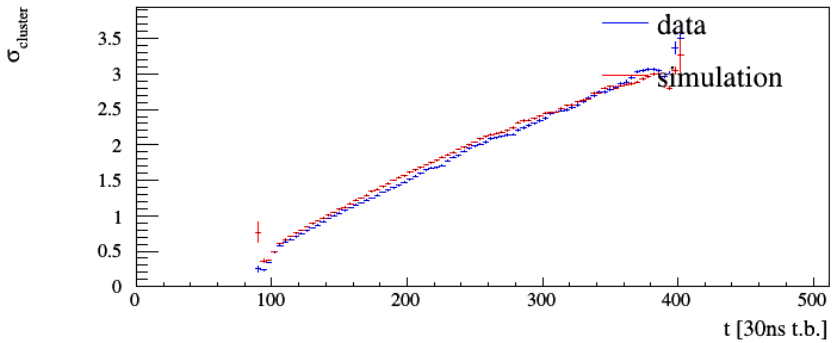
Detector simulation

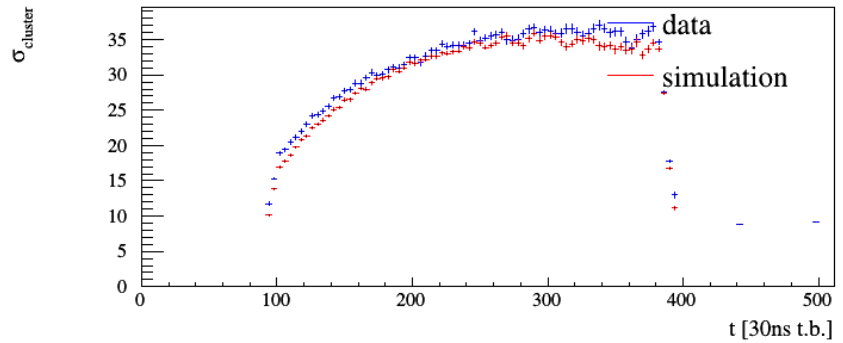
- Electron and positron 4-vectors from generator
- Track propagation and gas ionisation with Geant4
- Custom simulation of TPC
  - drift, diffusion, gain fluctuations, electronics response
  - output same format as HARPO data

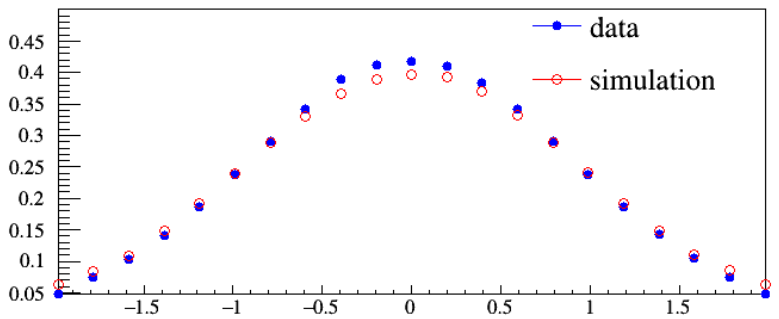
Validation/Calibration

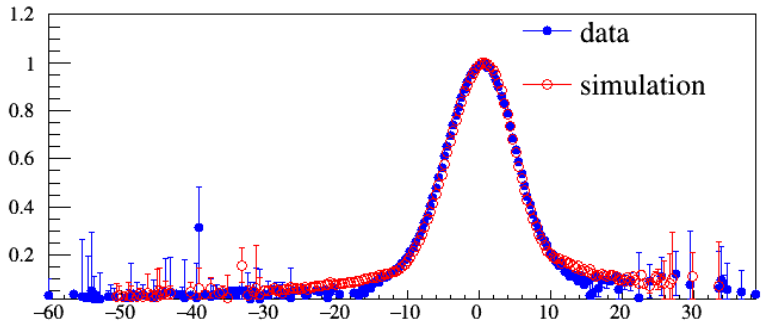




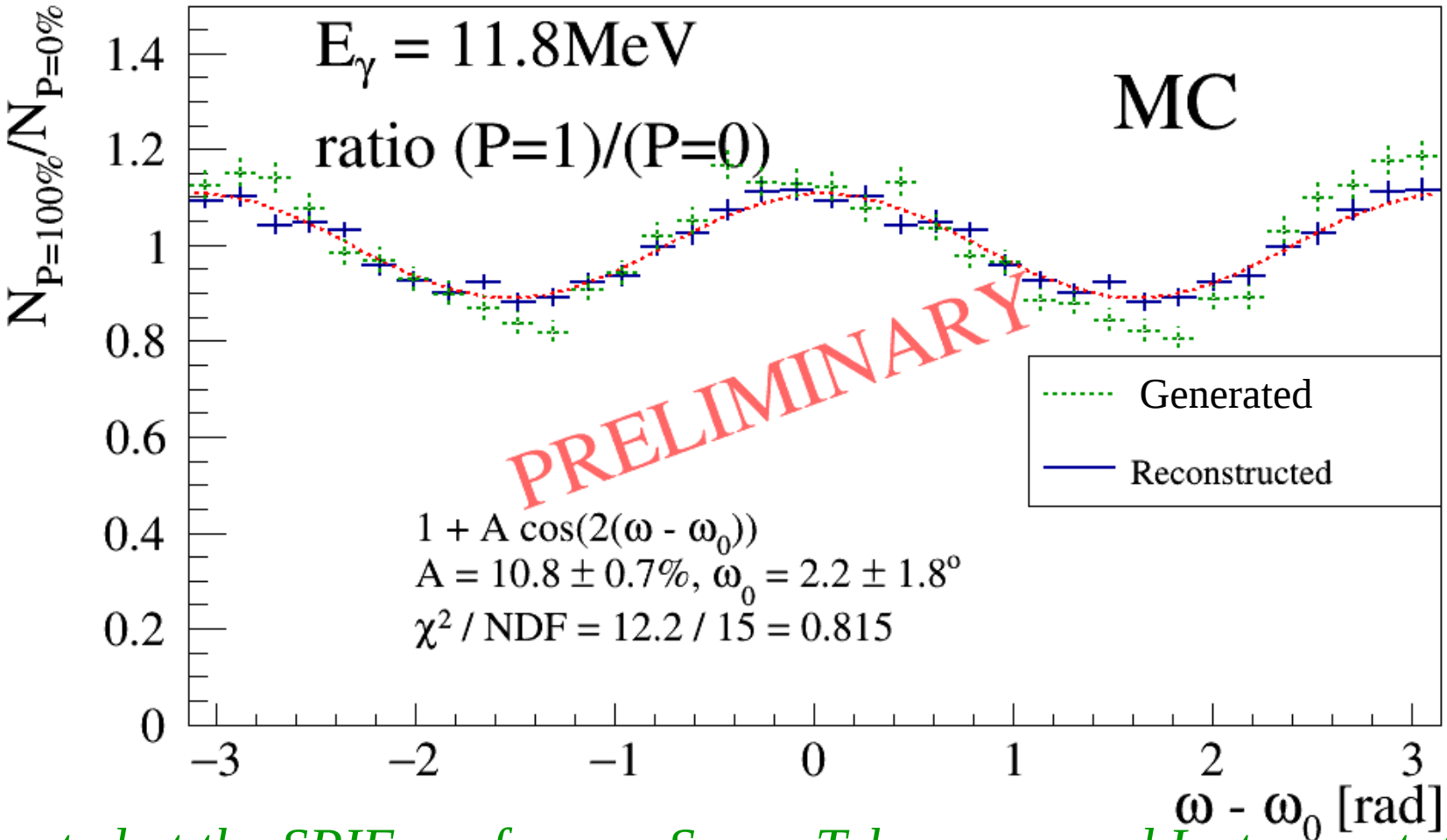






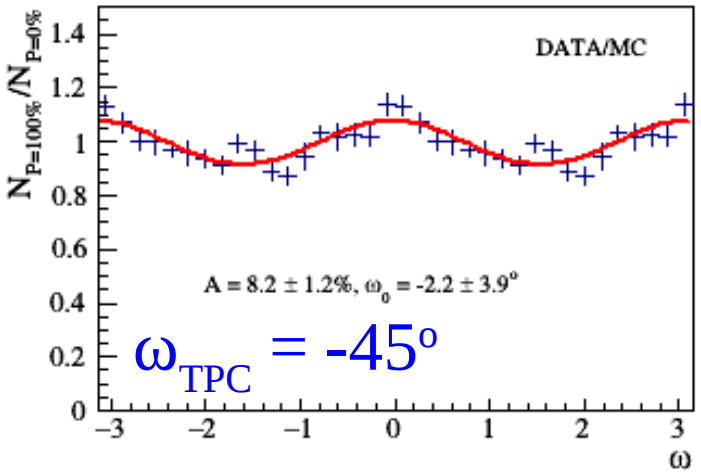


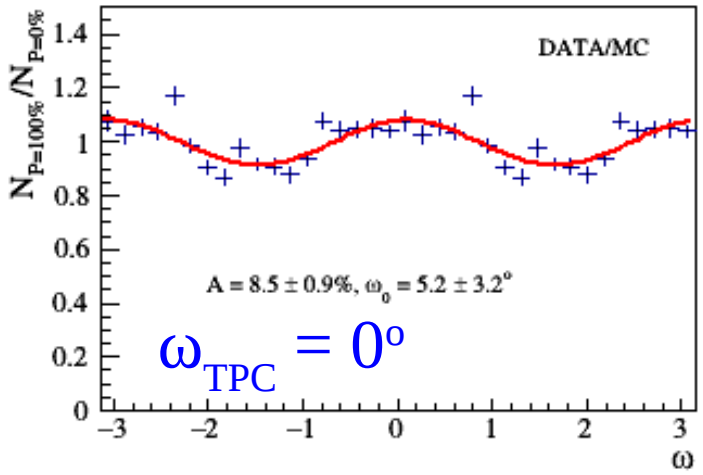
Polarisation: MC

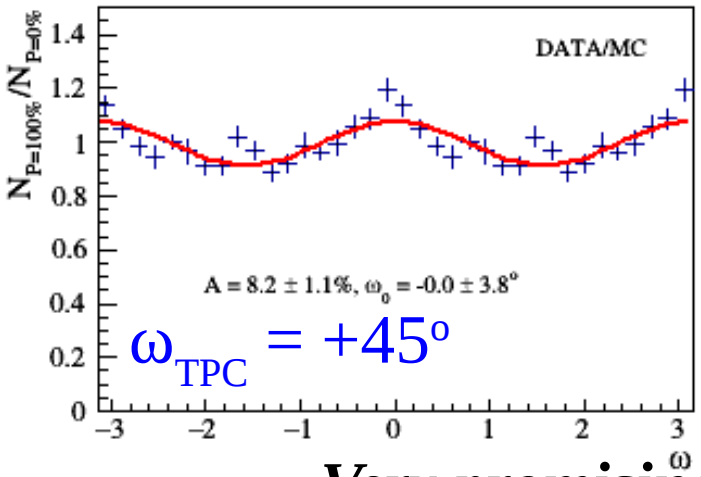


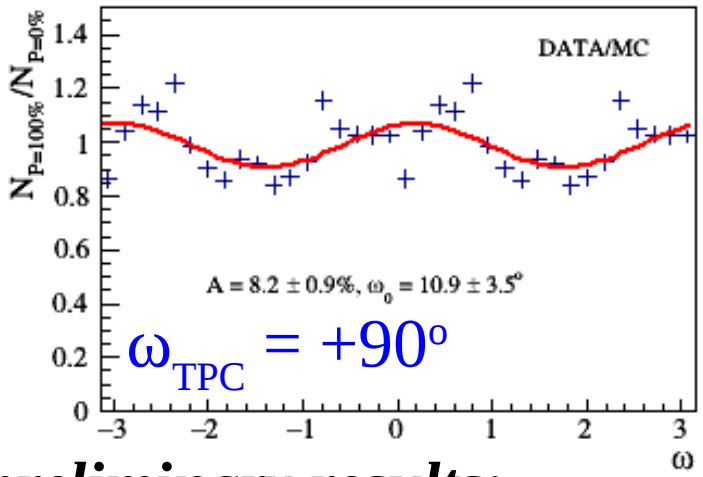
Presented at the SPIE conference Space Telescopes and Instrumentation
July 2016, Edinburgh

DATA/MC
4 TPC orientations









Very promising preliminary results:
systematic bias is well reproduced and cancelled by the simulation

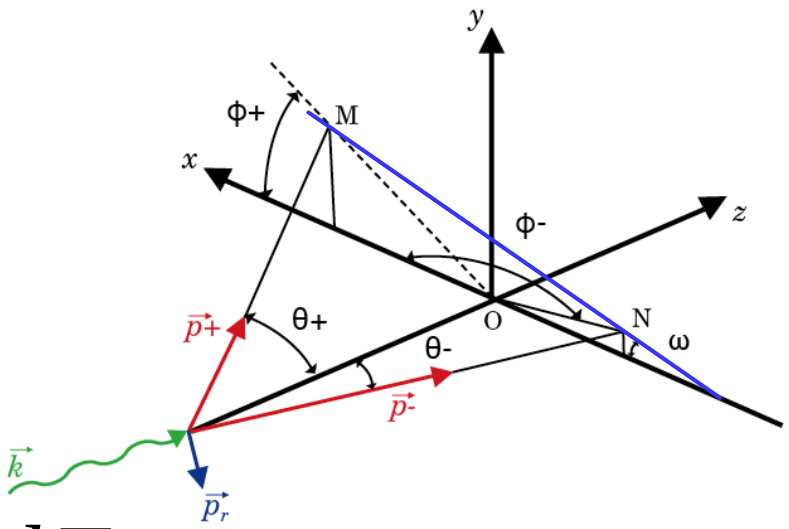
Conclusions

- HARPO data are well understood
- Detector can be well monitored with tracks
  - stable with occasional operation
  - starting test under full time operation
- Excellent beam polarisation measurement
- Good simulation for systematics study

Backup

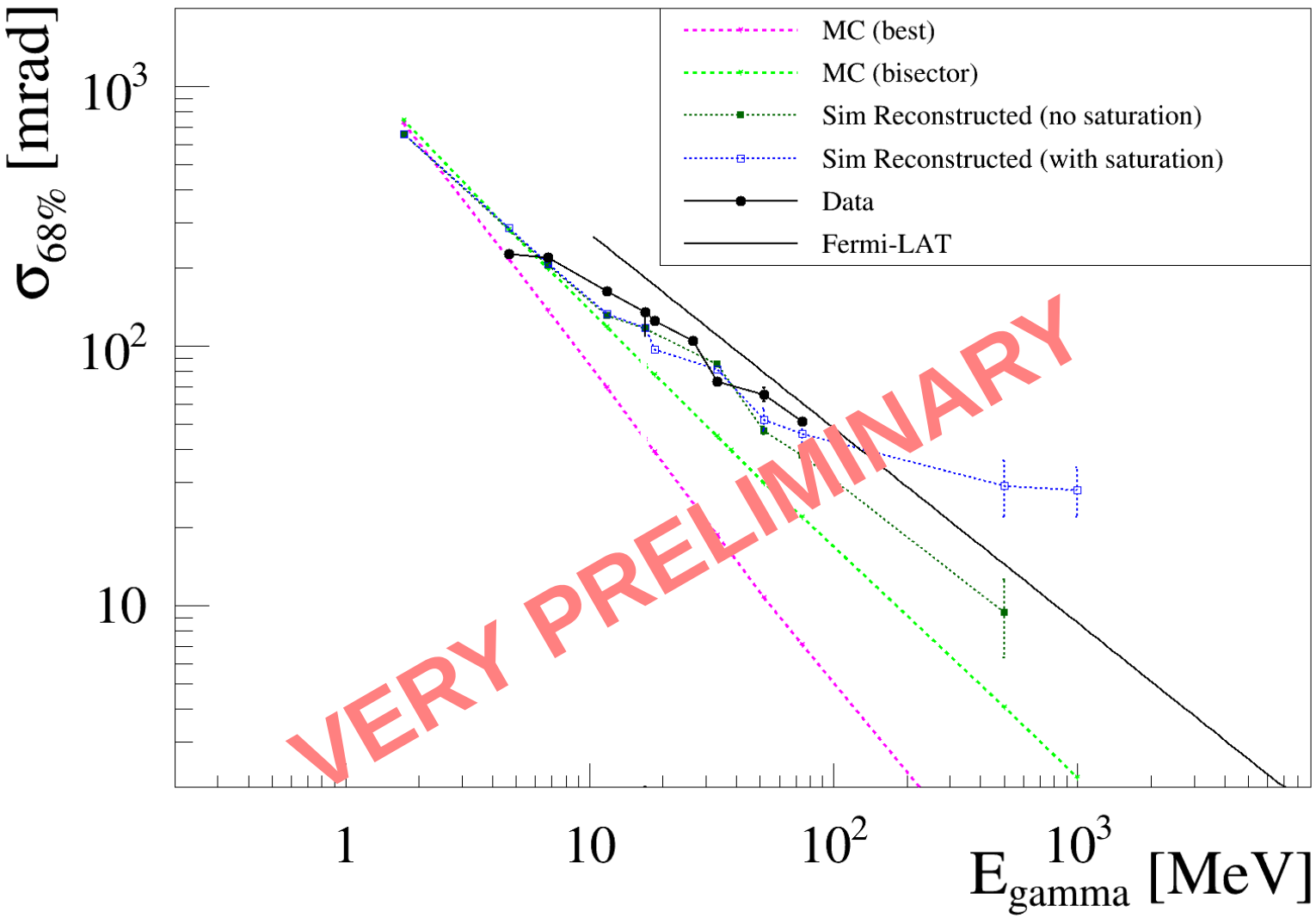
Polarisation

- Modulation of the azimuthal angle ω



$$\frac{d\Gamma}{d\omega} \propto 1 + A\cos\left(2\left(\omega - \omega_0\right)\right)$$

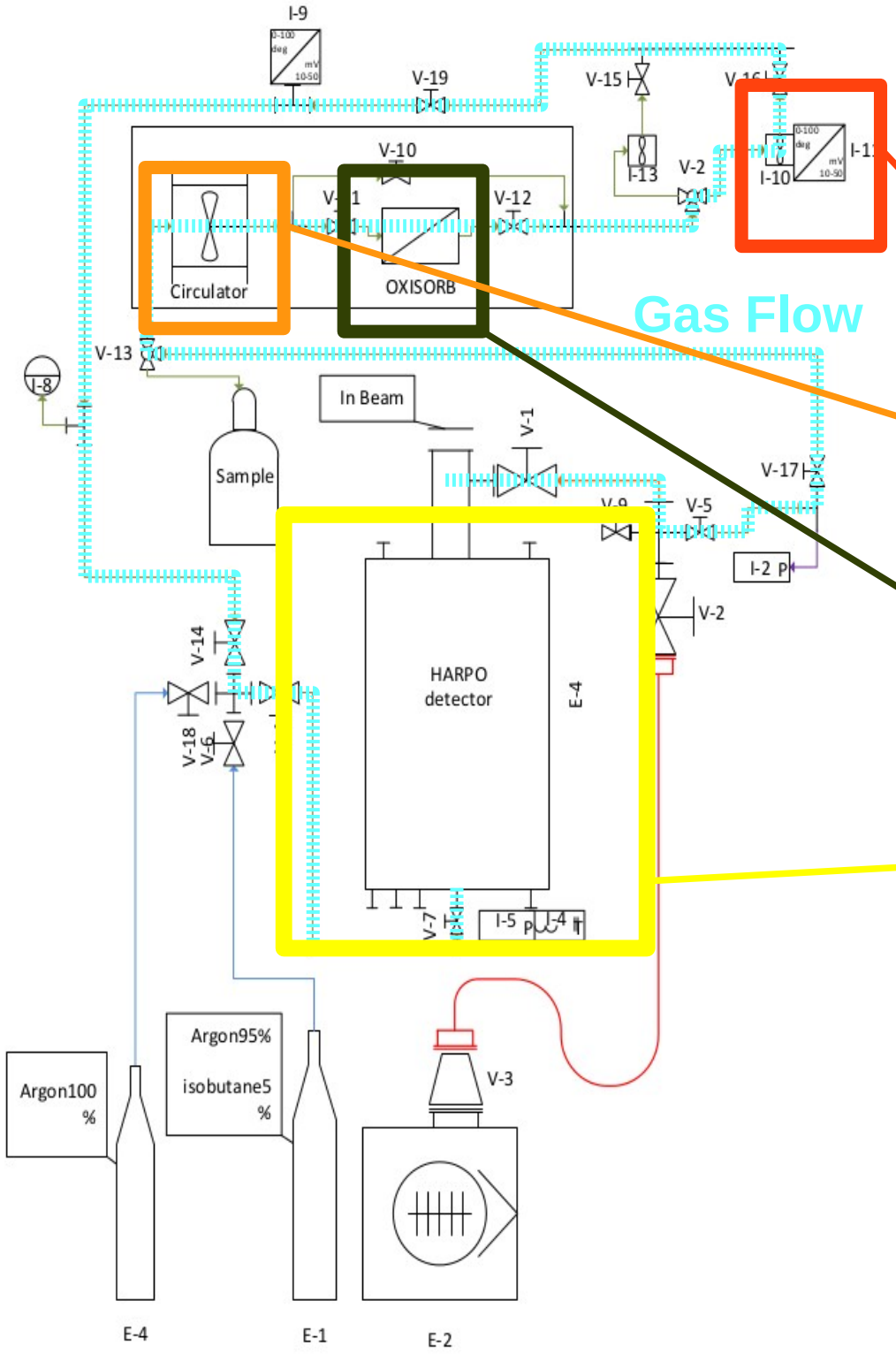
Angular resolution

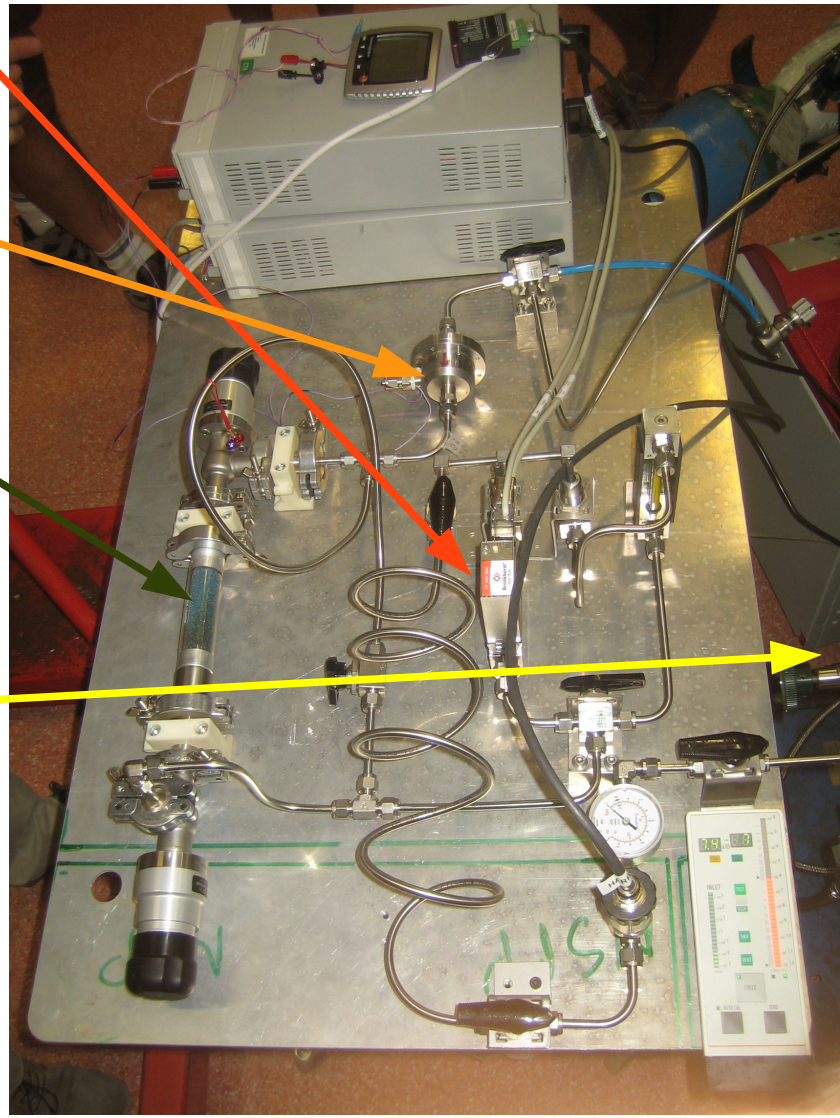


Angular resolution

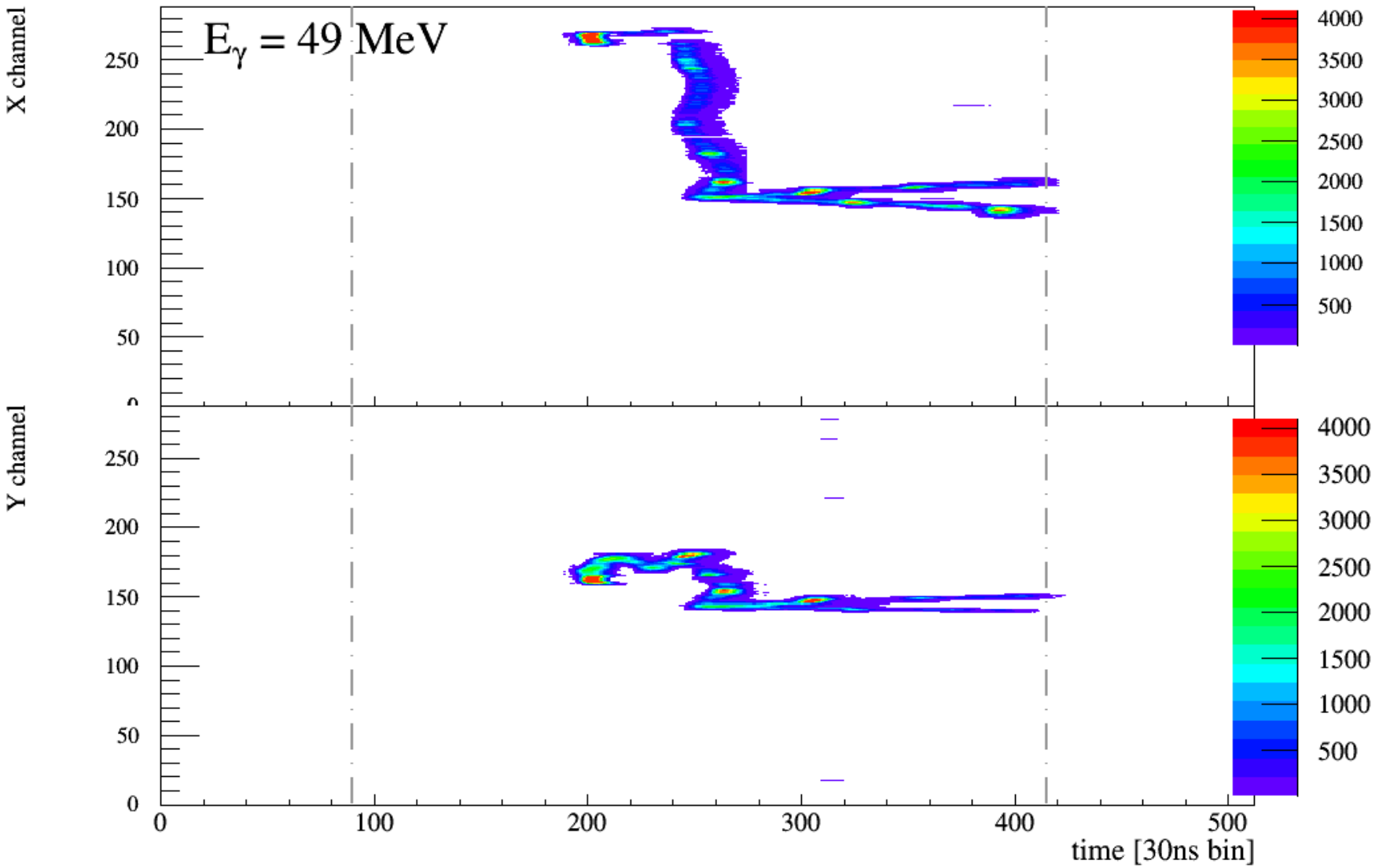
- Agreement with theoretical prediction
  - relatively small contribution of tracking
- Excellent agreement with simulation
  - effect of saturation dominates at high energy

- Potential for improvement
  - estimation of track momentum
  - even 100% resolution should significantly improve

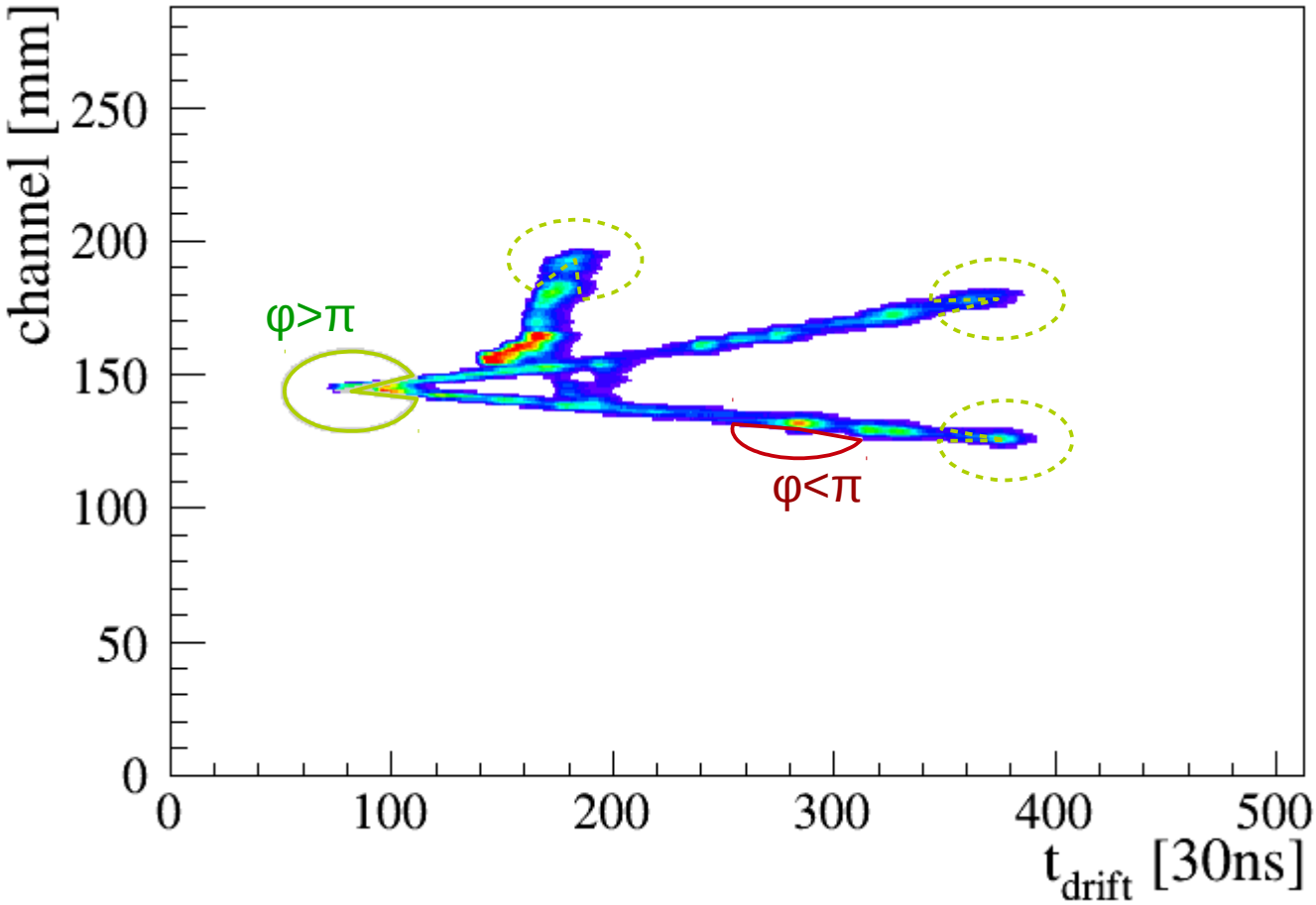

I-9
V-19
V-15
V-10
V-11
V-12
I-13
V-2
I-10
Circulator
OXISORB
Gas Flow
V-13
I-8
In Beam
V-1
Sample
V-17
V-9
V-5
I-2 P
V-2
V-14
V-18
V-6
HARPO
detector
E-4
V-7
I-5 P
I-4 T
Argon100
%
Argon95%
isobutane5
%
V-3
E-4
E-1
E-2



Triplet event

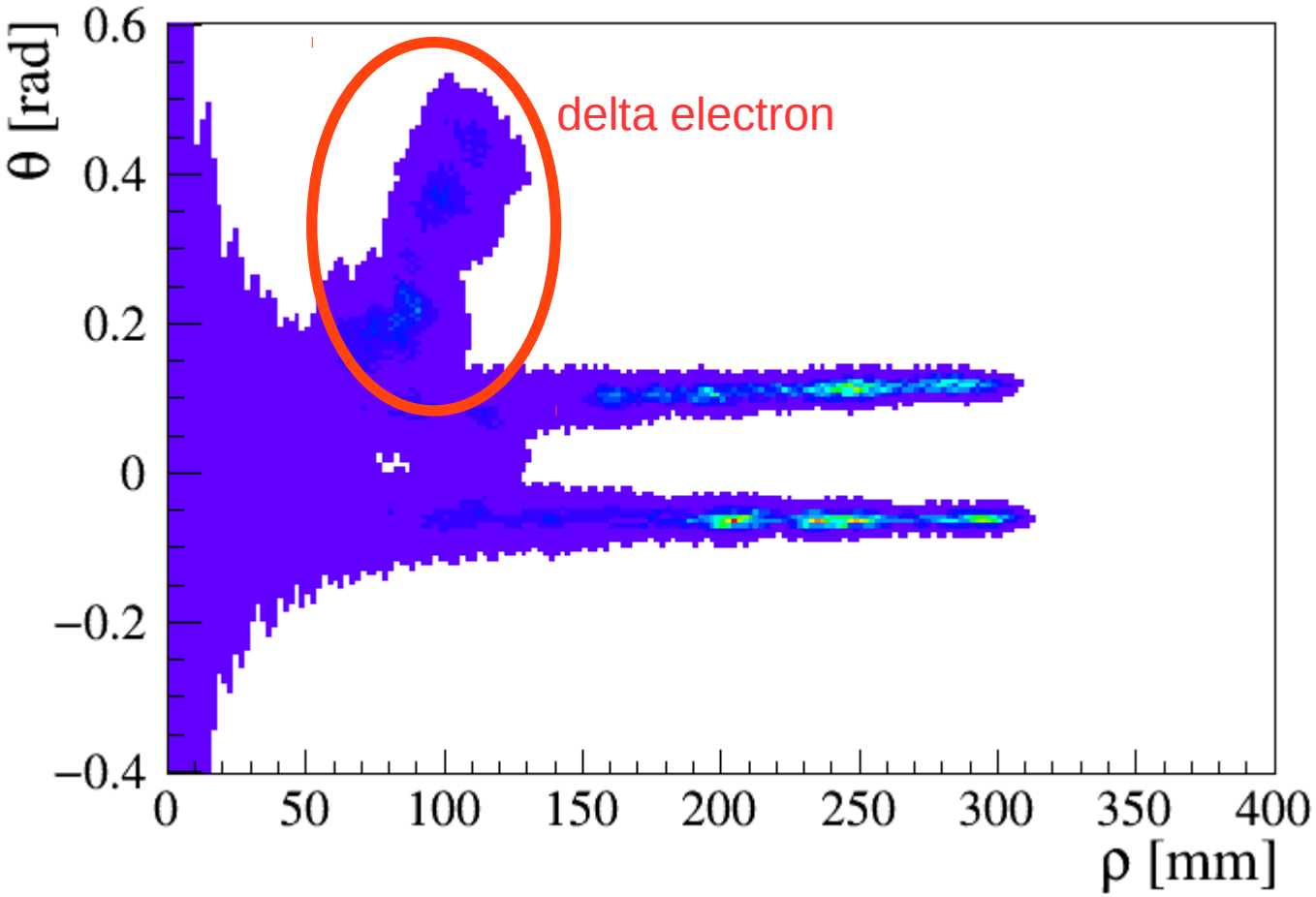


Vertex Finder



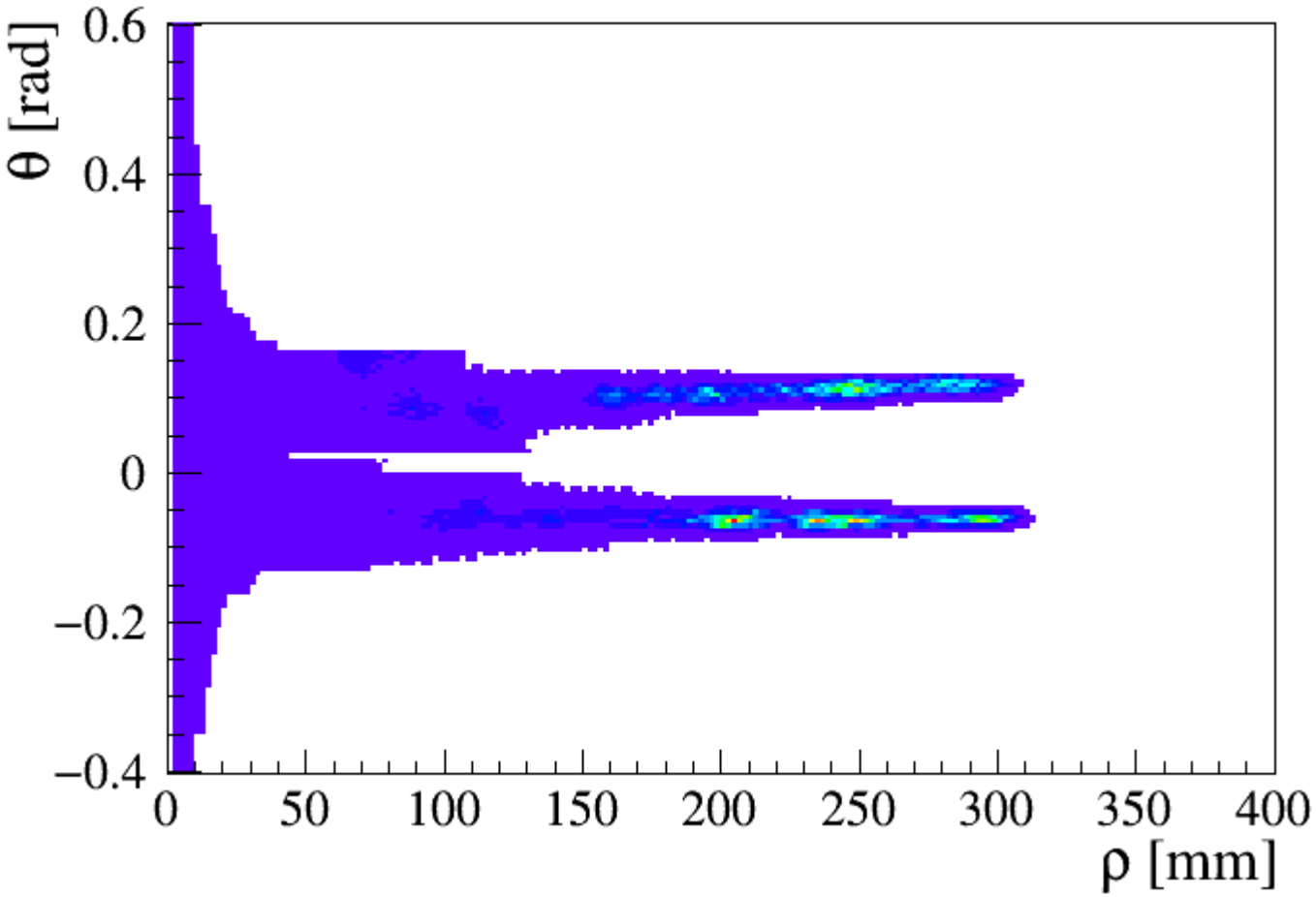
Vertex Fitting

- Polar charge distribution around vertex



Vertex Fitting

- Clean up: keep only straight lines



Vertex Fitting

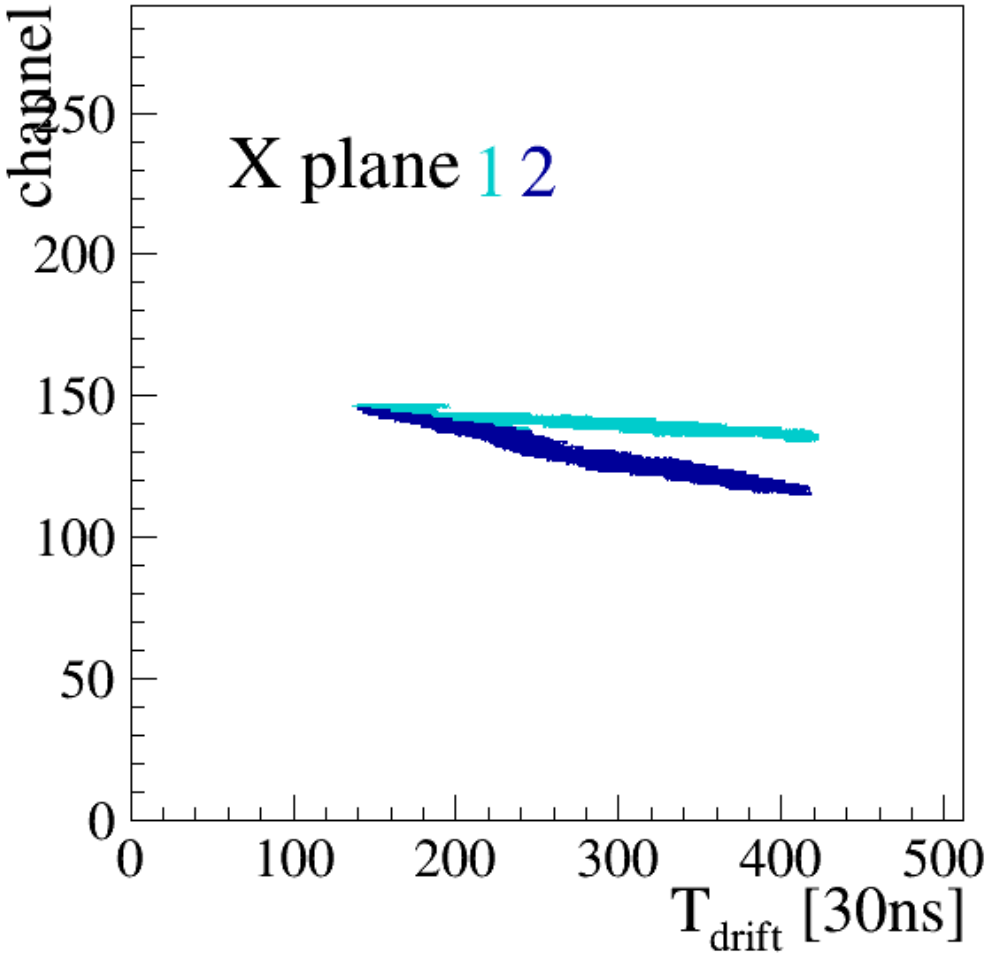
- Simple
- Robust:
  - ignores obvious scattering and background
  - potential for small opening angle
- Potential for improvement
  - better peak finding
  - use of distance info (focus on short distance for large opening angle, long distance for small)

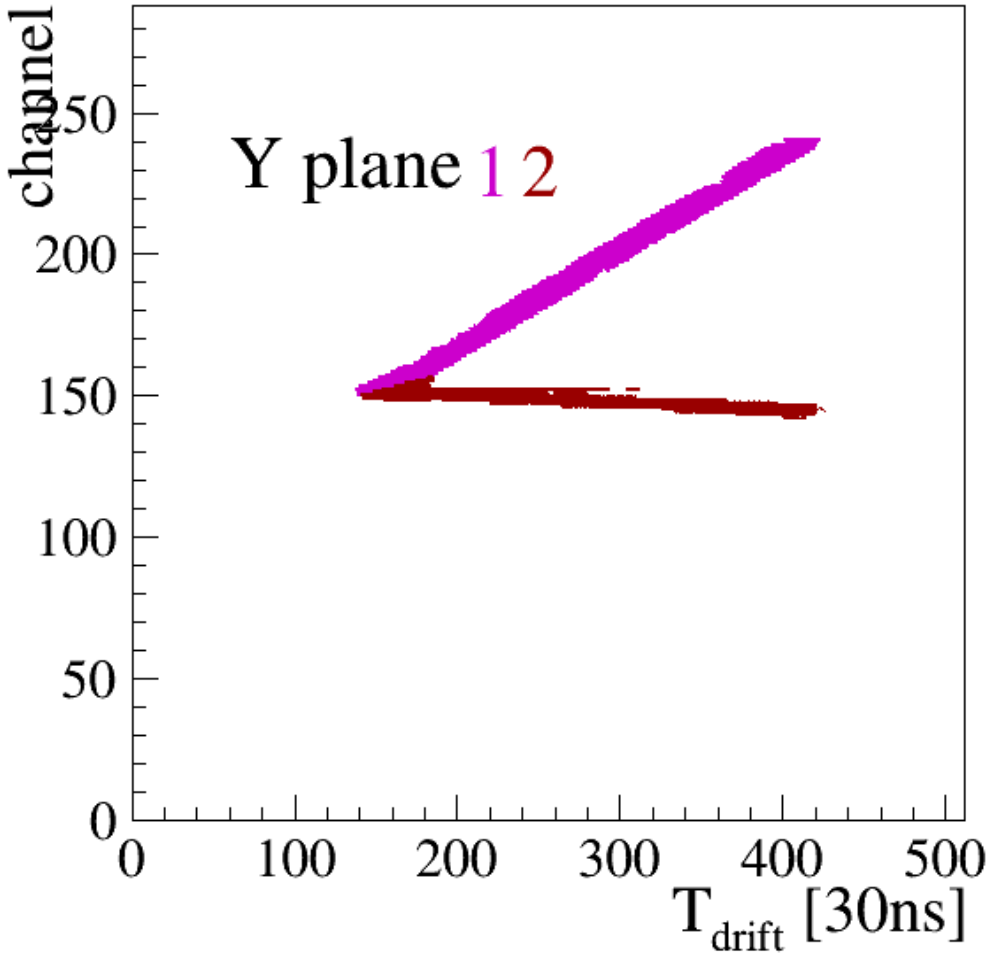
Vertex Matching

- As before: compare charge profile
  - 1: match vertexes if there are several with same Z position
  - 2: match the tracks in the vertex (simple: only 2 possibilities)

Vertex Matching

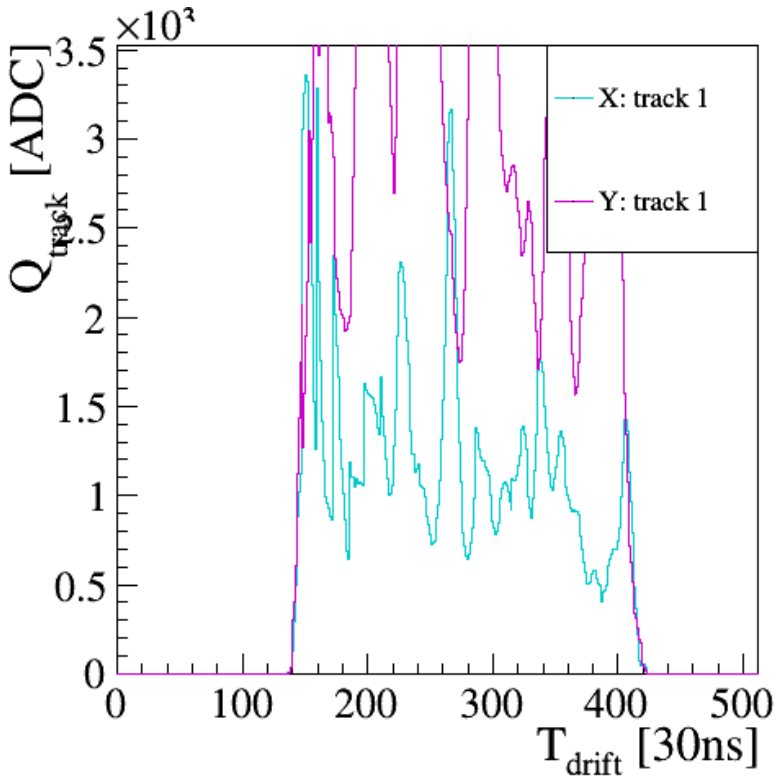
- Assign signal to tracks

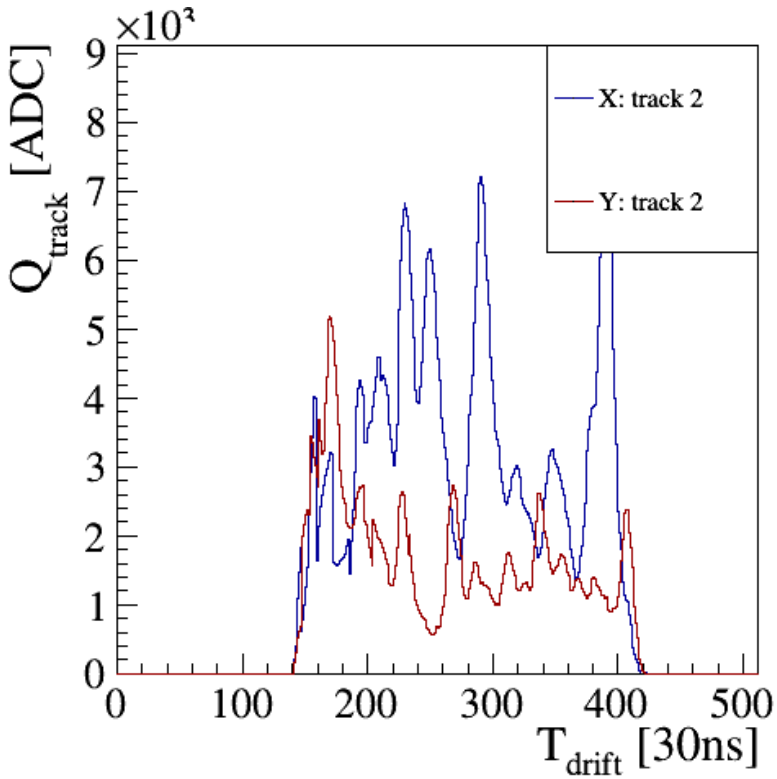




Vertex Matching

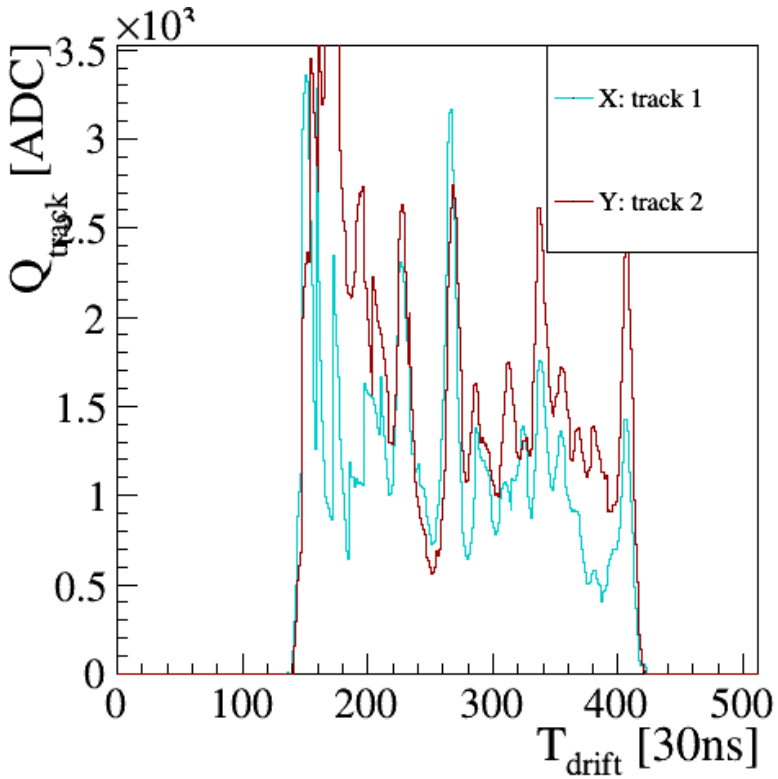
- Compare profiles: X(1,2) ↔ Y(1,2) "same"

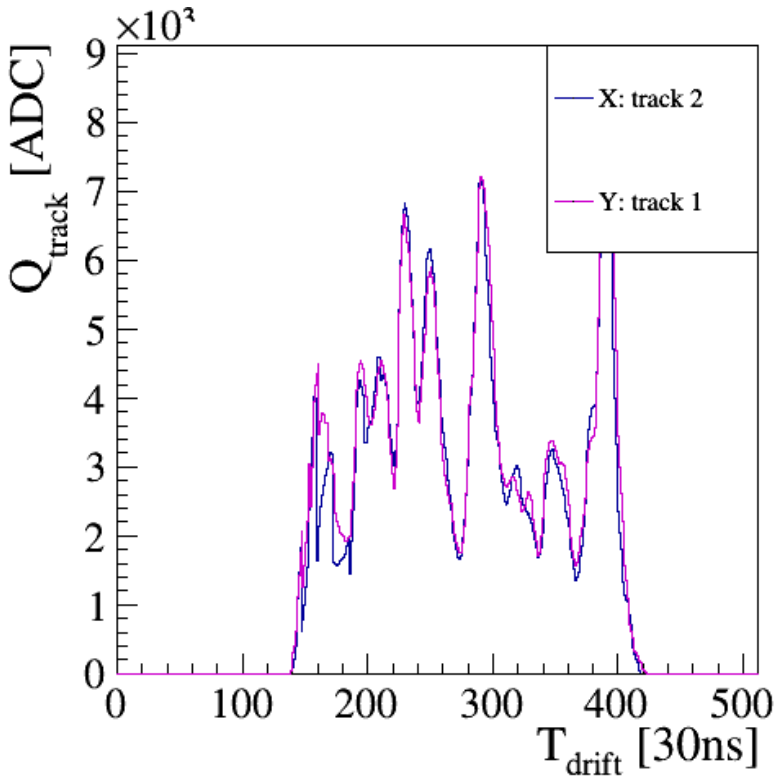




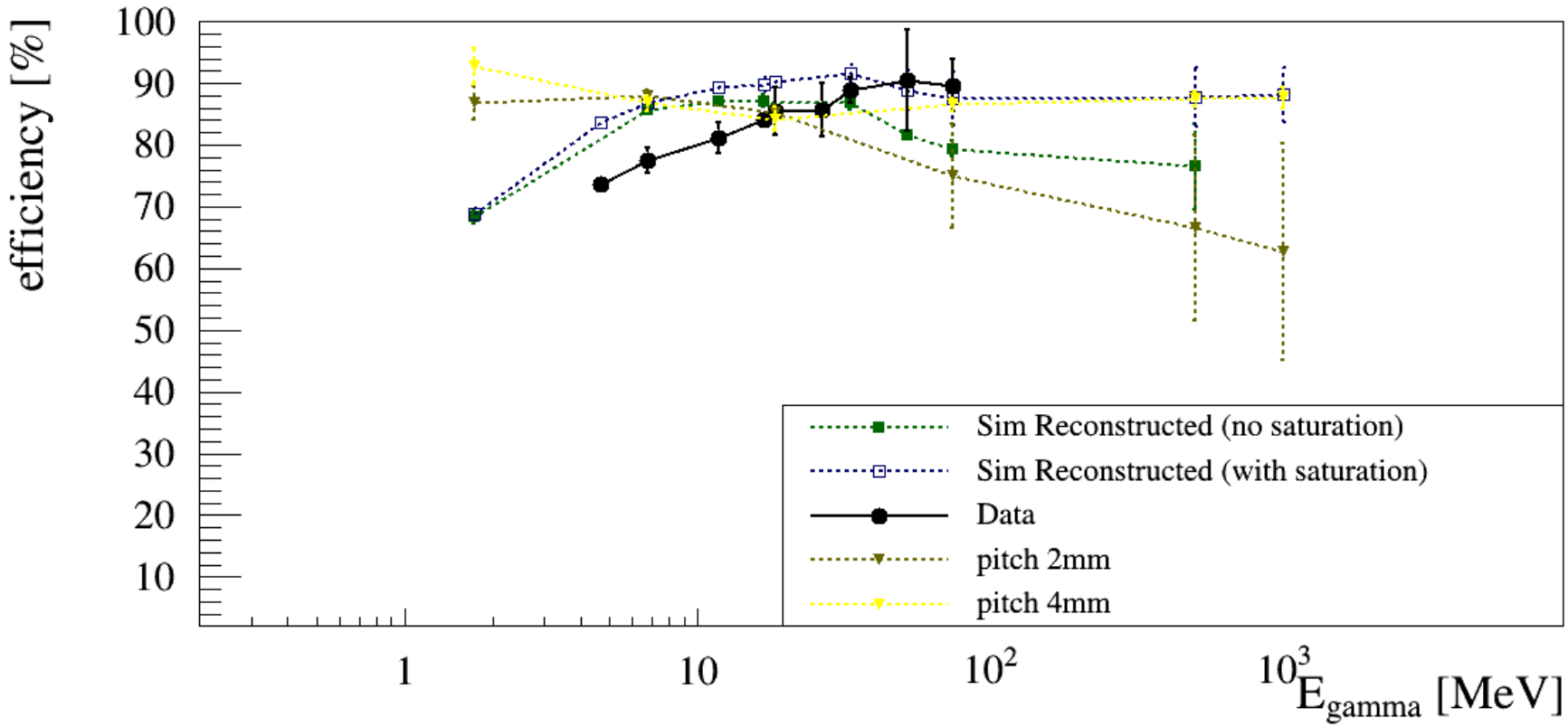
Vertex Matching

- Compare profiles: X(1,2) ↔ Y(2,1) "switch"





Efficiency


efficiency [%]
100
90
80
70
60
50
40
30
20
10
1
10
10^2
10^3
E_{gamma} [MeV]
Sim Reconstructed (no saturation)
Sim Reconstructed (with saturation)
Data
pitch 2mm
pitch 4mm

Polarisation asymmetry