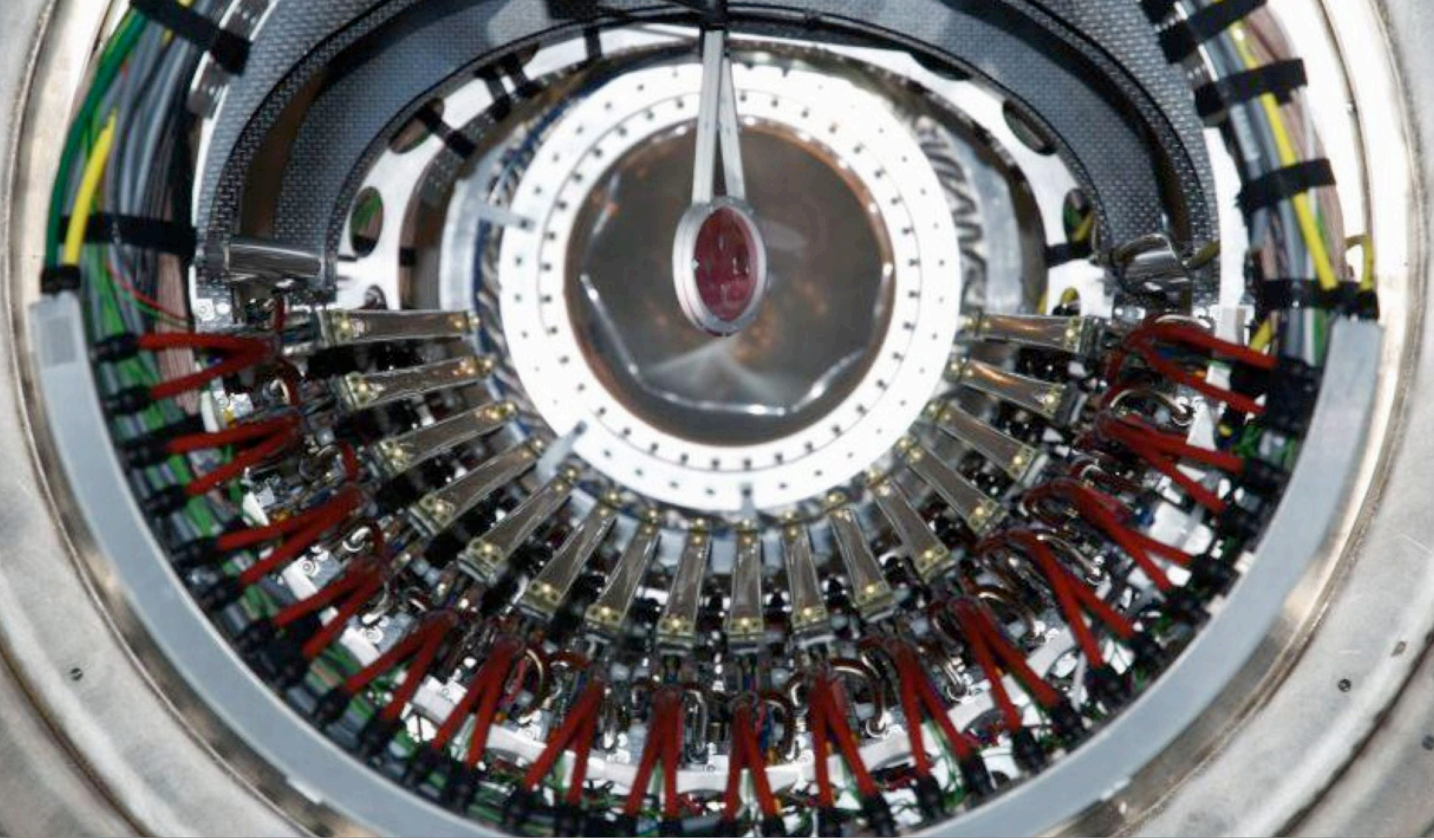


MEG陽電子スペクトロメータの性能

西口 創 @ 東京大学

他 MEG Collaborations

JPS meeting, 2008 spring
Kinki University
2008.03.23-26

contents

- Positron Spectrometer
- Run 2007
- Performances
- Plan in 2008
- Conclusions

Requirements for the e^+ Spectrometer

- **Very high counting rate**
- the most intense DC muon beam in the world
- muon stopping rate : 3×10^7 muon/sec

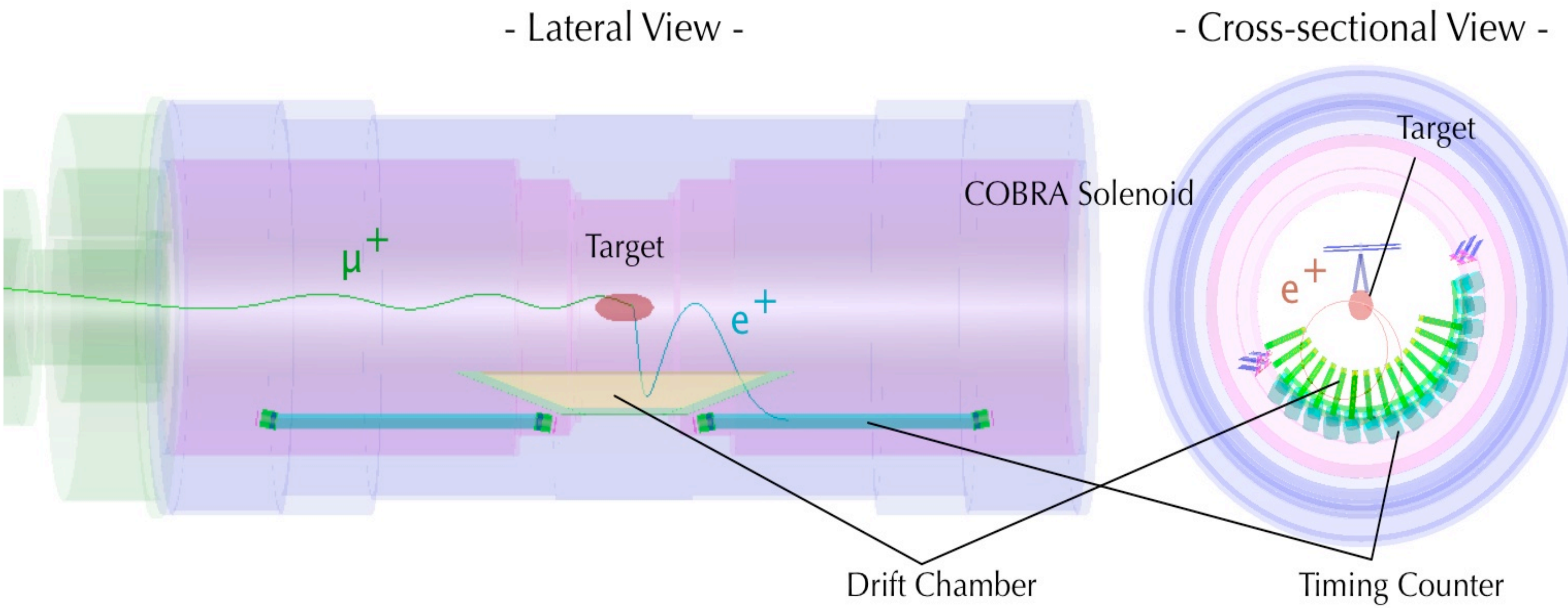
Special B-field

- **Good momentum/position/timing resolution**
- aiming excellent sensitivity
- 0.4-1% momentum resolution, 500μm position resolution for both direction(r,z) and 40 ps timing resolution

- **Low-mass material**
- 52.8MeV/c positron can be affected by multiple Coulomb scattering easily
- γ background generation should be suppressed as much as possible

new sensitive & light DC

MEG Positron Spectrometer



Solenoid

superconducting solenoid
gradient B-field (0.5-1.7 T)
very thin conductor and cryostat wall ($0.2X_0$)

Drift Chamber

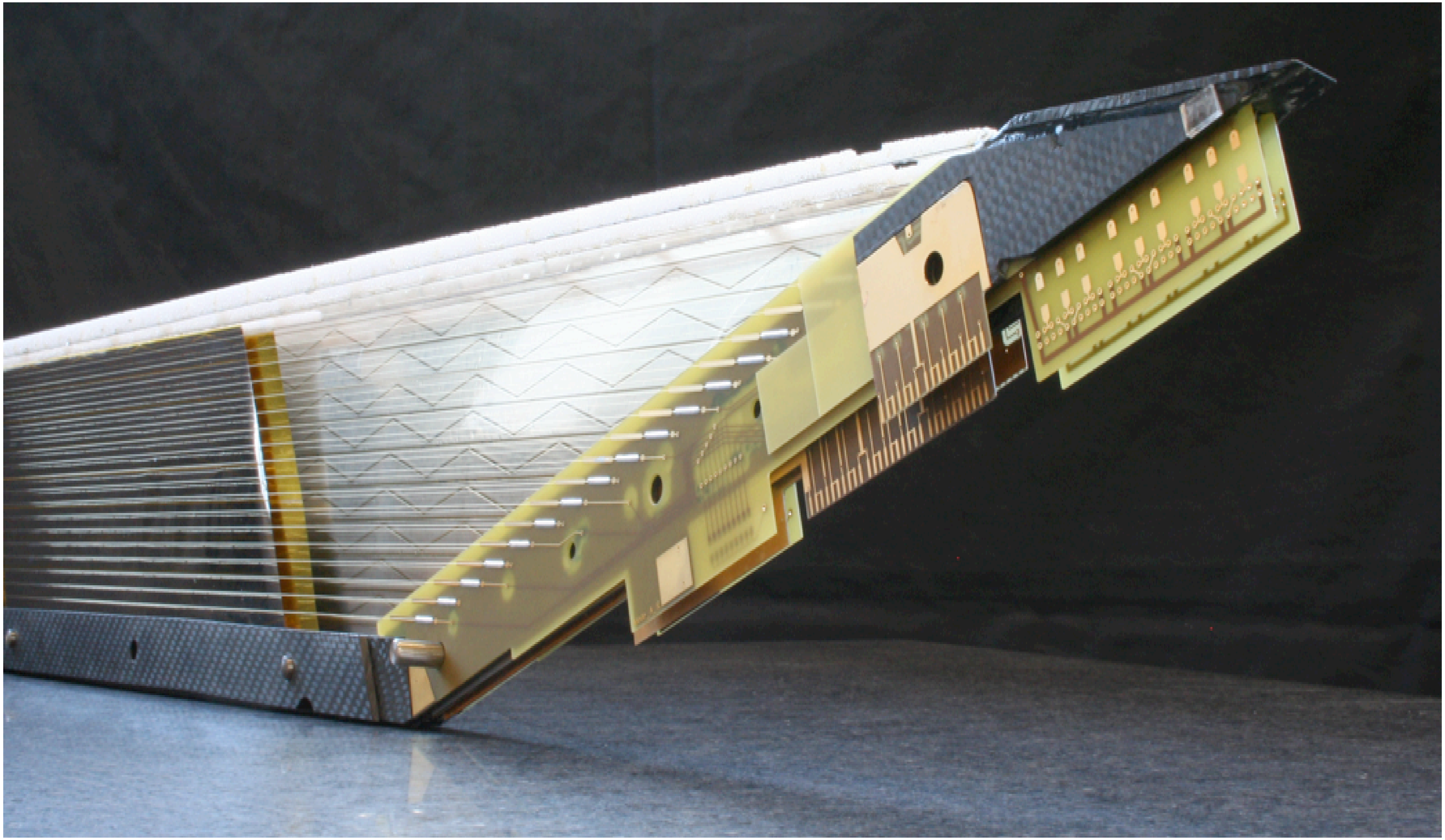
segmented radially (16 sectors)
helium:ethane (50:50)
opened-frame
very thin cathode foil with pads

Timing Counter

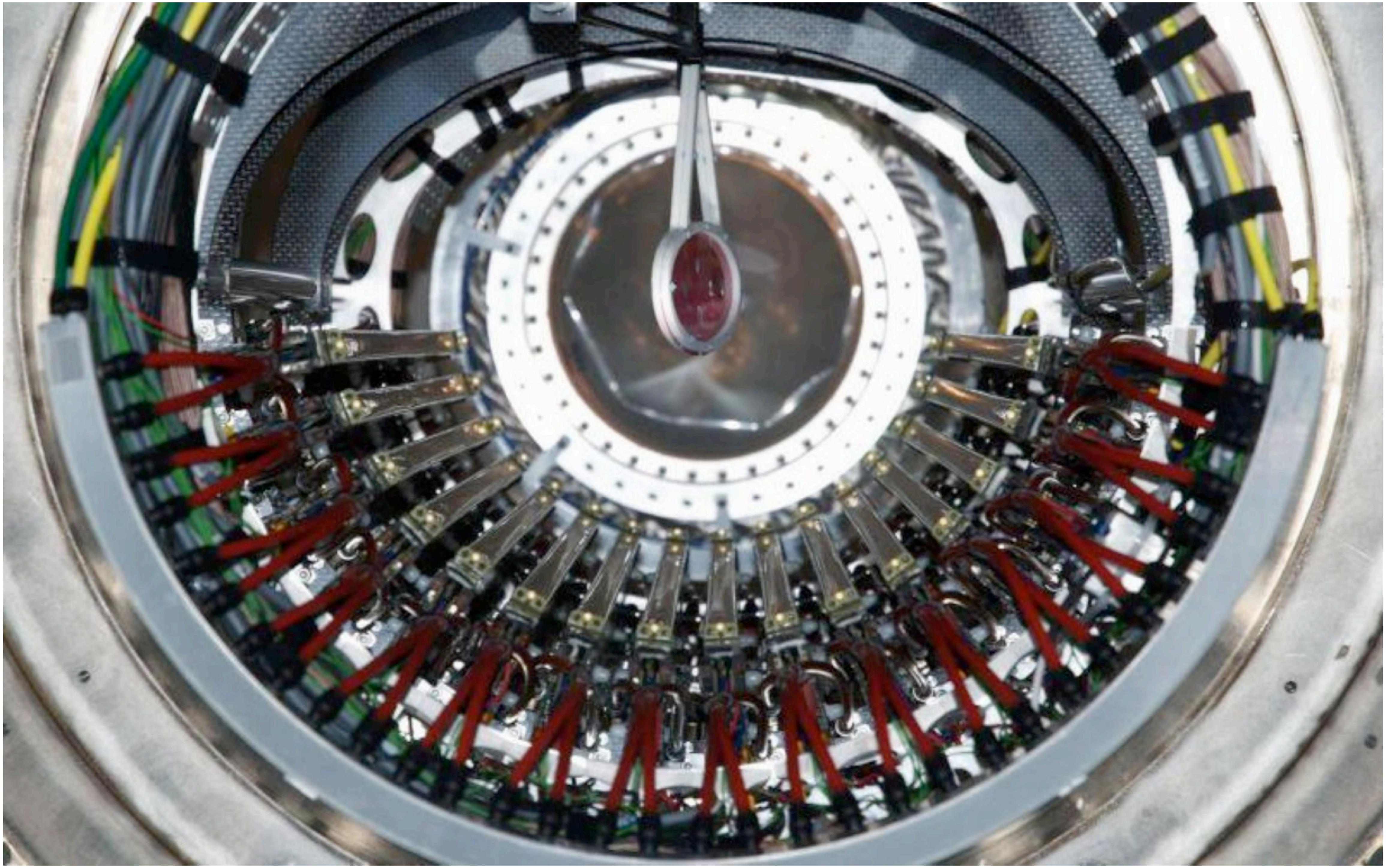
2-layers of scintillators
- scintillator bars (outer)
- scintillator fibres (inner)

Drift Chamber Module

Drift Chamber Module (Assembled)

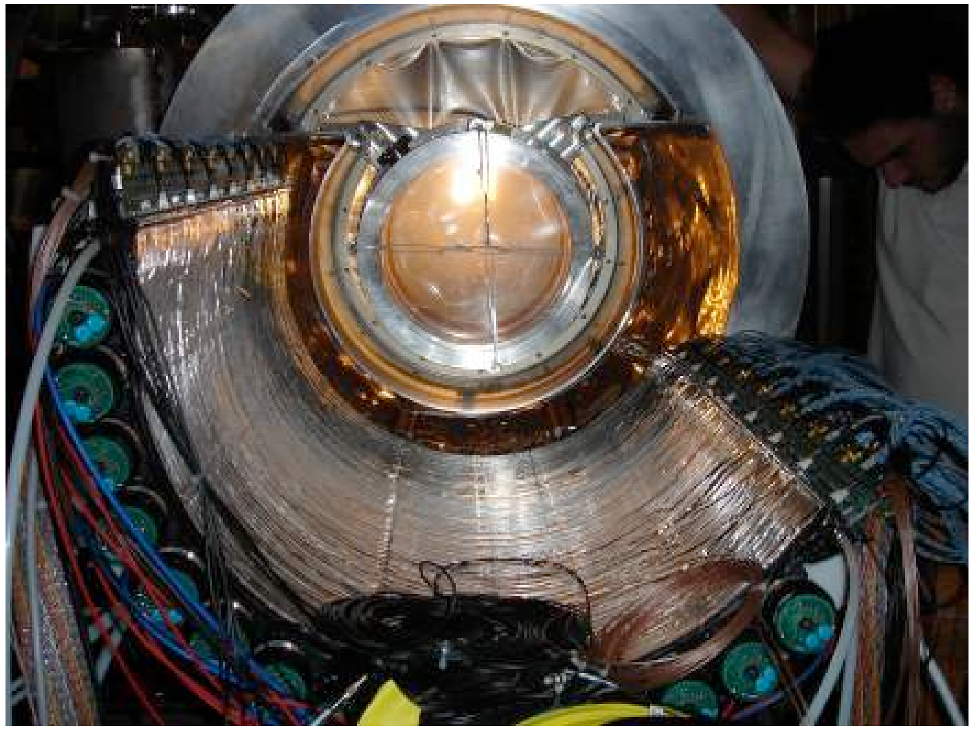


Installed Drift-Chamber System



Timing Counter System

- 2-layers of scintillators
  - Scintillator bars (outer layer)
    - read out by PMTs for timing
  - Scintillator fibres (inner layer)
    - read out with APDs for z-trigger
- Aiming goal
  - σ_T ~ 40psec (100psec FWHM)
  - Achieved at test-beam experiment
- This is Best existing Timing Counter

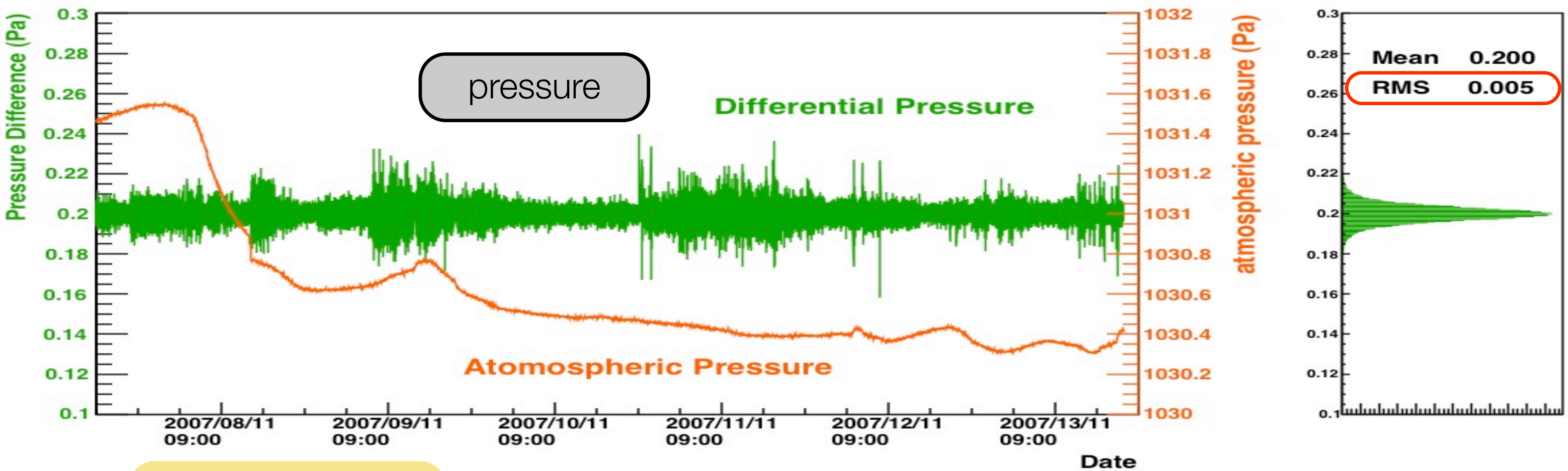


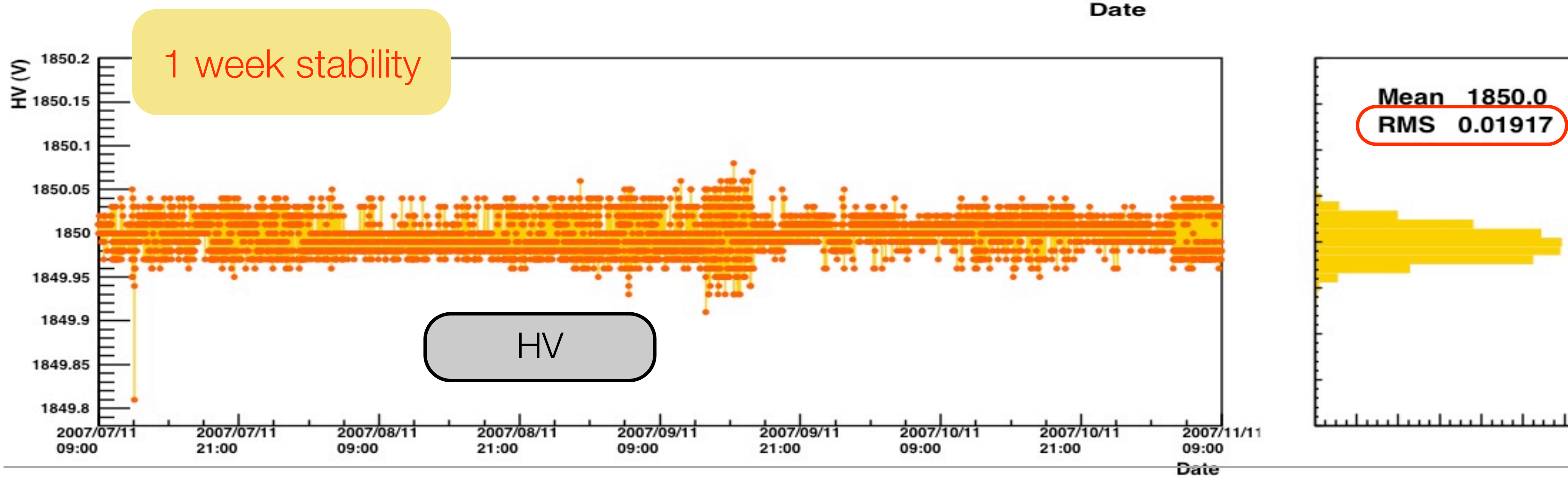
Run 2007

Purposes

- All Detector Integration / Operation / DAQ
  - Full Intensity Muon Beam (5×10^6 & 3×10^7 muon/sec)
  - Trigger - Front-end Elec. - DAQ chain
- Conditioning with Final Settings
  - Slow Control System
  - Long Term Monitoring
- Full Set of Calibration
  - Wire Alignment
  - Position Measurement Calibration (Longitudinal/Transverse)
  - XT Calibration
- Performance Evaluation and Offline Analysis
  - Efficiency, Resolution

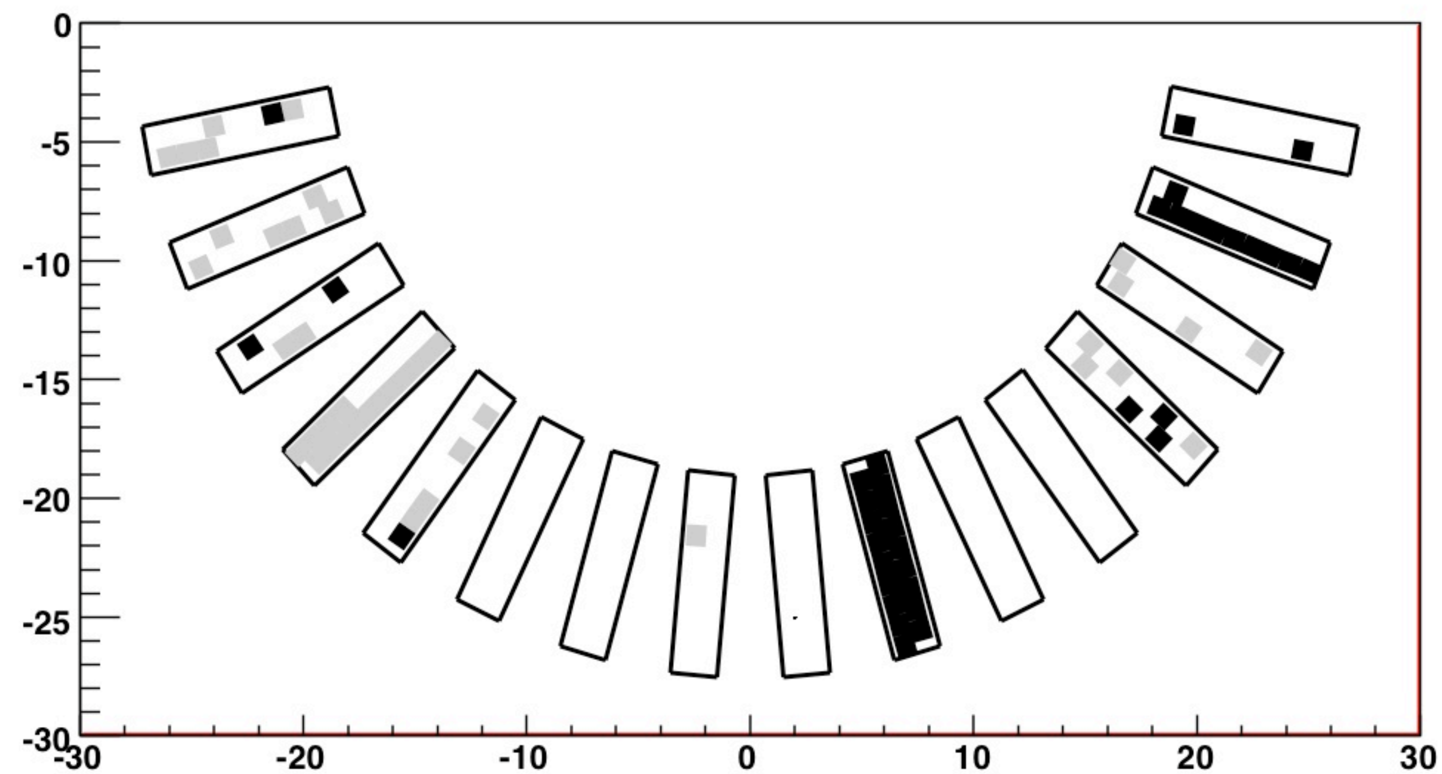
Slow Control & Long Term Monitoring





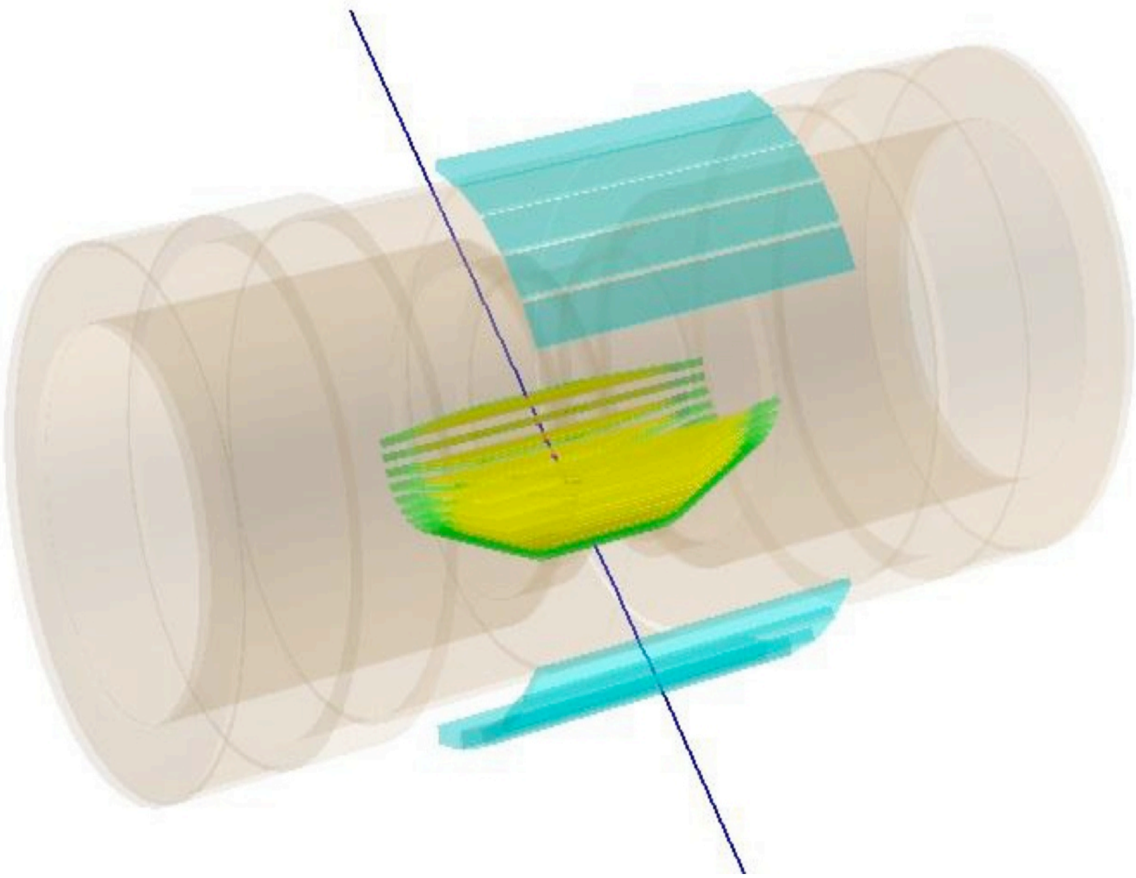
Problems

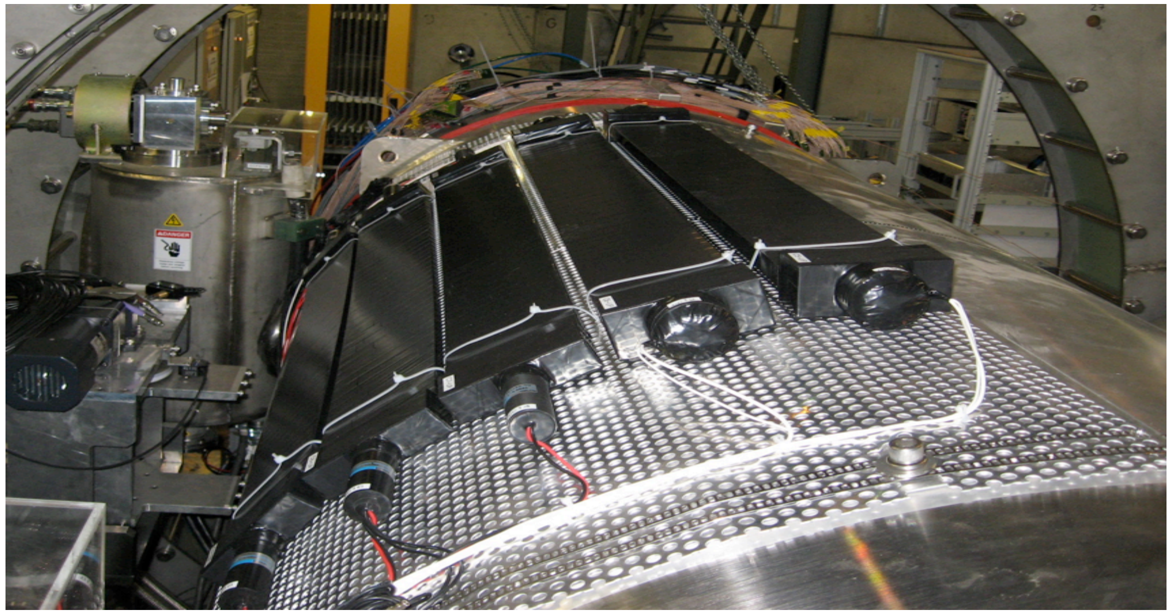
- Several Drift Chambers have problems
  - Discharge
  - Disconnection
- Exposed HV point on the chamber board in pure Helium
- Some connectors of feed-through was disconnected at the patch panel due to lack of latch
- We decided to leave it since the first priority was to keep the run-schedule.

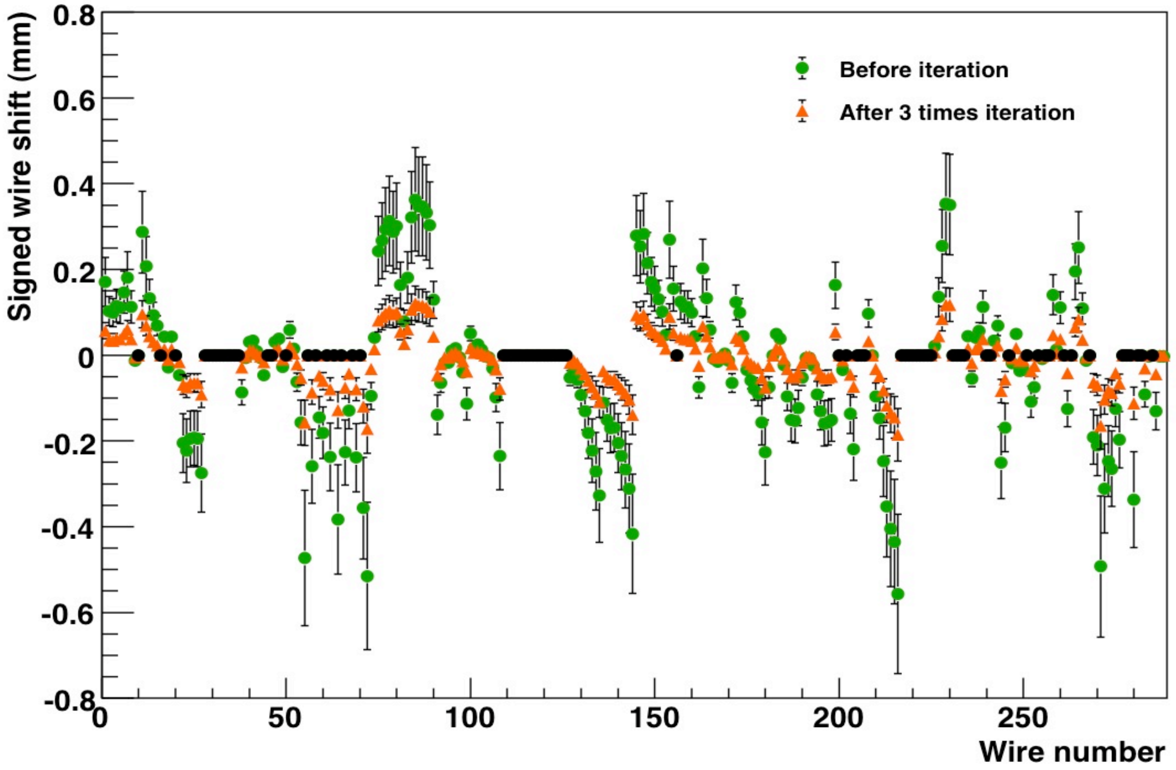


- Detector performances are partially degraded.
- Problems are being repaired now during winter shutdown 2007-2008.

Wire Alignment

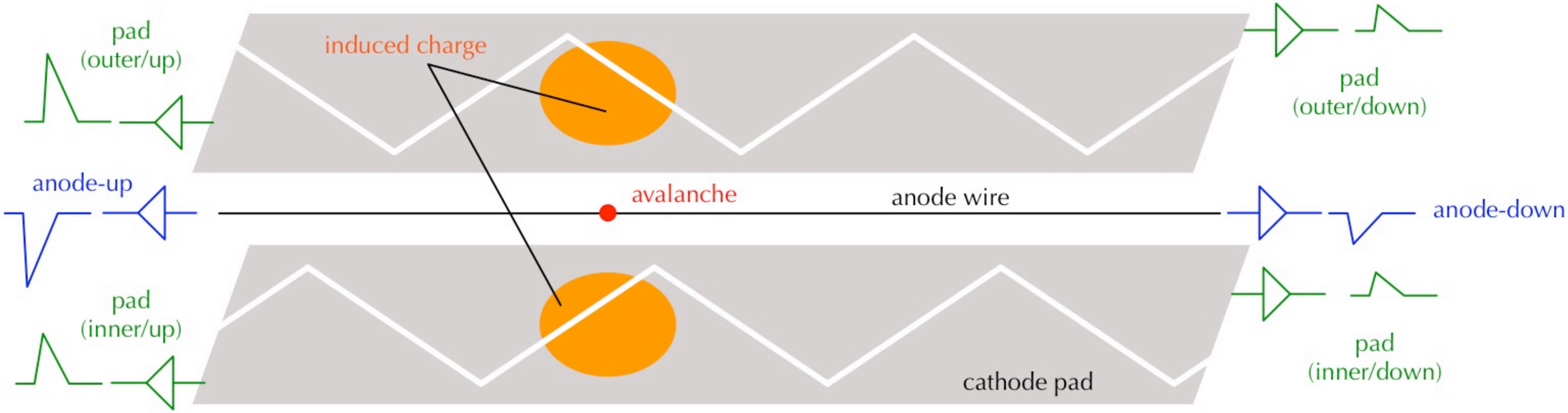




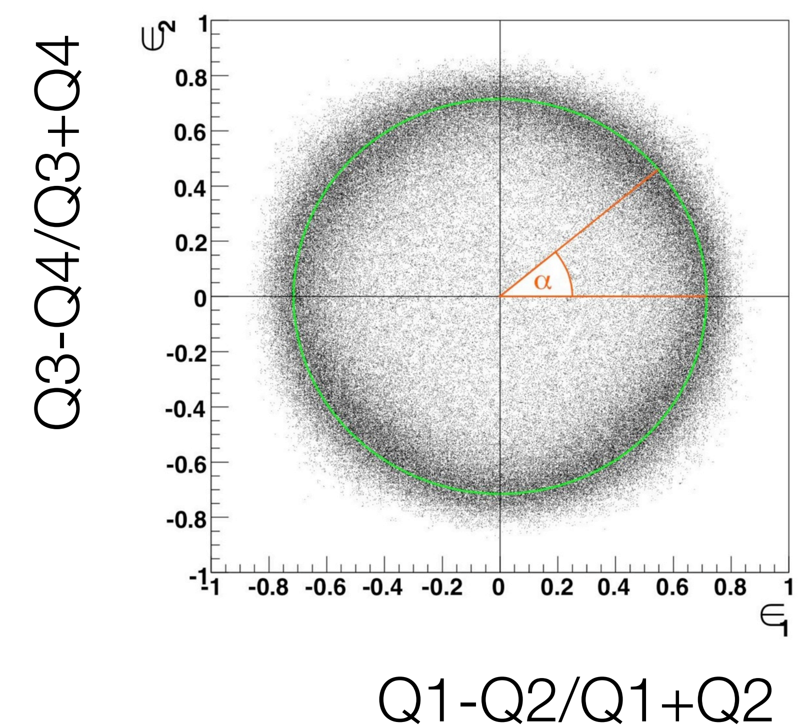


- Position of DC modules are surveyed
- Wire relative alignment done by Cosmic ray
- ~ 270 um wire displacement
- 3 times iteration, relative shift < 100 um

Cathode Pads with Vernier Pattern

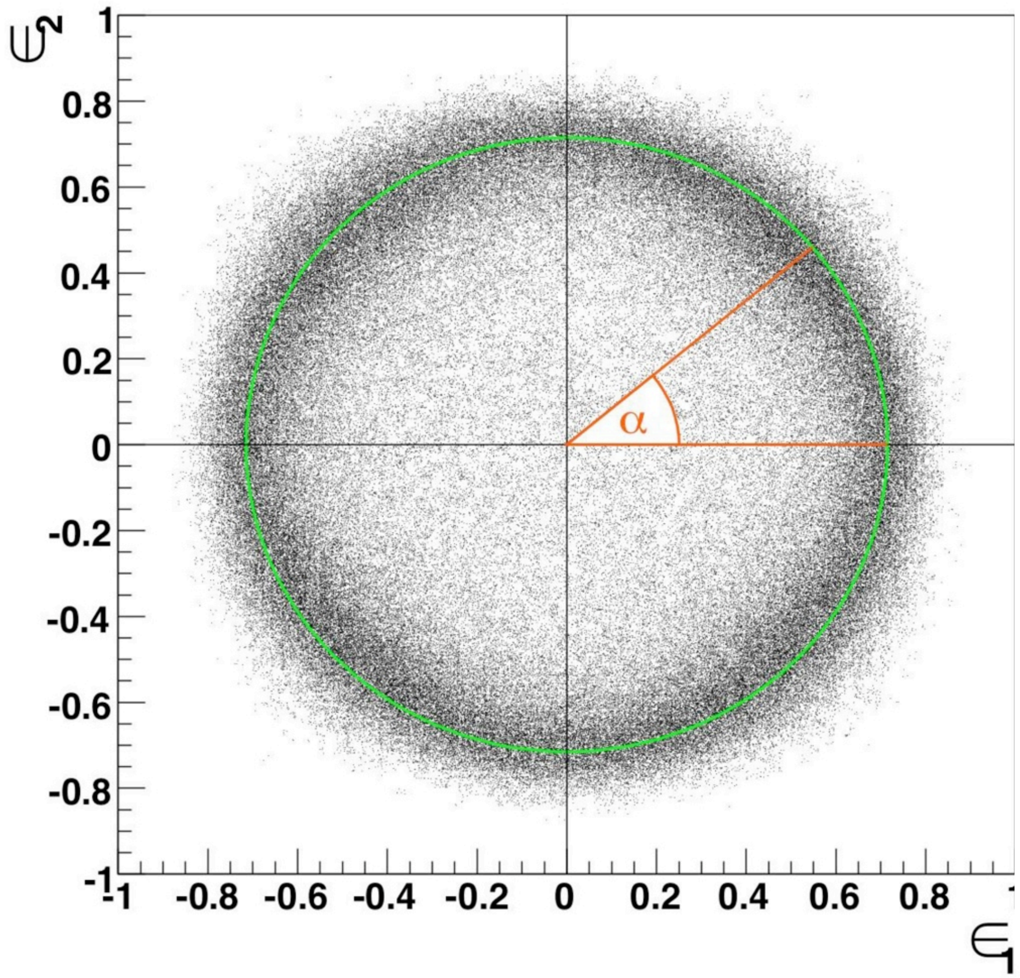


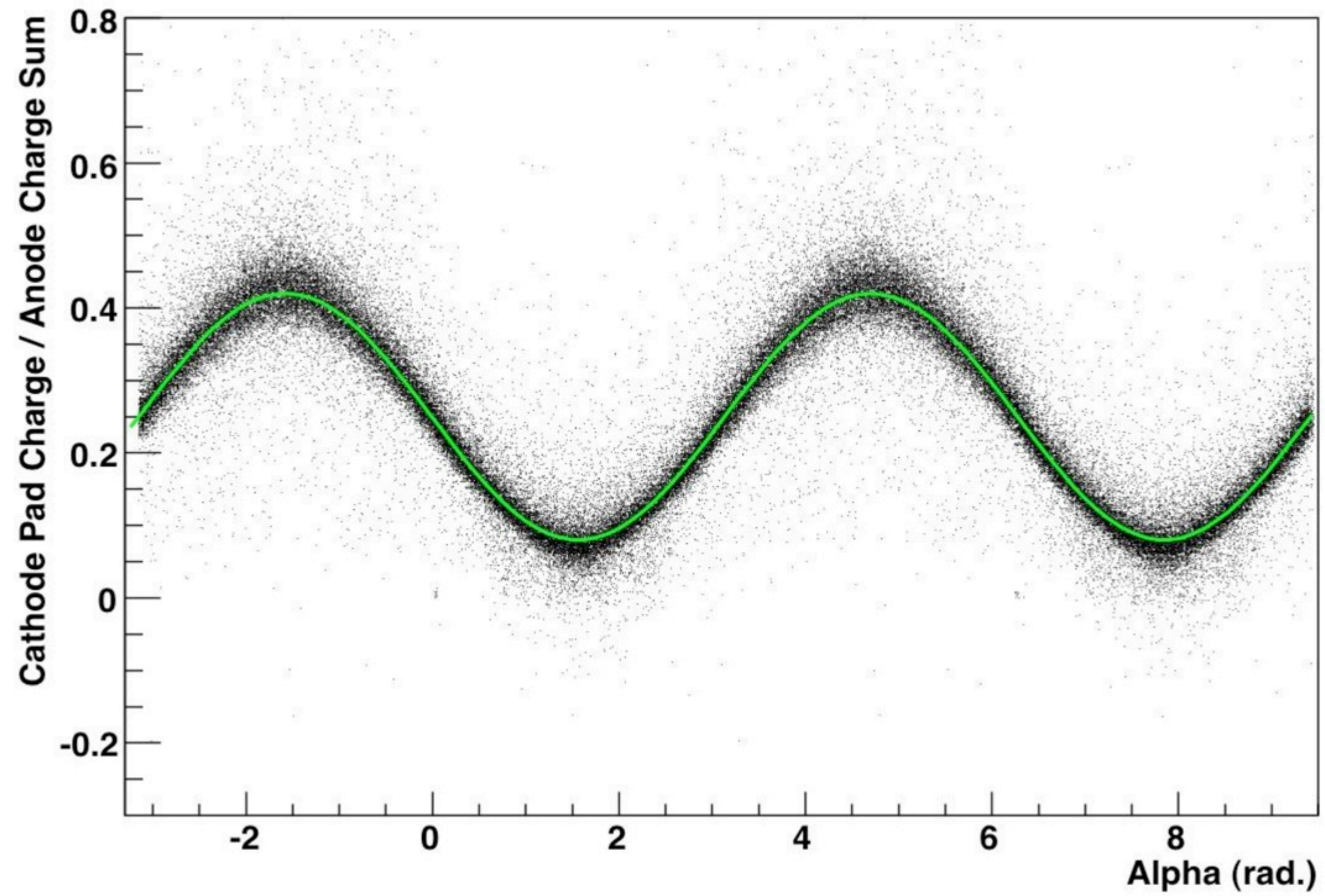
- two big advantages, position resolution improvement and readout channel decrease
- rough estimation by charge division method (~1cm)
- using the ratio of induced charge on each 4 strips, z coordinate with 500μm accuracy is available



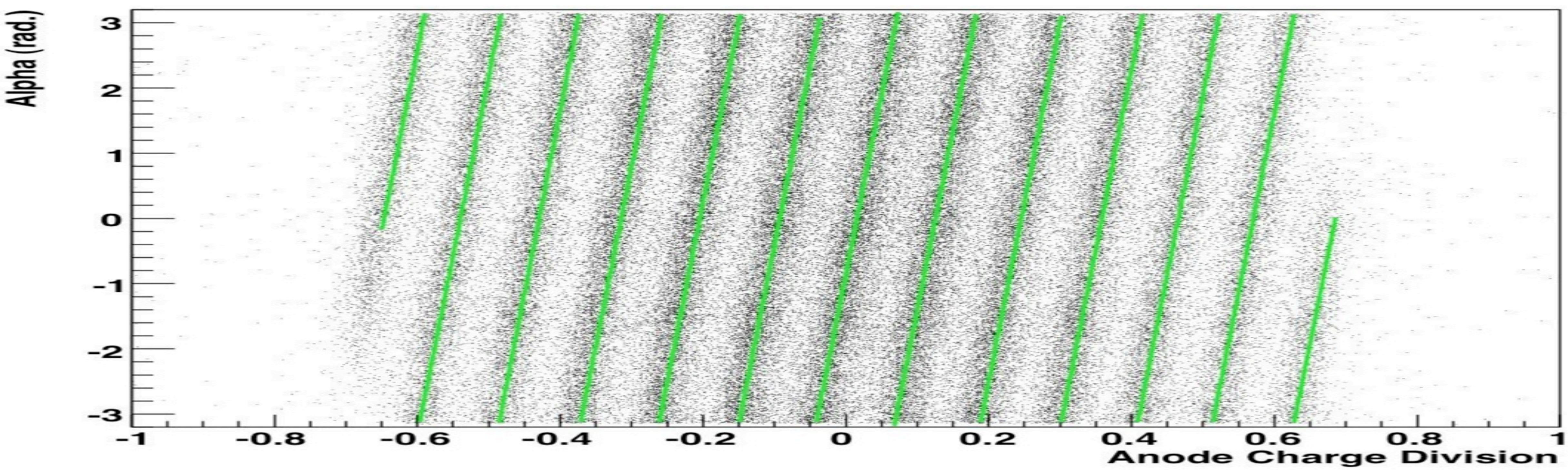
Z Coordinate Calibration

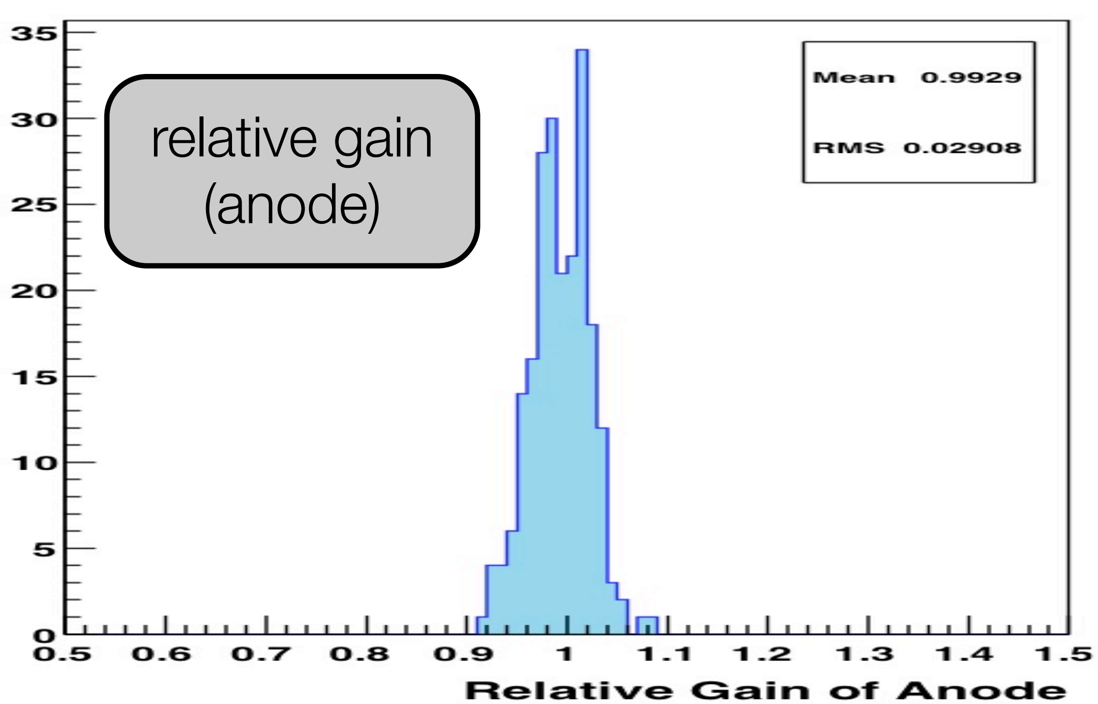
- Z Coordinate Calibration = Preamp. Gain Calibration
- Vernier pattern can be very precise position reference
- By using “phase” of vernier period, anode and cathode calibration can be done each other iteratively.

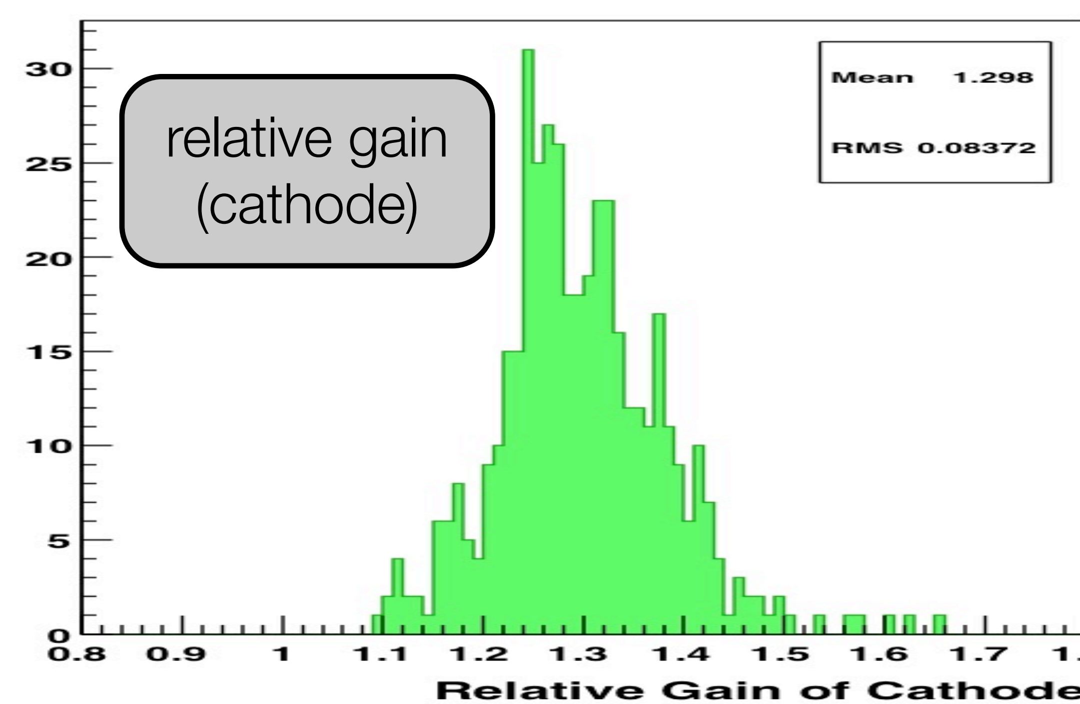




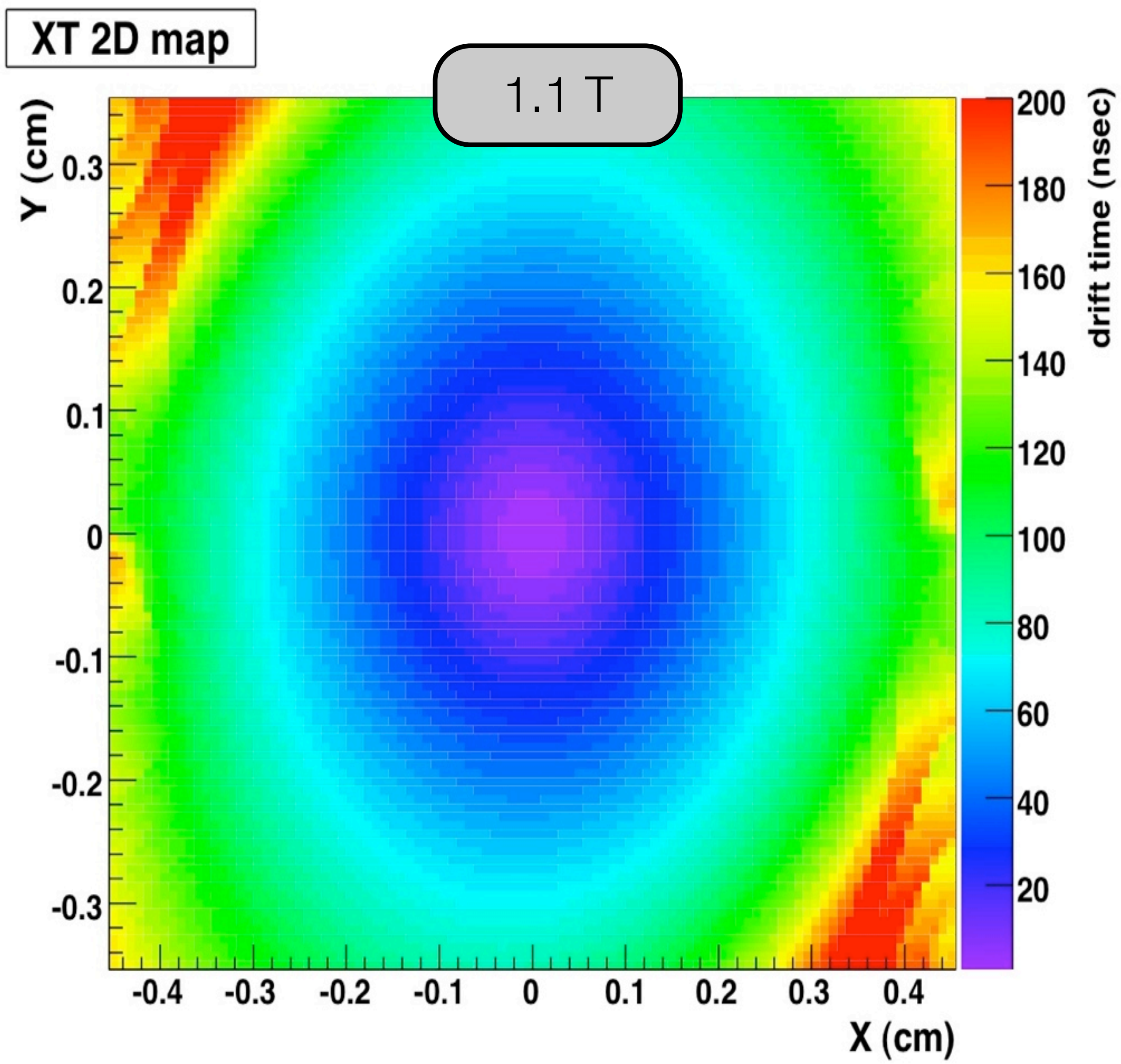
Z Coordinate Calibration

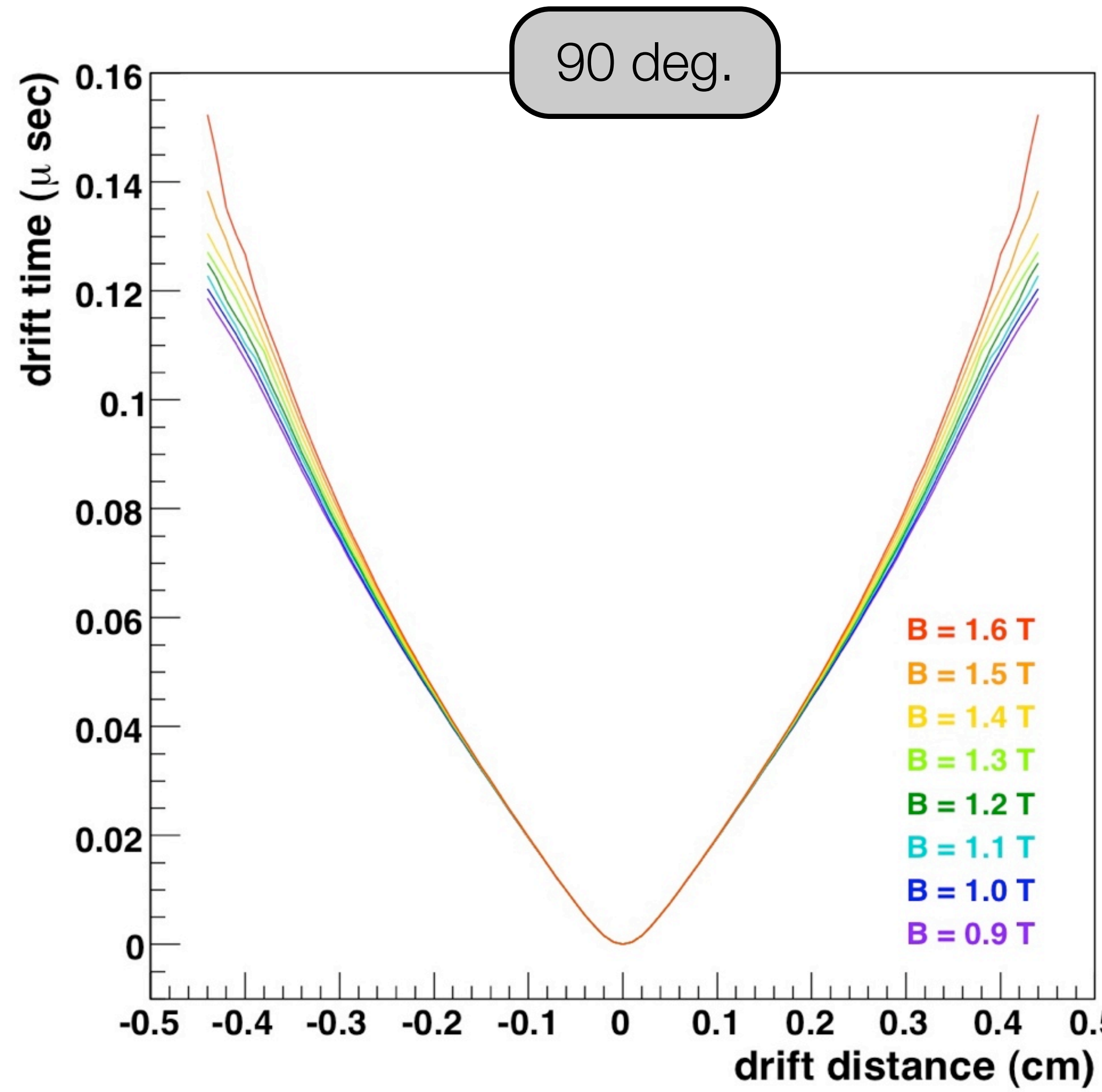






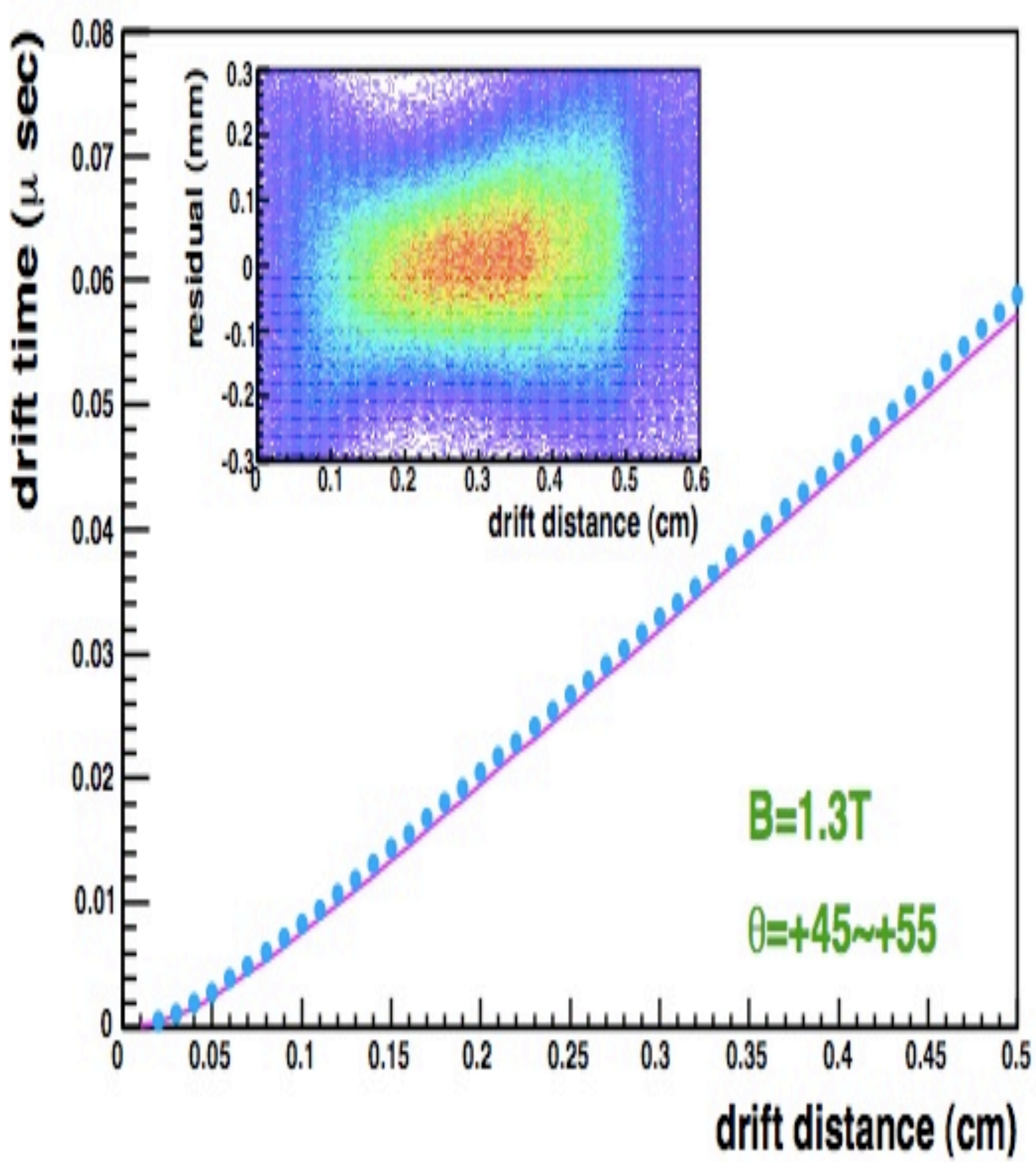
Time-to-Distance Calibration

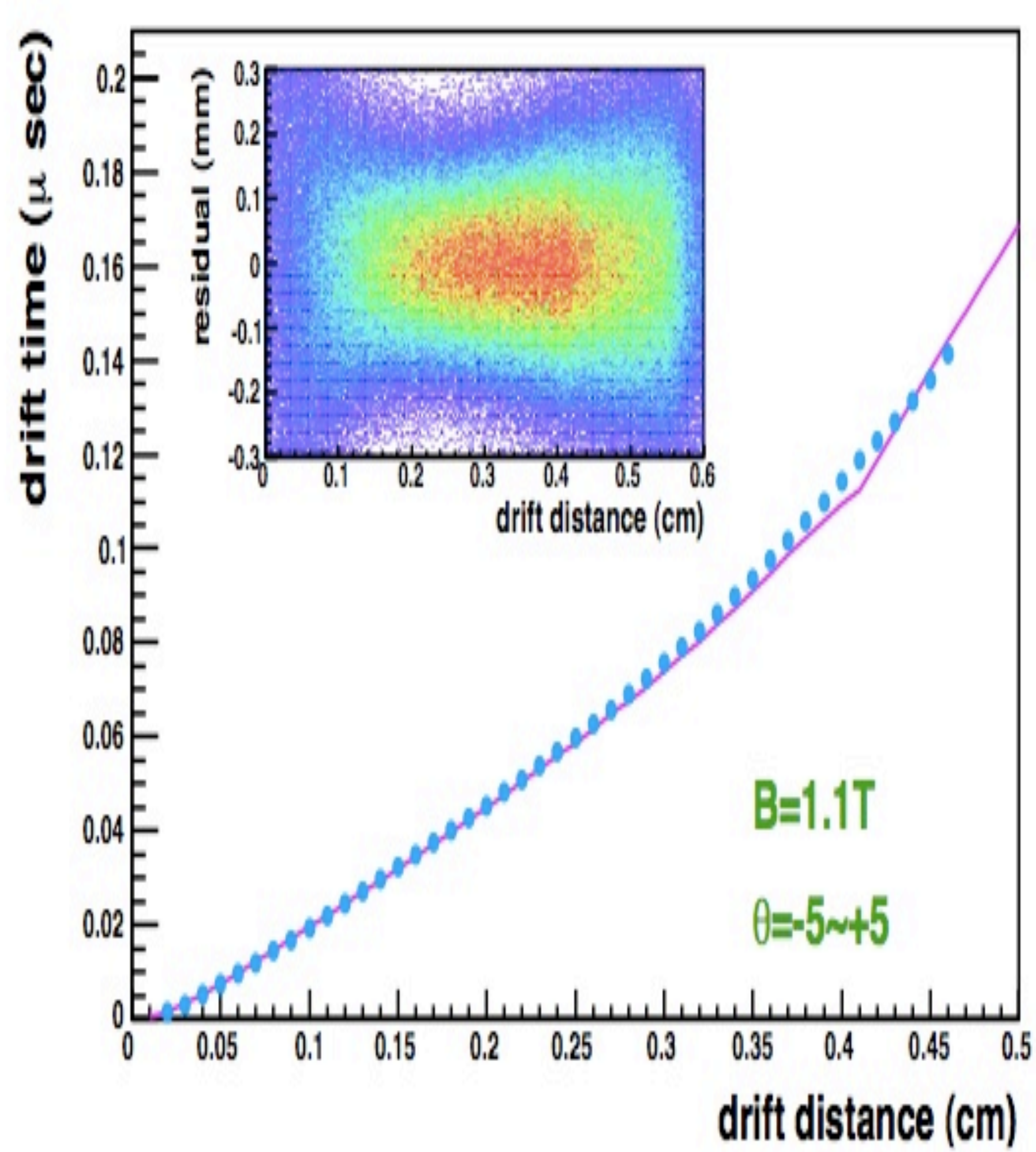




- Simple Cell Configuration / Small Lorentz Angle
- Angular / B-field dependence should be maintained

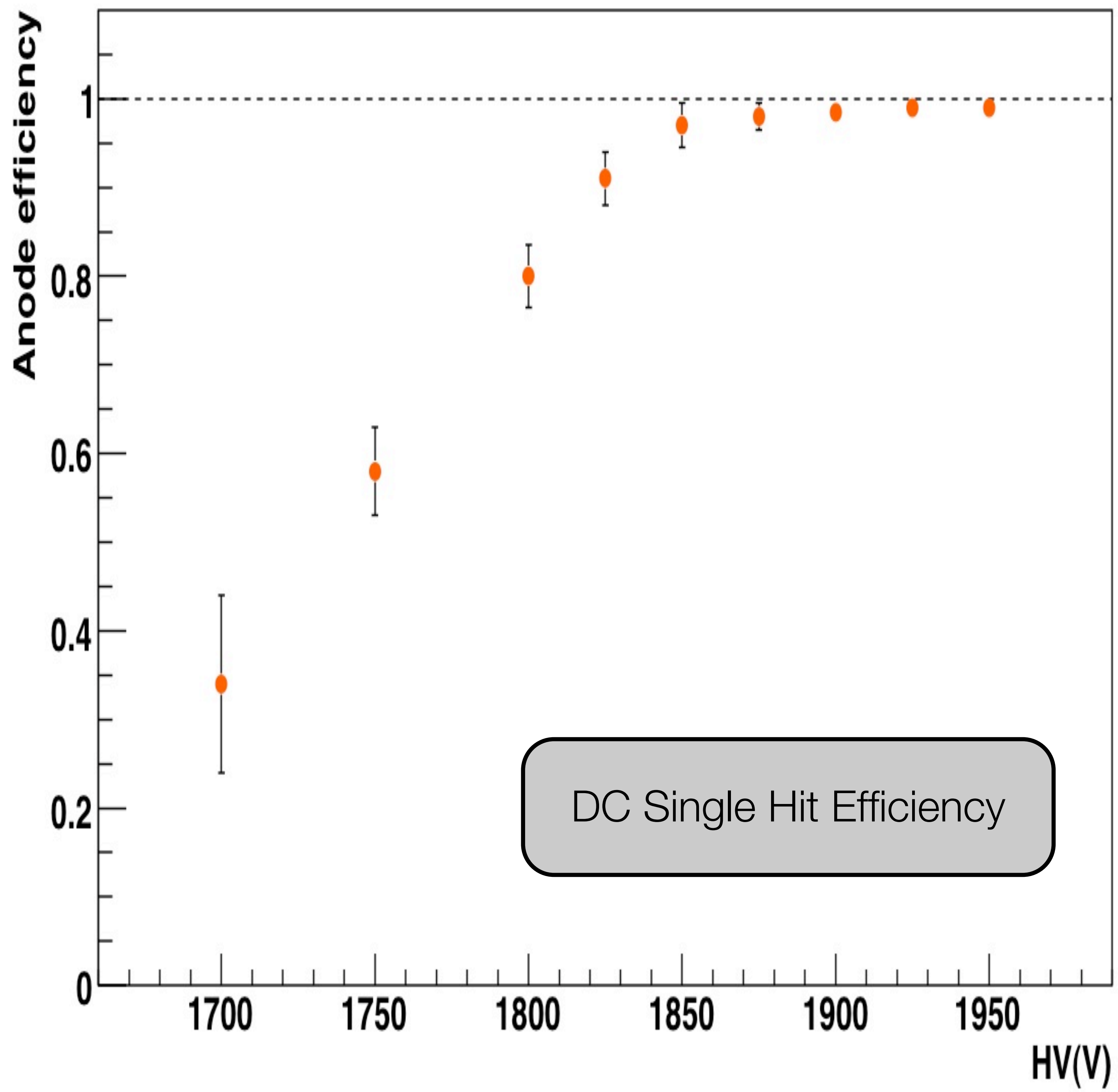
Time-to-Distance Calibration





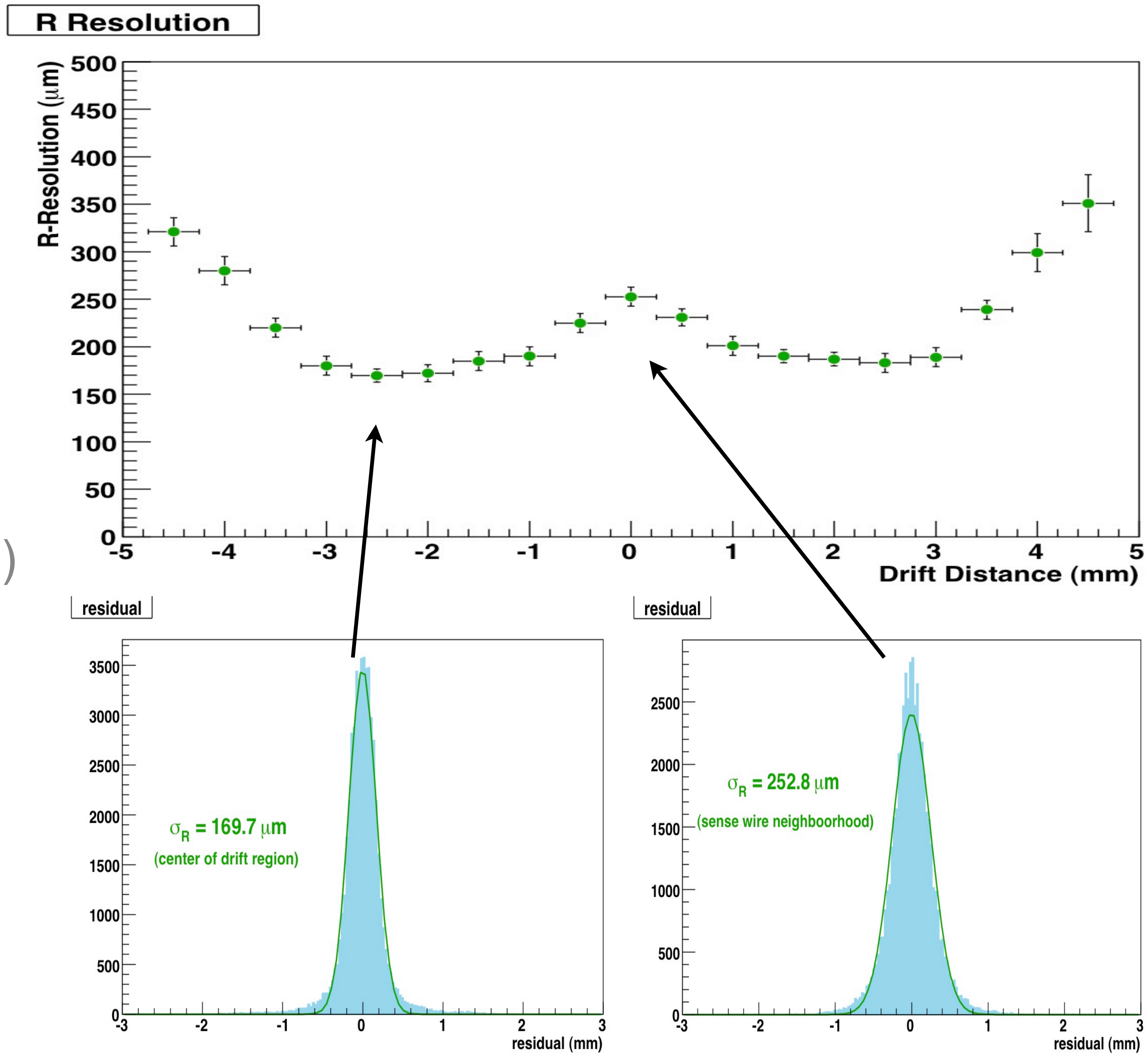
Performances

- Intrinsic Performances
    - DC Single Hit Efficiency
    - Spacial Resolutions (R, Z)
    - TC Timing Resolution
- Spectrometer Performances
    - Reconstruction Efficiency
    - Momentum Resolution



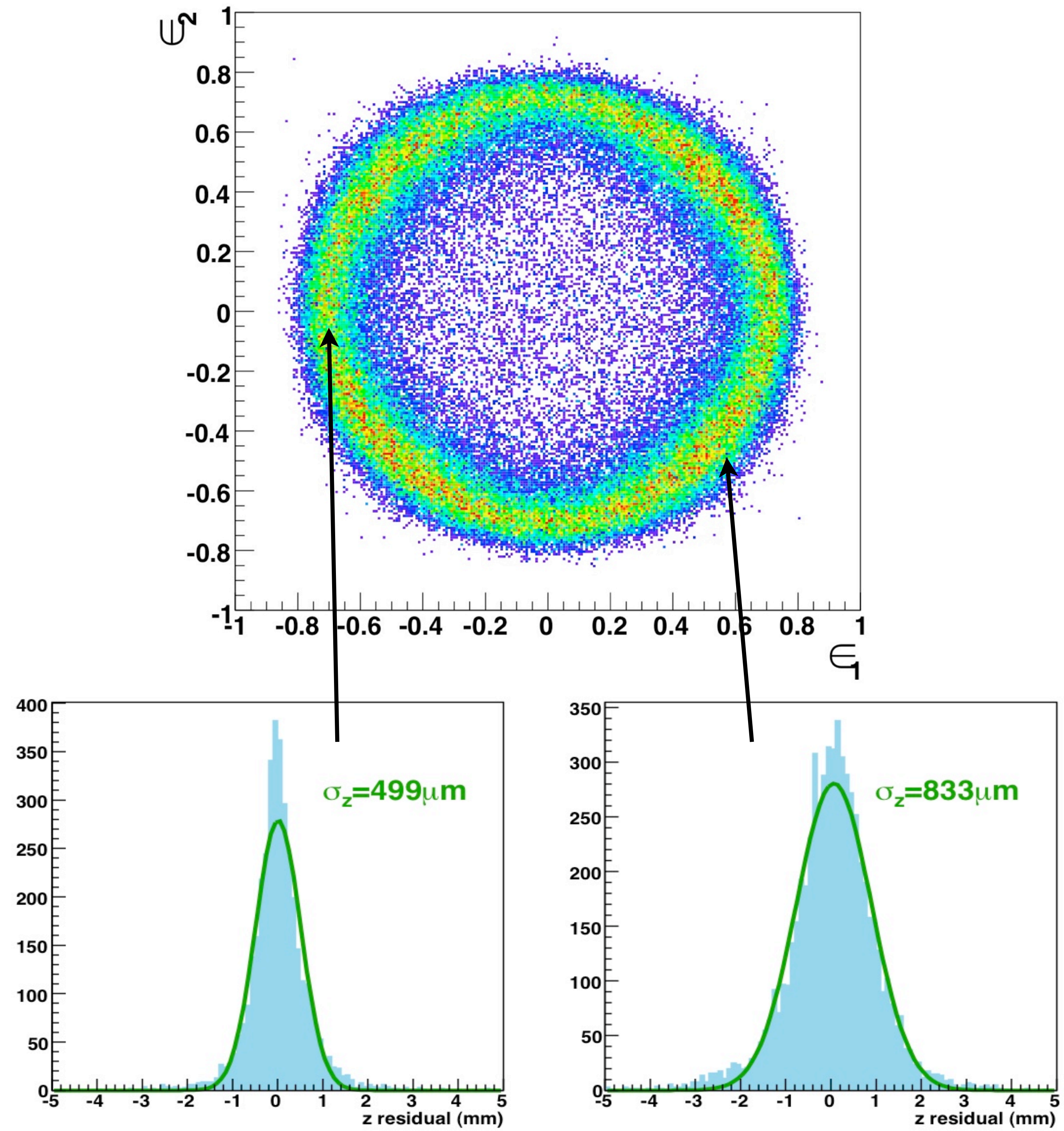
Spacial Resolution (Transverse)

- Residual "*reconstruct - fit*"
- σ_r =170~350 um (230 ave.)



Spacial Resolution (Longitudinal)

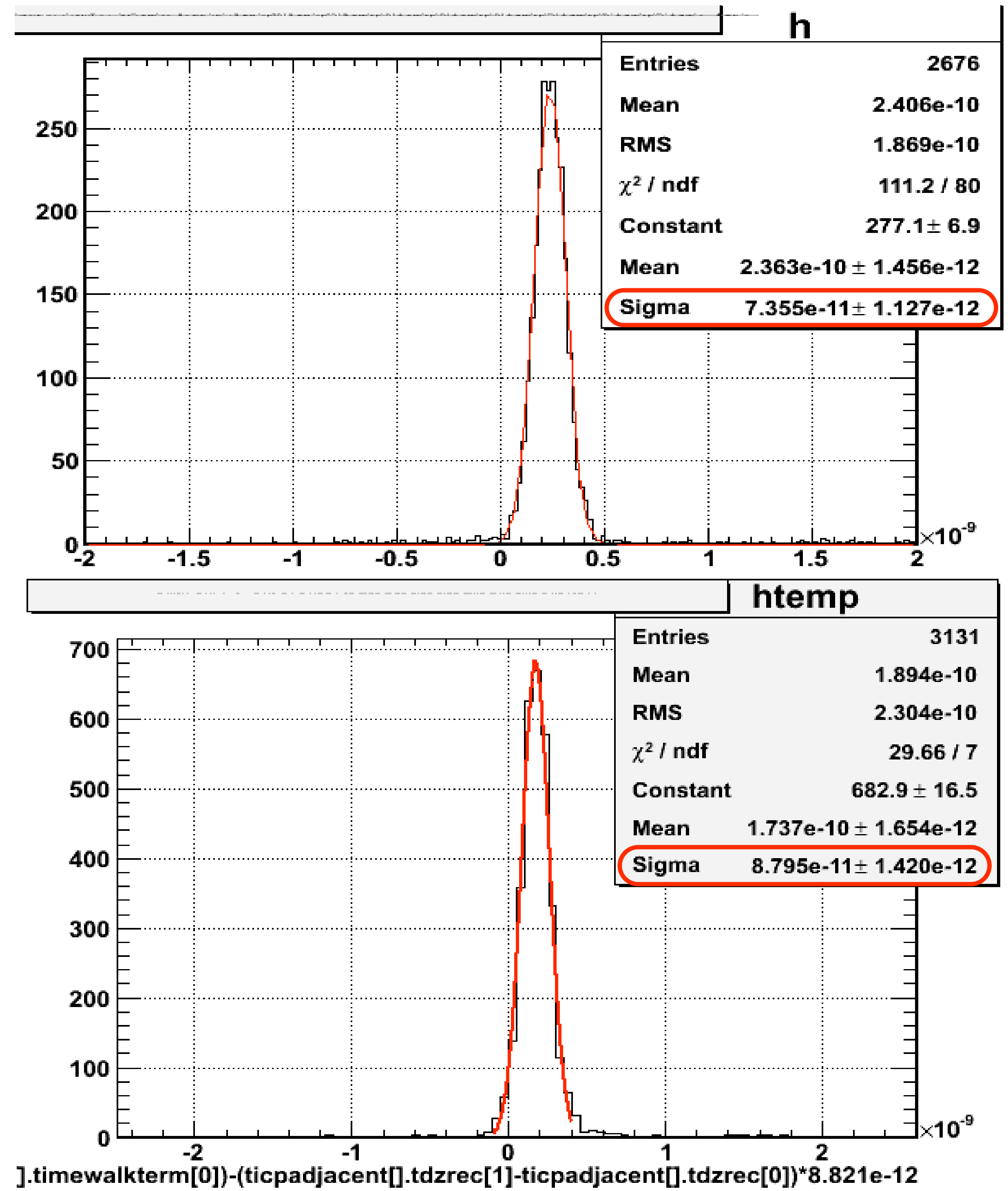
- Residual "*reconstruct - fit*"
- σ_z =600~1000 um (810 ave.)
- The intrinsic resolution indicated by the thickness of the vernier-circle
- The residual distribution is not biased by the reconstruction algorithm



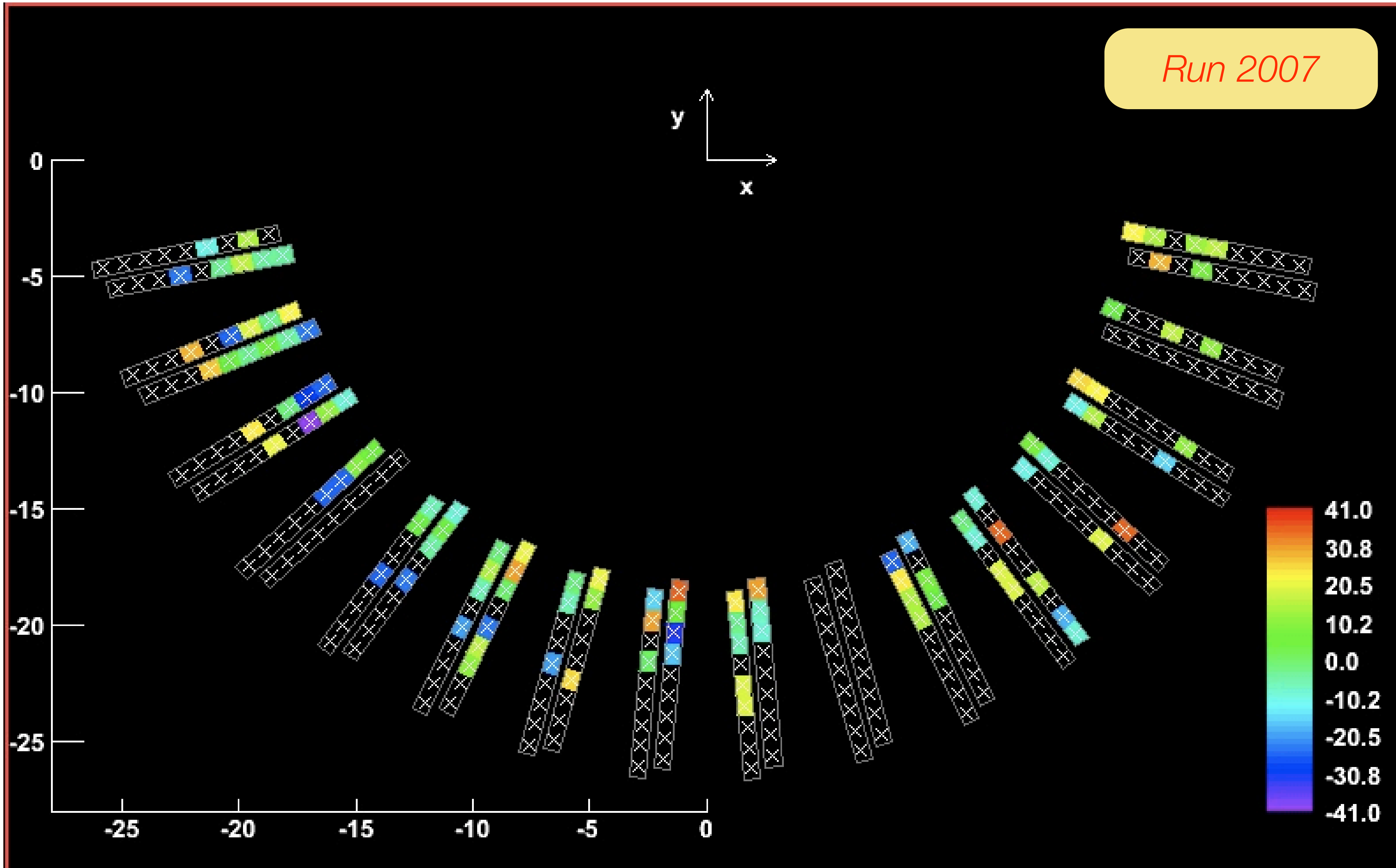
Timing Resolution

- TC intrinsic timing resolution
- Difference “Bar1 - Bar2”
- Double Threshold Discriminator
  - σ_t = 52 ps
- PMT waveform
  - σ_t = 62 ps

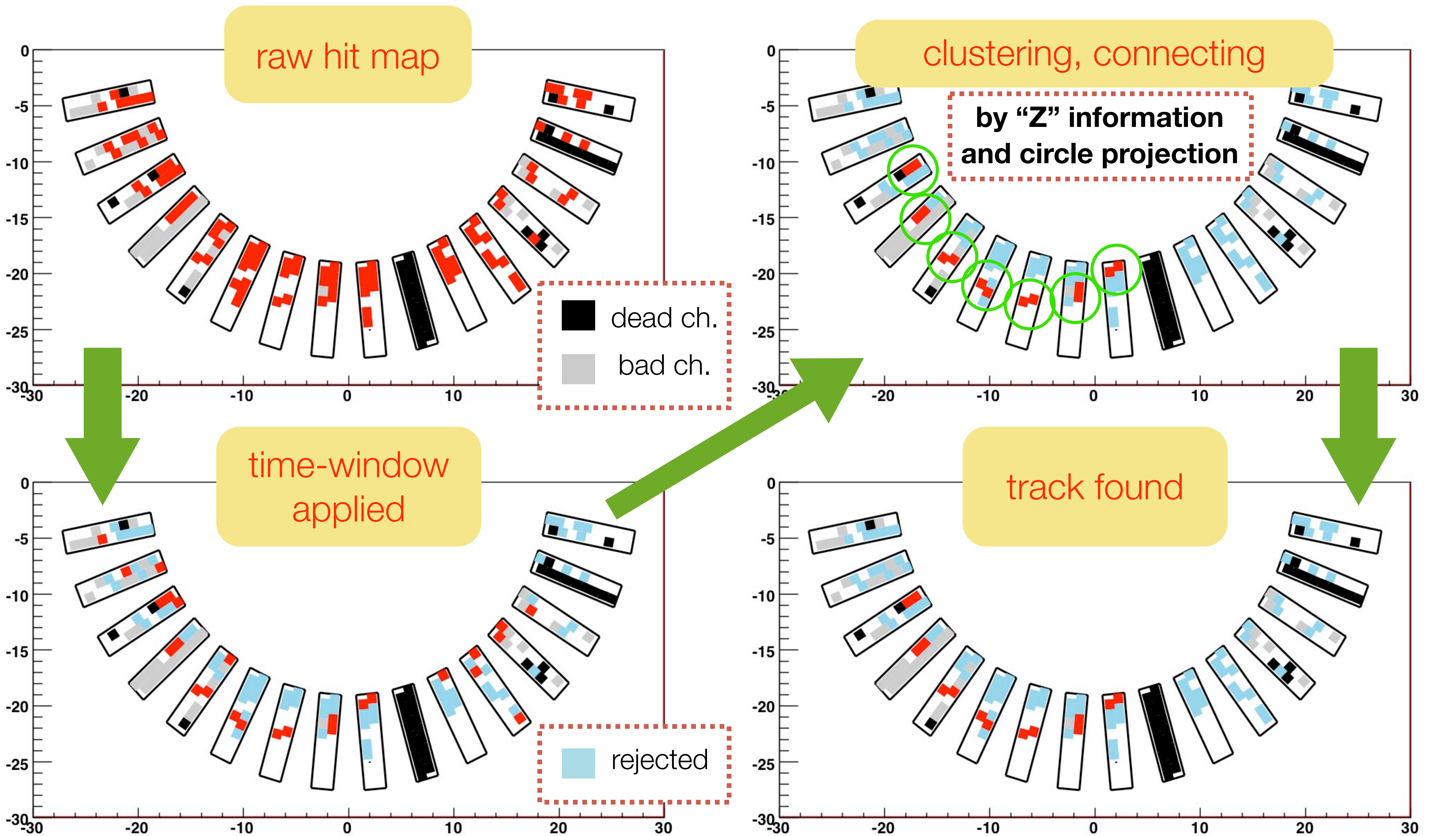
27pZJ, 内山雄祐
「MEG時間測定」



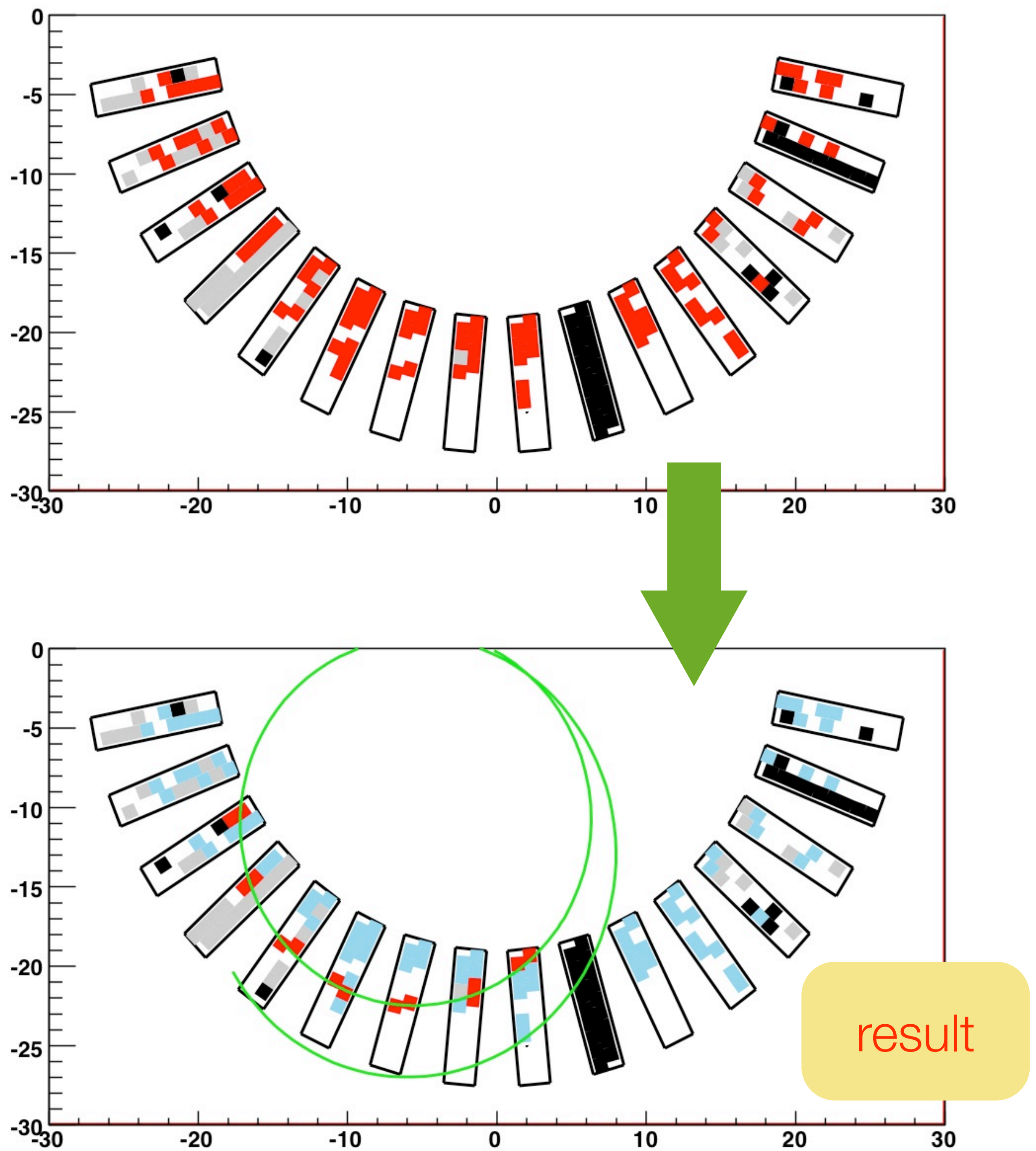
DC event display (3x10^{7} /sec muon intensity, normal mode)

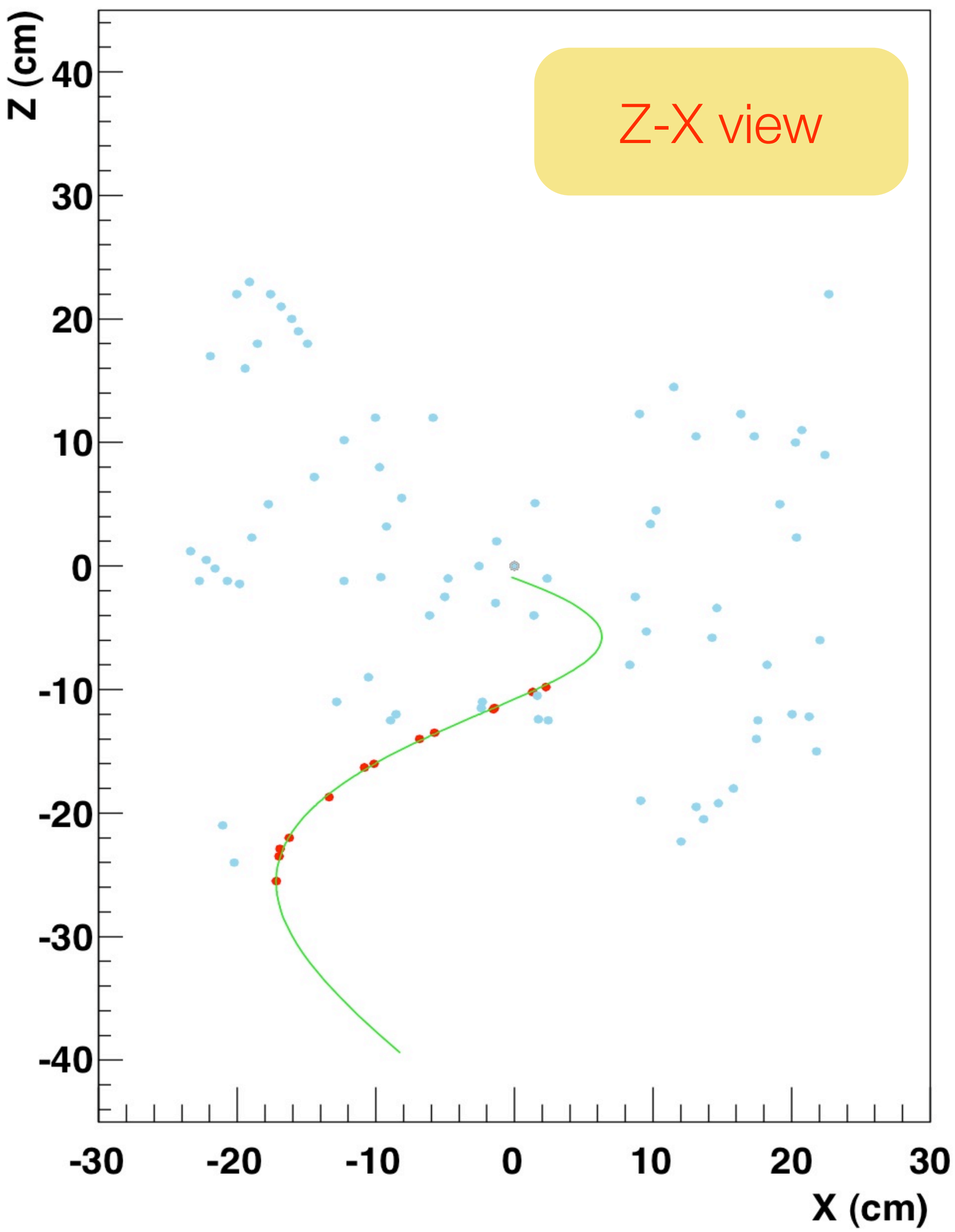


Track Finding

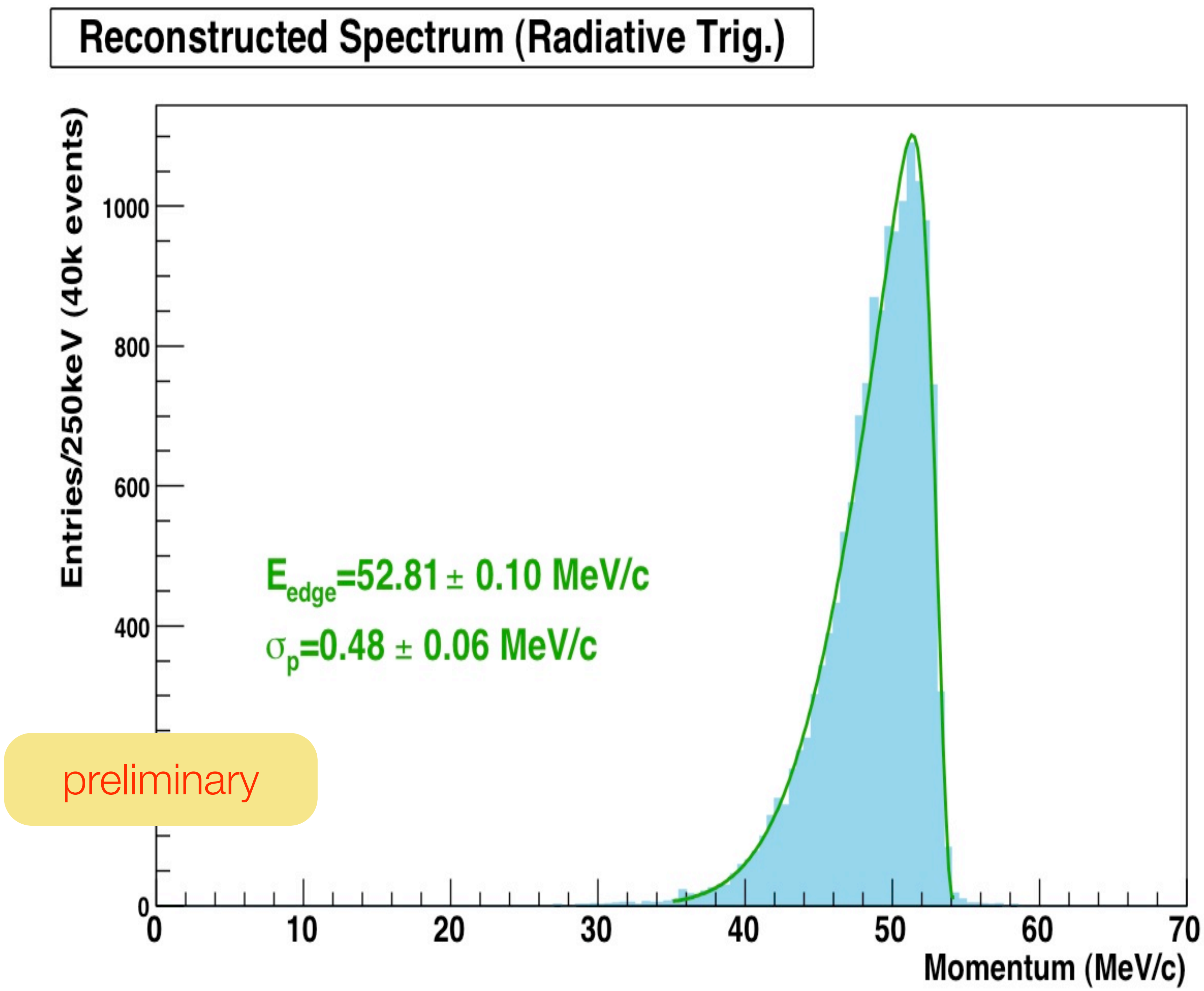


Track Finding → Track Fitting





Momentum Resolution



- End-point is fitted to the convolution of "theoretical response function" and "Gaussian", with three free parameters; "E_{edge}", "σ_p" and "Normalization"
- σ_p =480 keV (=0.9 %)

Reconstruction Performances

- For the RUN2007, we have a certain number of missing channels and one blank chamber, and hence the track finding/fitting efficiency is limited.
- Momentum Resolution is also degraded due to bad condition.
- All the deterioration is reproduce by “degraded MC” and confirmed.

	track finding eff.	good tracking eff.	mom. resolution
Run 2007	85%	65.2%	0.9%
MC (full spec)	99%	97.5%	0.4-0.6%

Plan in 2008

- Several bad DCs are being repaired now (winter shutdown)
  - Better molding HV-line to avoid discharges
  - Better Connectors at feed-through of patch panel to avoid defluxion
- mid. April
  - Installation
  - Wire Alignment Run with Cosmic-Ray Trigger
- May - June
  - Conditioning with Low / High Rate Muon Beam
  - Calibration with Michel e^+ Trigger
- July -
  - Physics Run until end of FY2008

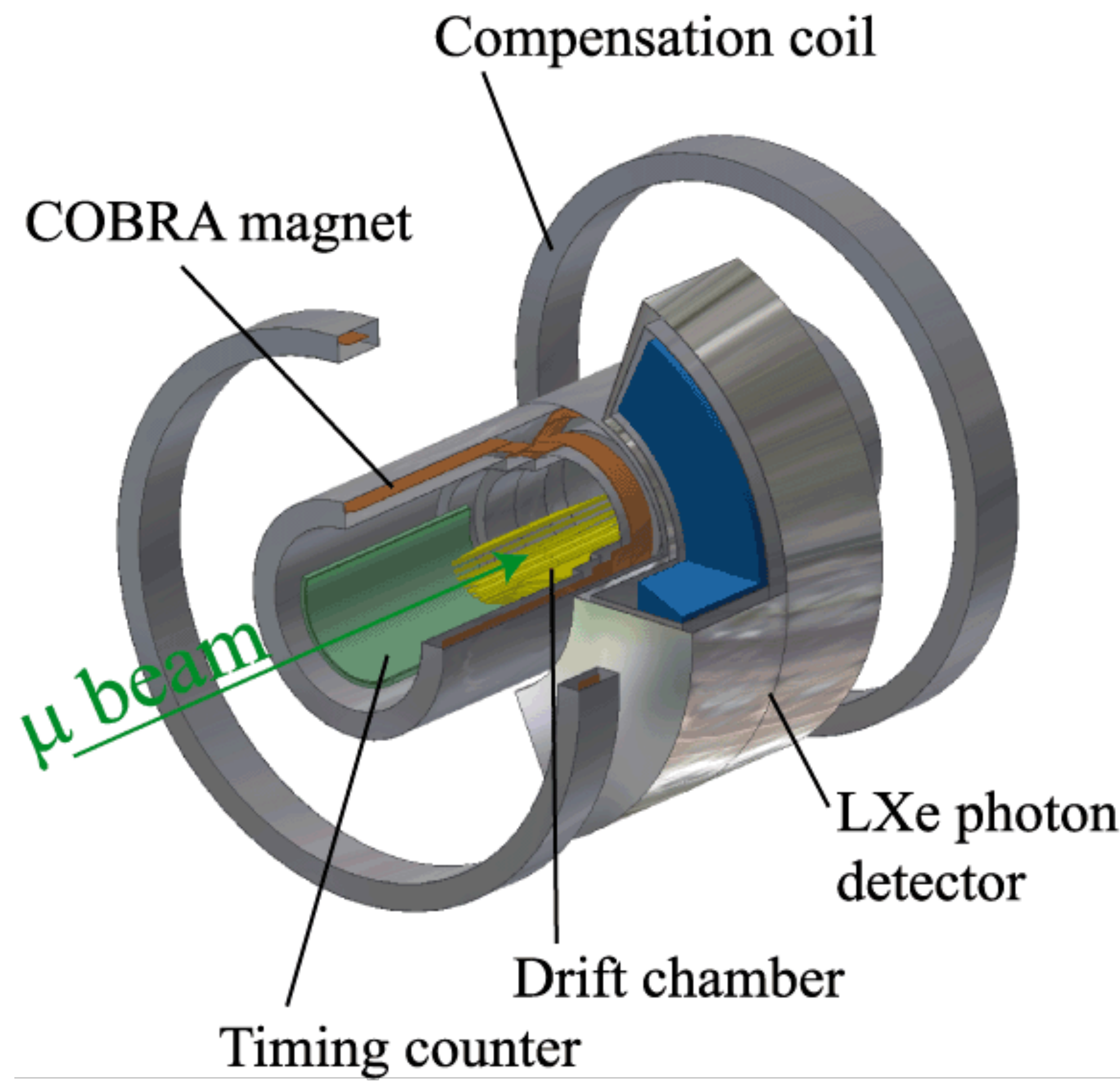
Conclusions

- MEG Spectrometer Construction / Installation / Setup, Completed 2007
- Engineering Run was carried out in Sep.-Dec. 2007
  - Conditioning with Full Muon-Beam Intensity / COBRA B-field
  - Long Term Stability is OK
  - DAQ, Trigger electronics Integration / Setup / Data Taken
  - All Survey - Alignment - Calibration chain was performed and established
- Detector Performances are Confirmed
  - DC and TC intrinsic resolutions are evaluated
    - σ_r = 170~350 um / σ_z = 600~1000 um for DC
    - σ_t = 52 ps for TC
- Spectrometer Performances are Confirmed
  - 480 keV of momentum resolution @ 52.8 MeV

backup slides

MEG Experiment

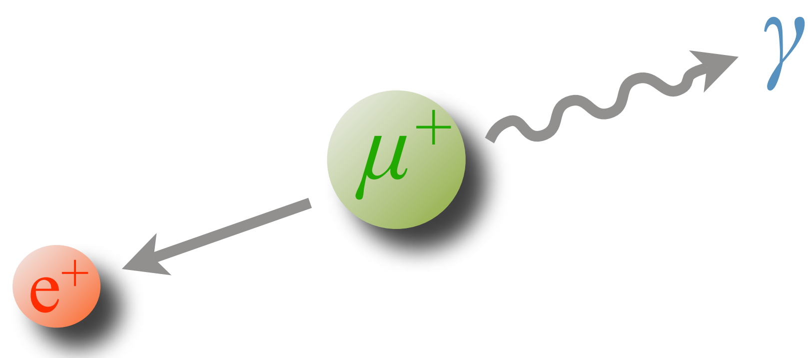
- Search experiment for "$\mu \to e\gamma$"
  - "$\mu \to e\nu\nu$" (Michel decay) ~ 100% in SM
  - SUSY-GUT models predict higher branching ratio $Br(\mu \to e\gamma) = 10^{-11} \sim 10^{-15}$
  - "$\mu \to e\gamma$" decay is the most sensitive, exploring GUT/seesaw via SUSY
  - New experiment, MEG, with a sensitivity of $Br = 10^{-13}$ is being carried out at Paul Scherrer Institut (PSI) in Switzerland
- Detector concept
  - The most intense DC muon beam @ PSI
  - Liquid xenon γ detector; see **23pZJ5-8**
  - Positron spectrometer with gradient magnetic field
  - "Light" drift chamber system and high-accuracy timing measuring counter



- MEG detector -

$\mu \rightarrow e\gamma$ Signal and Background

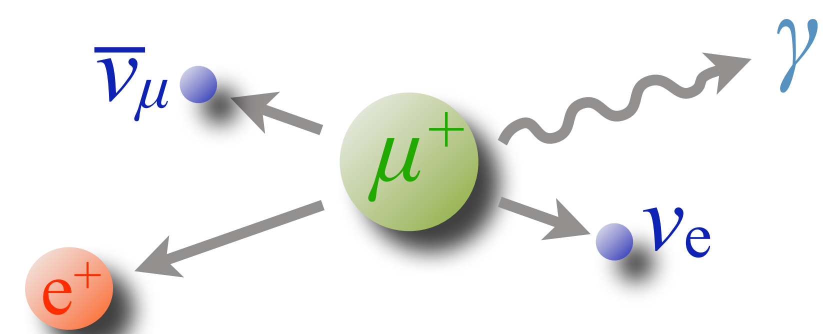
- Signal



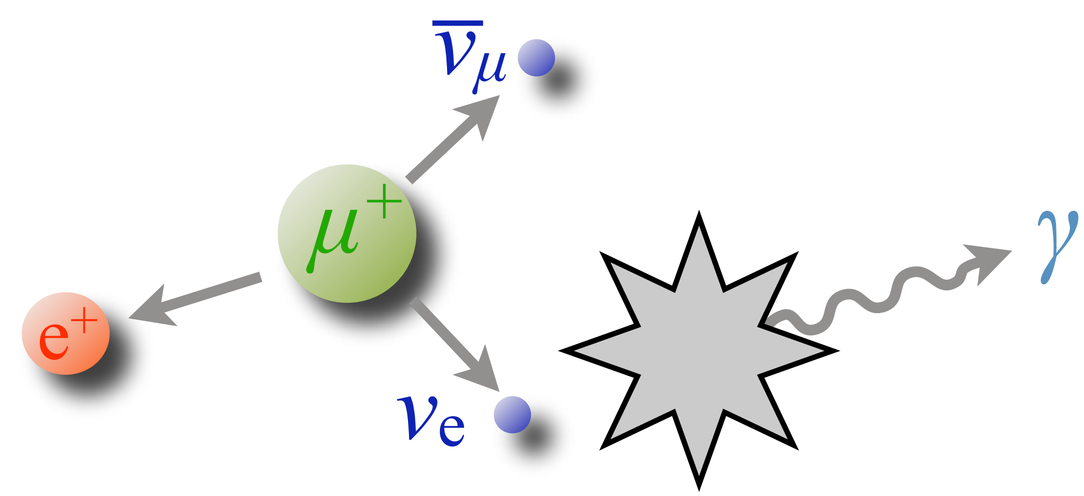
- $E_e = E_\gamma = m_\mu/2 = 52.8$MeV
- $\theta = 180$deg.
- time coincidence

Clear 2-body kinematics
use μ^+ to avoid capture inside stopping target
Background dominated by Accidental overlap
 - lower muon beam rate is better
 - DC muon beam is the best

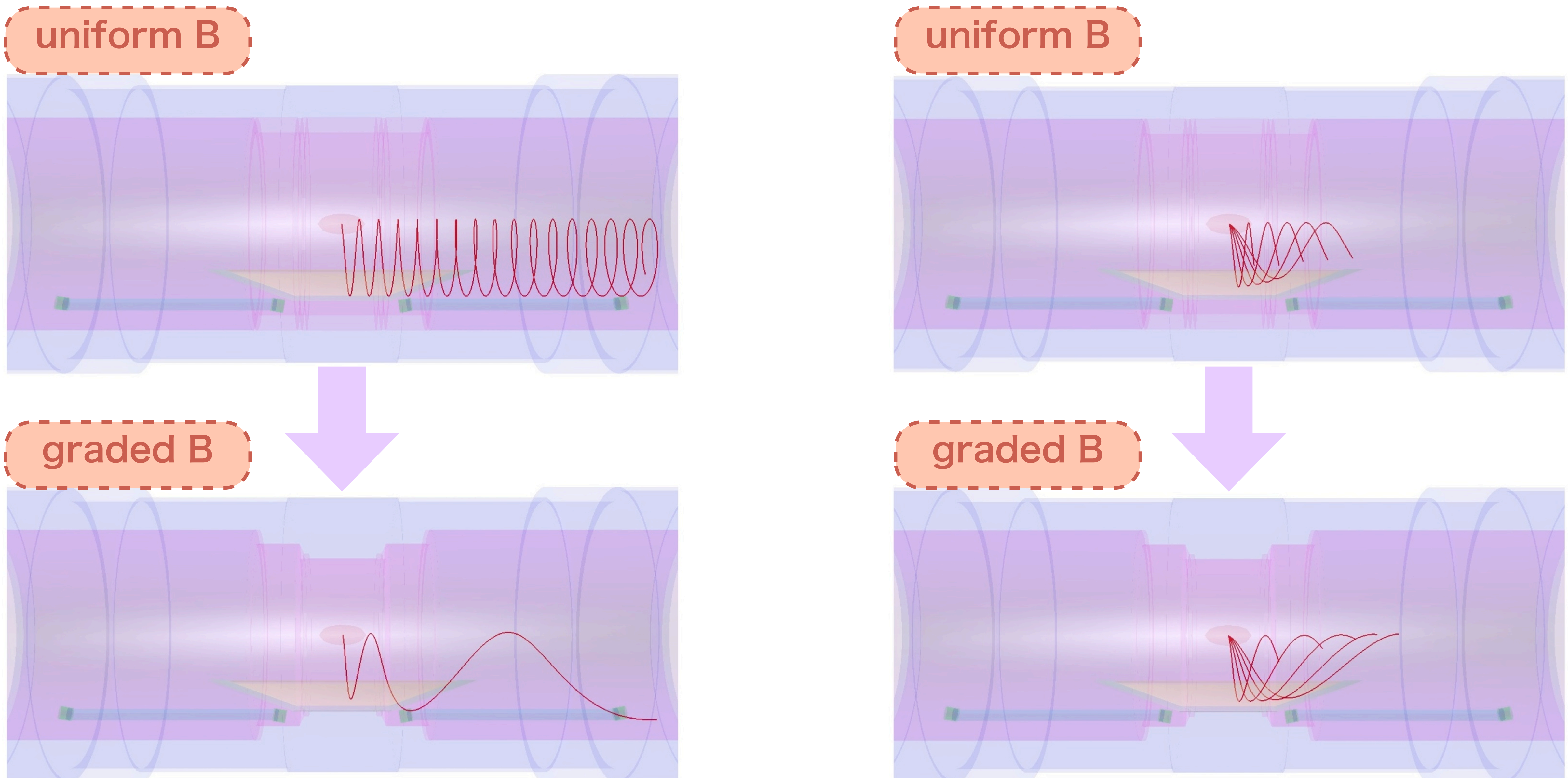
- Background
  - radiative muon decay



  - accidental overlap



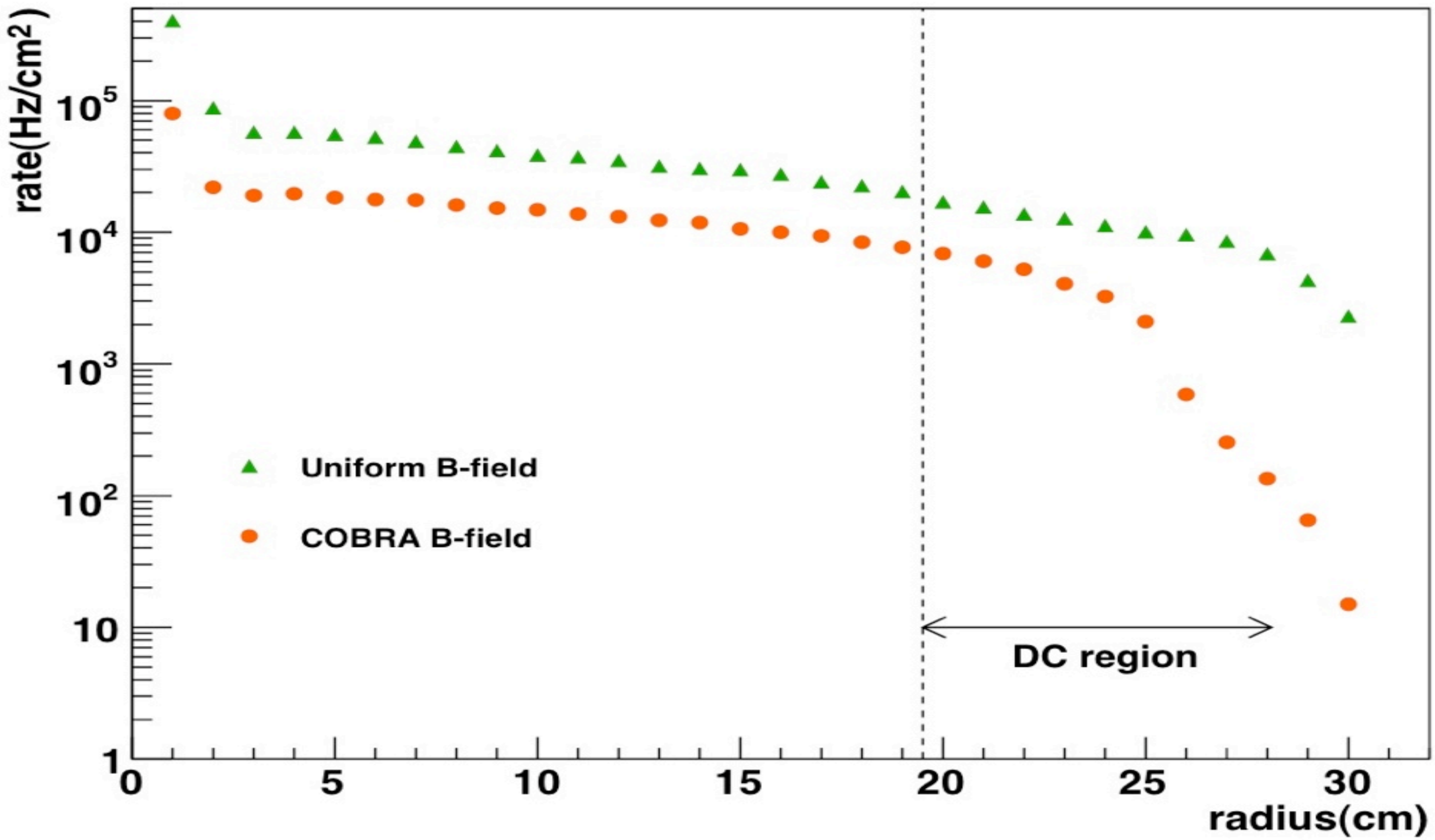
COnstant Bending RAdius Solenoid



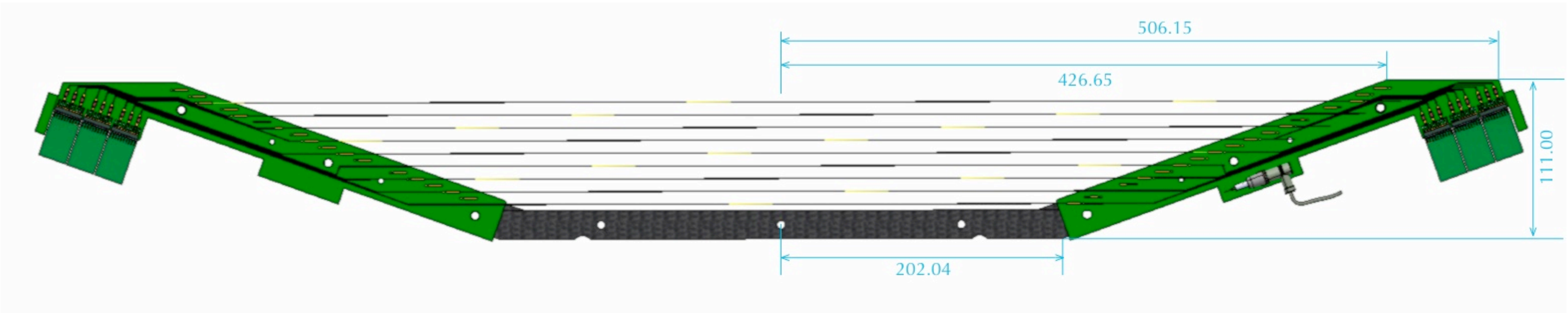
low energy e+ quickly swept out

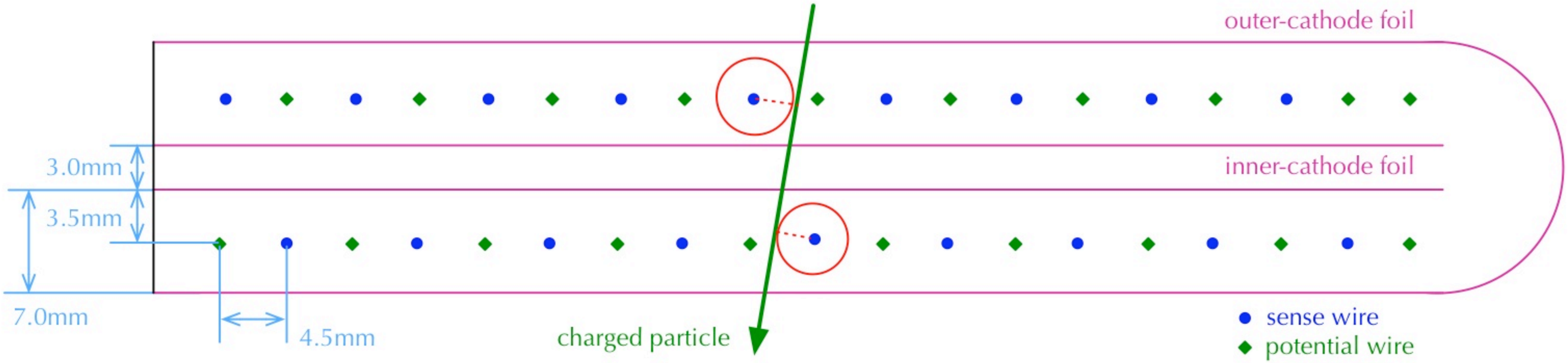
constant bending radius
independent of emission angles

COnstant Bending RAdius Solenoid

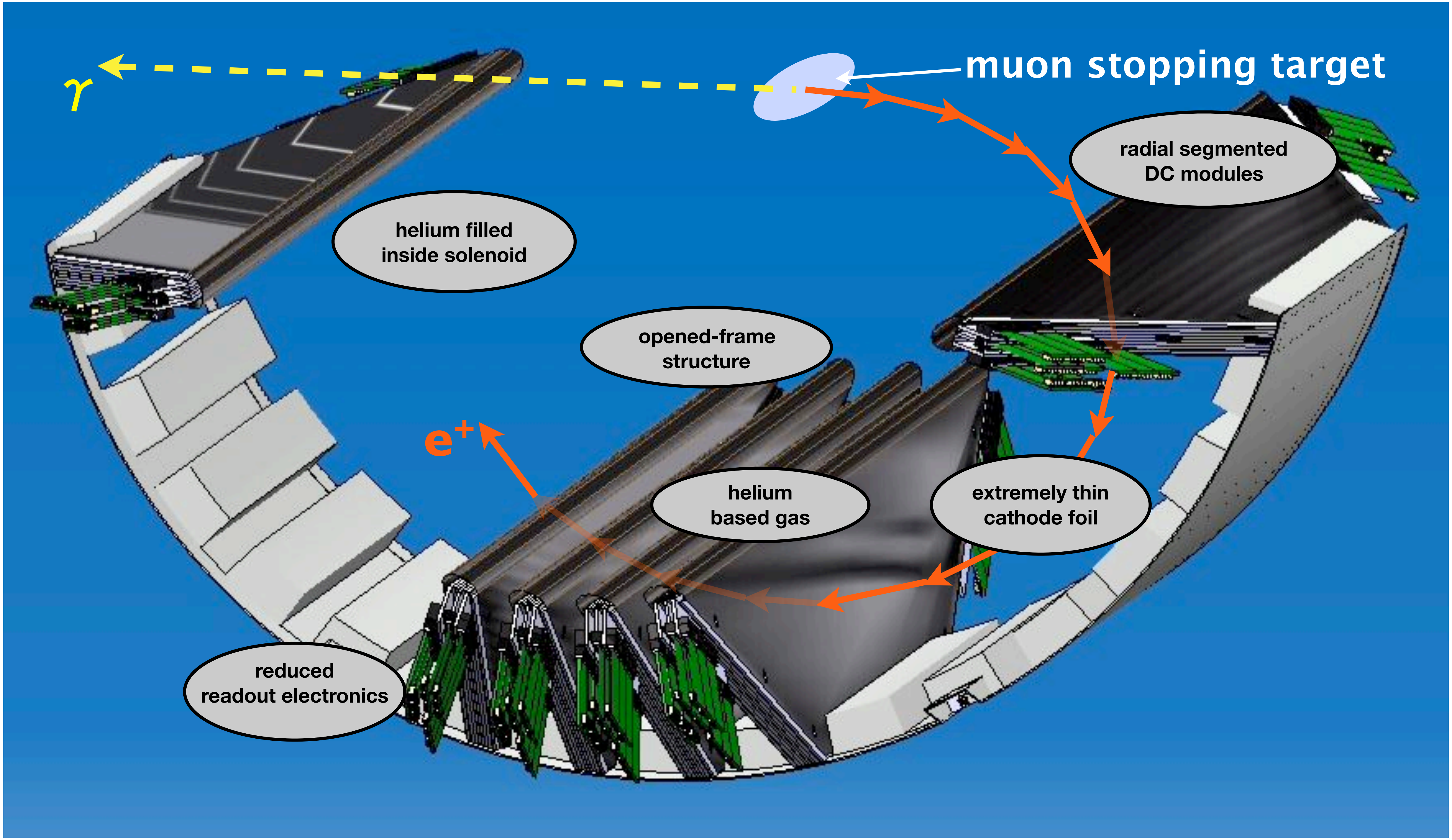


Drift Chamber Design



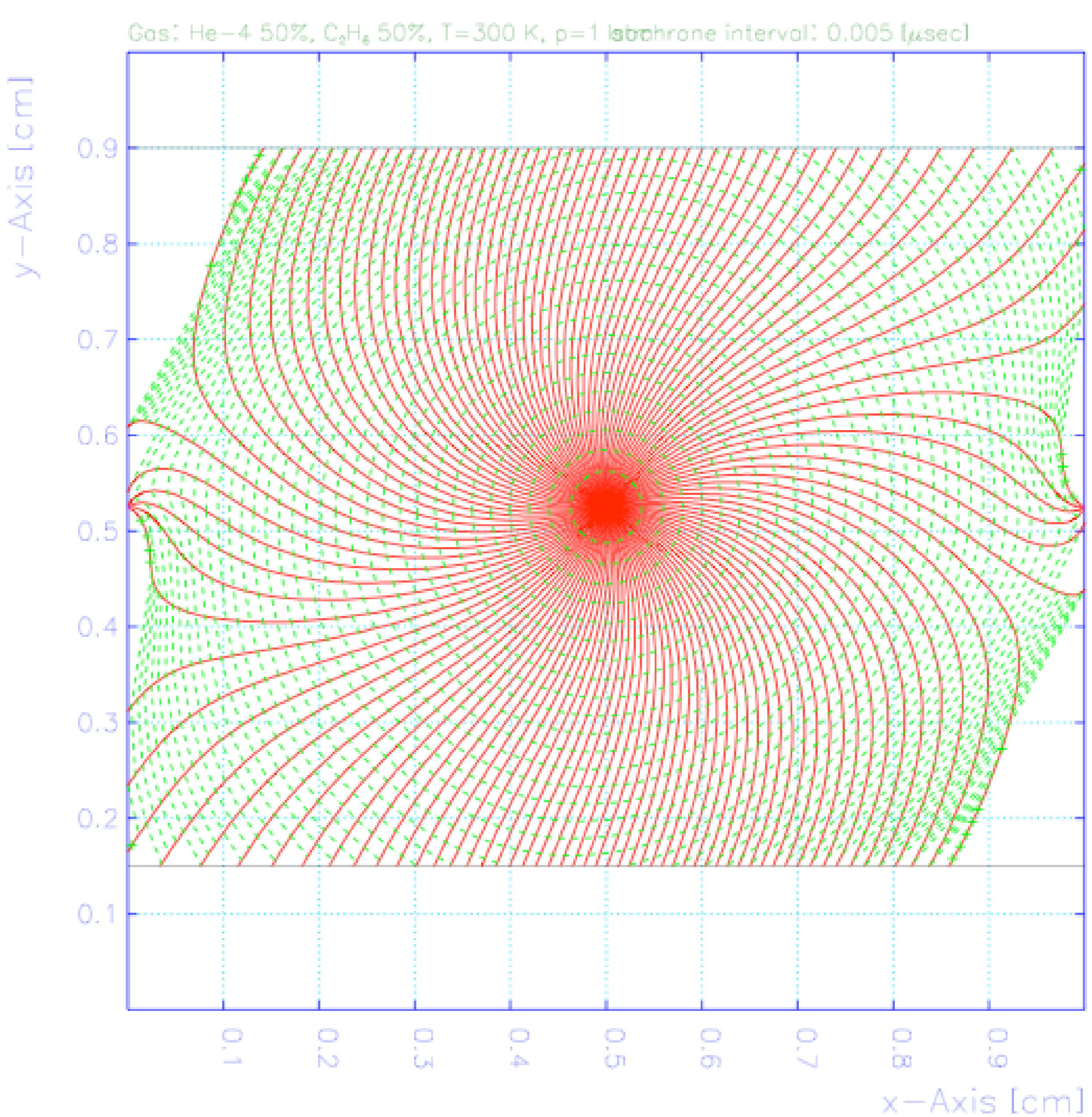


Drift Chamber System

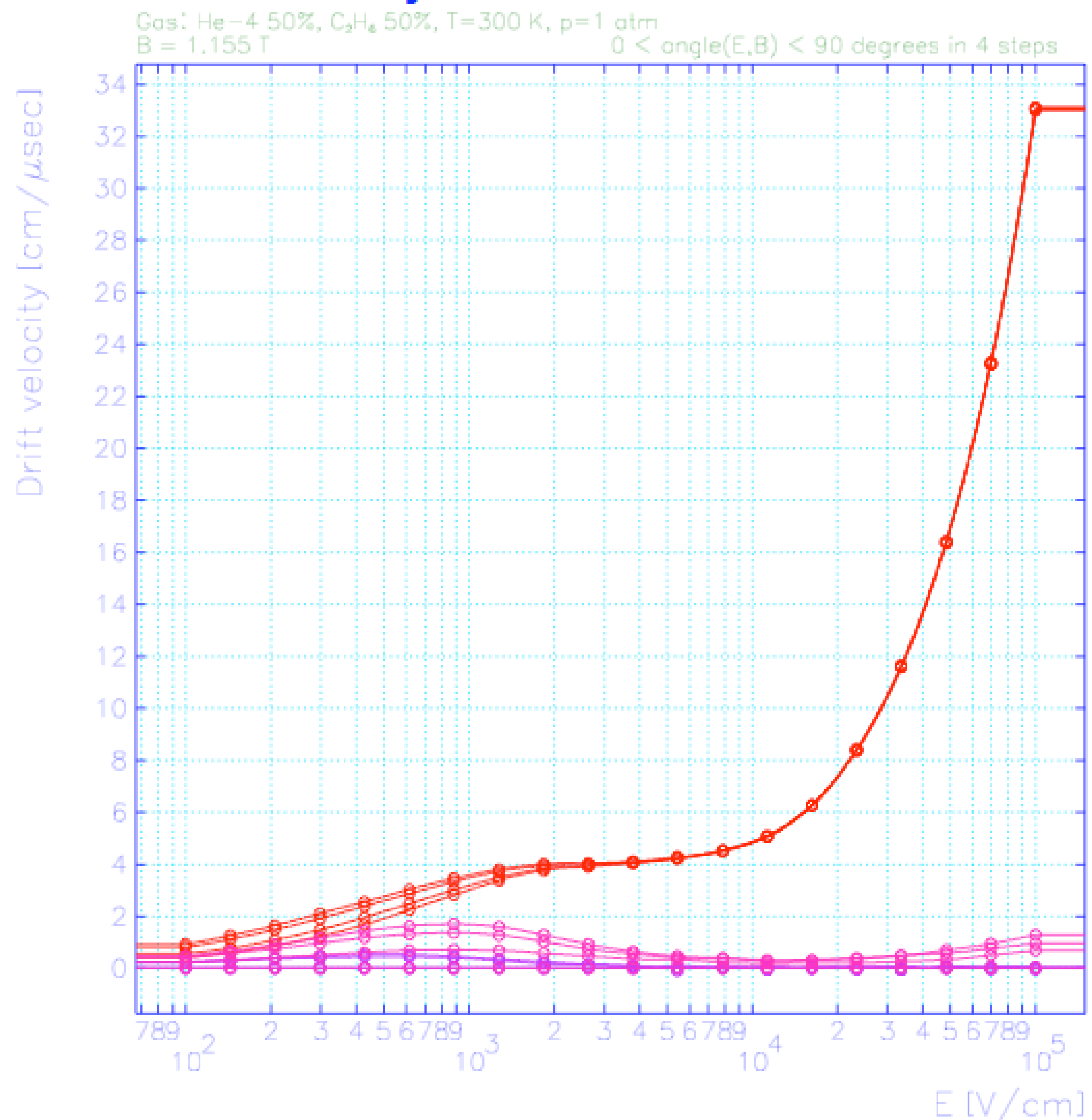


DC characteristics Simulation (Garfiled)

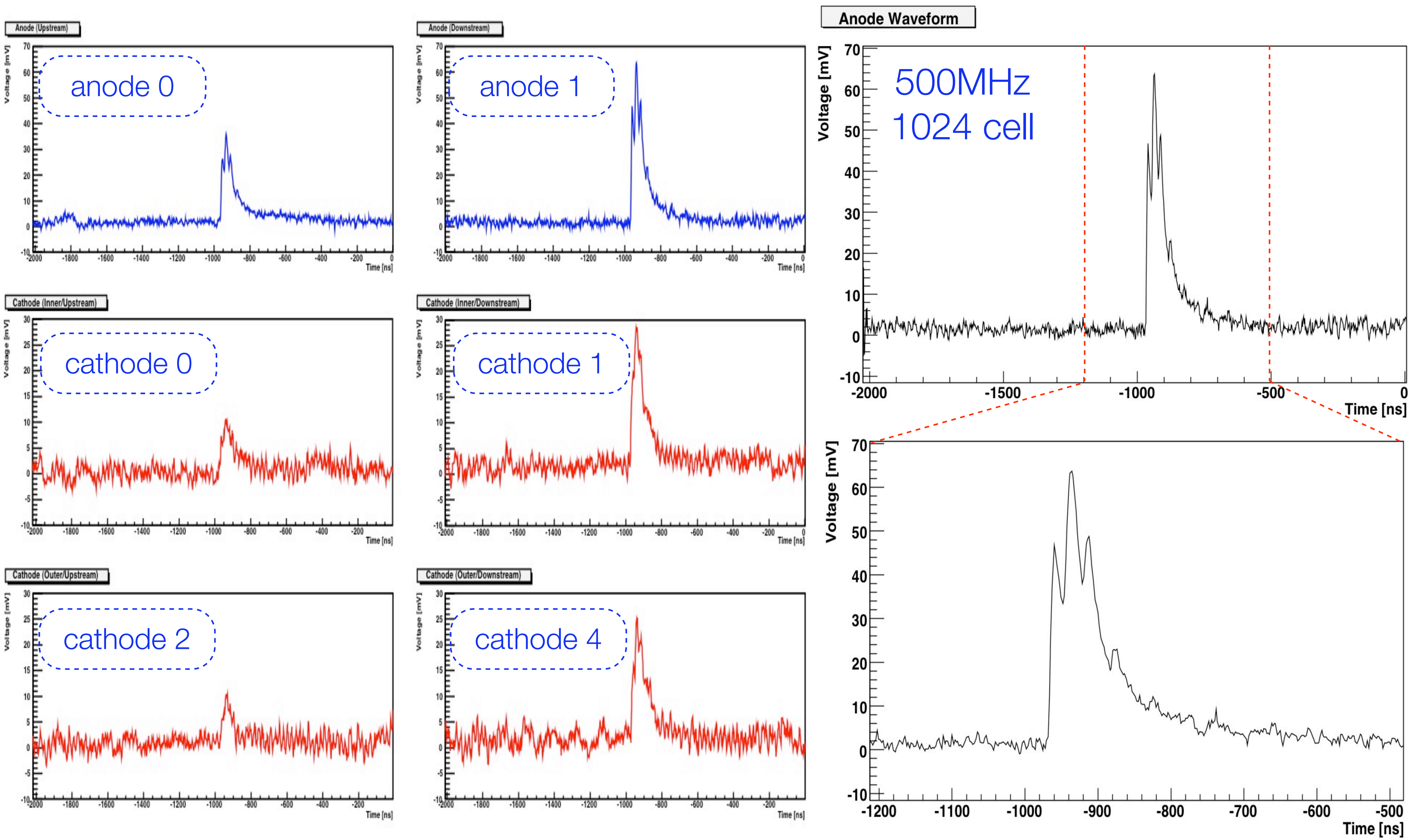
Electron drift lines from a wire



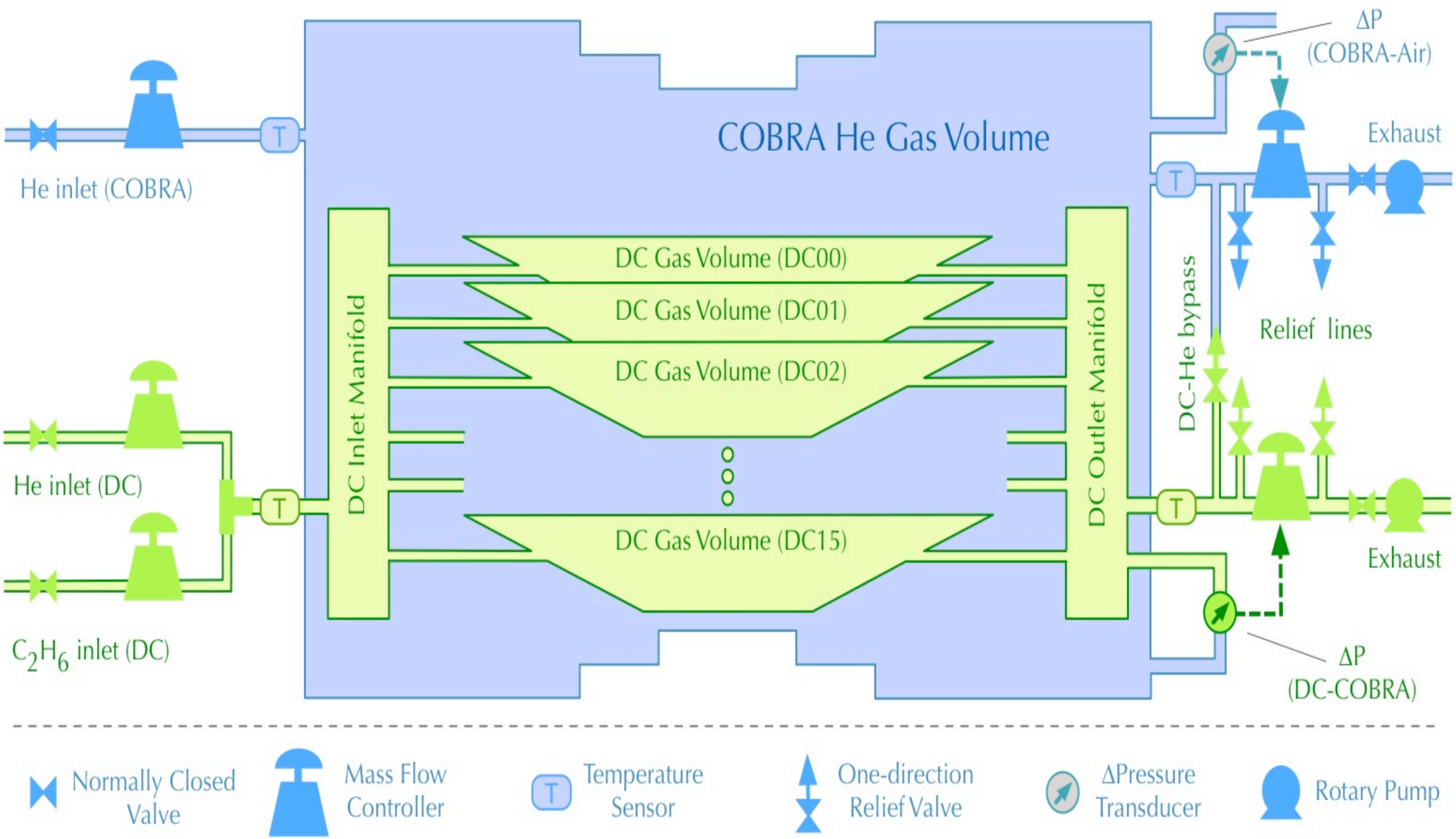
Drift velocity vs E



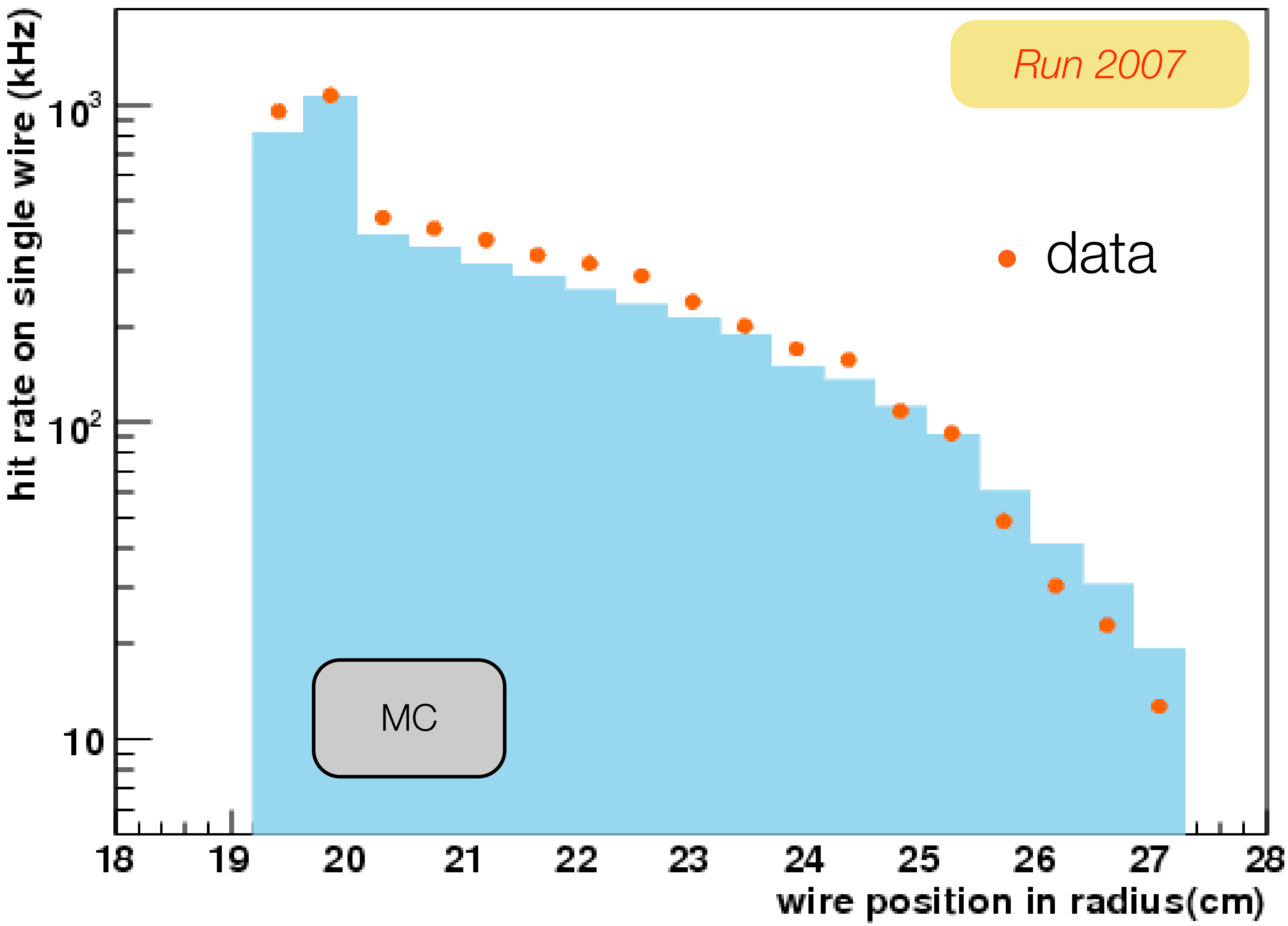
DC Output Waveform (Domino Ring Sampler)



Pressure Equalization System

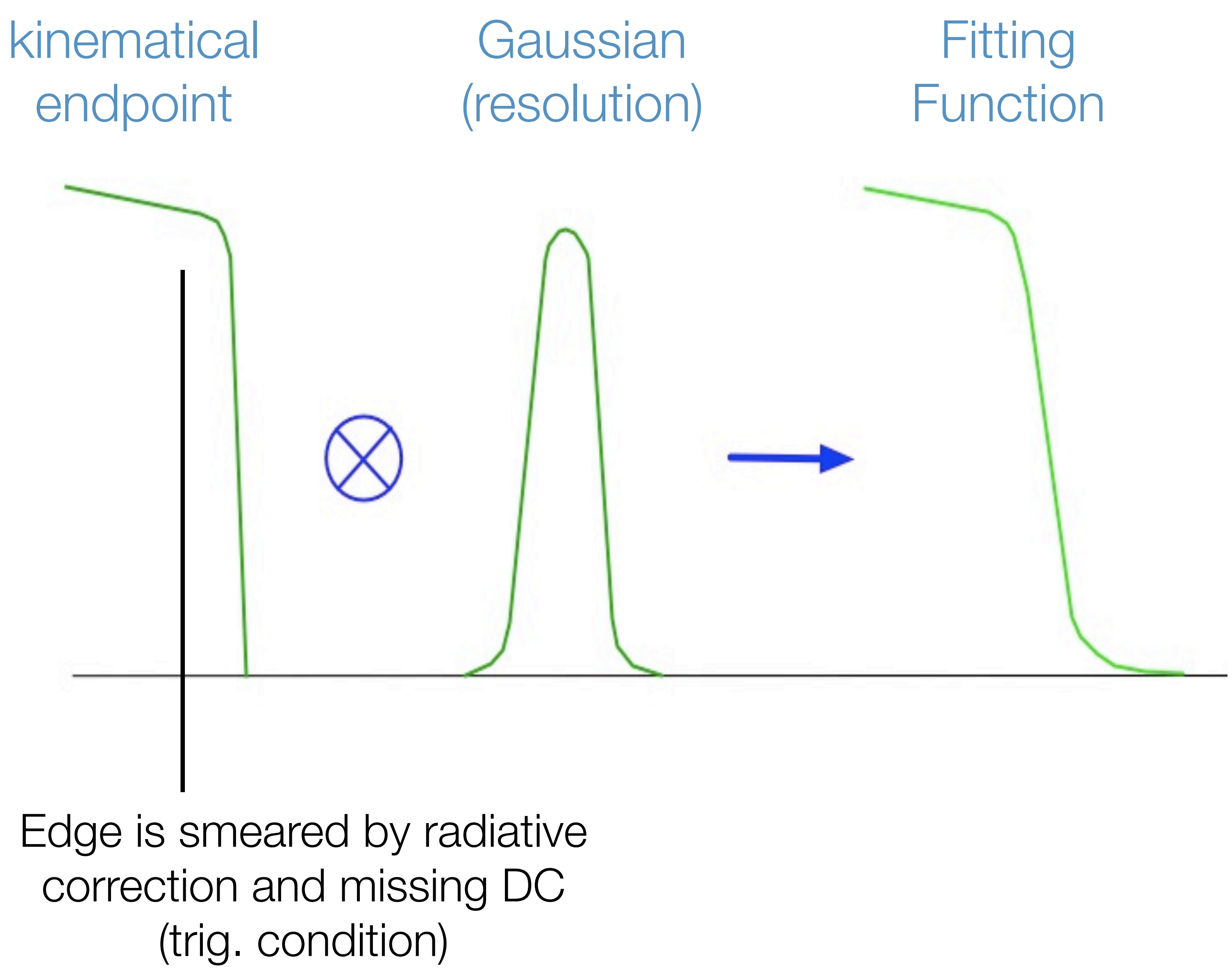


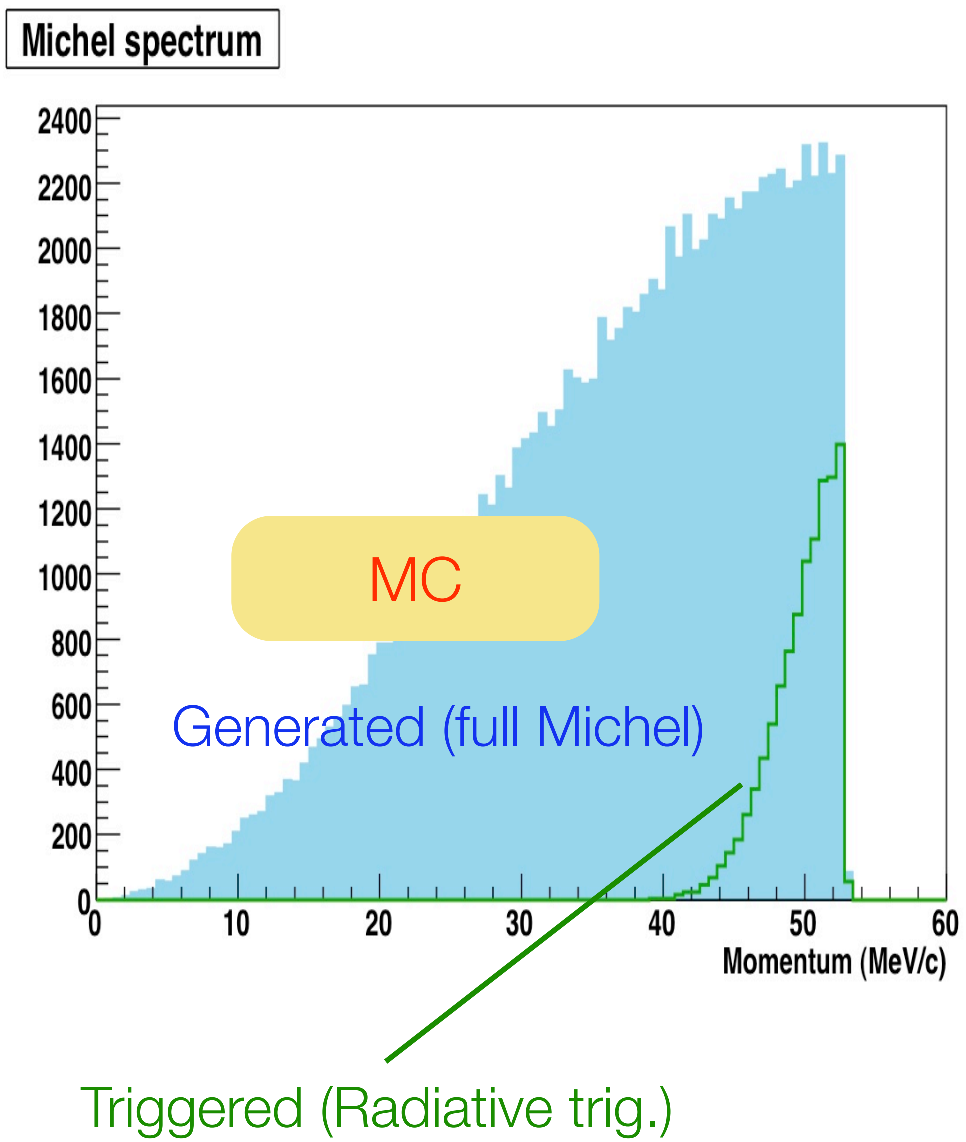
Hit Rate Analysis, Comparison with MC



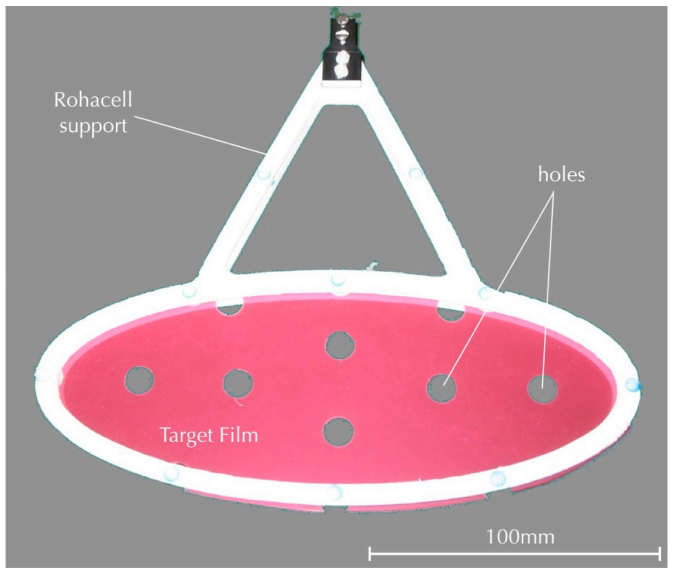
Momentum Resolution Estimation

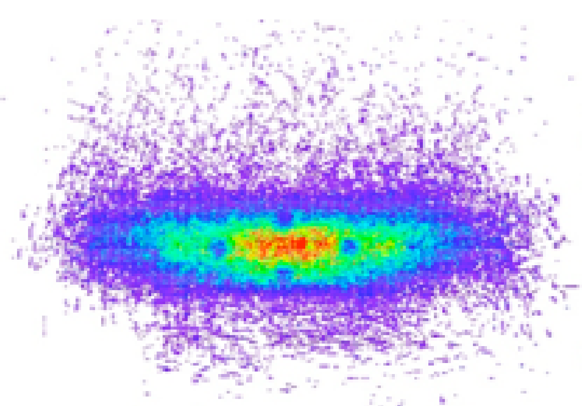
- End-point is fitted to the convolution of “theoretical response function” and “Gaussian”, with three free parameters; “E_{edge}”, “σ_p” and “Normalization”



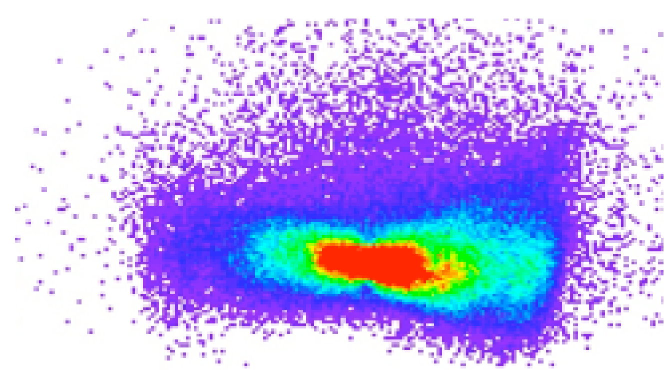


Vertex and Angular Resolutions

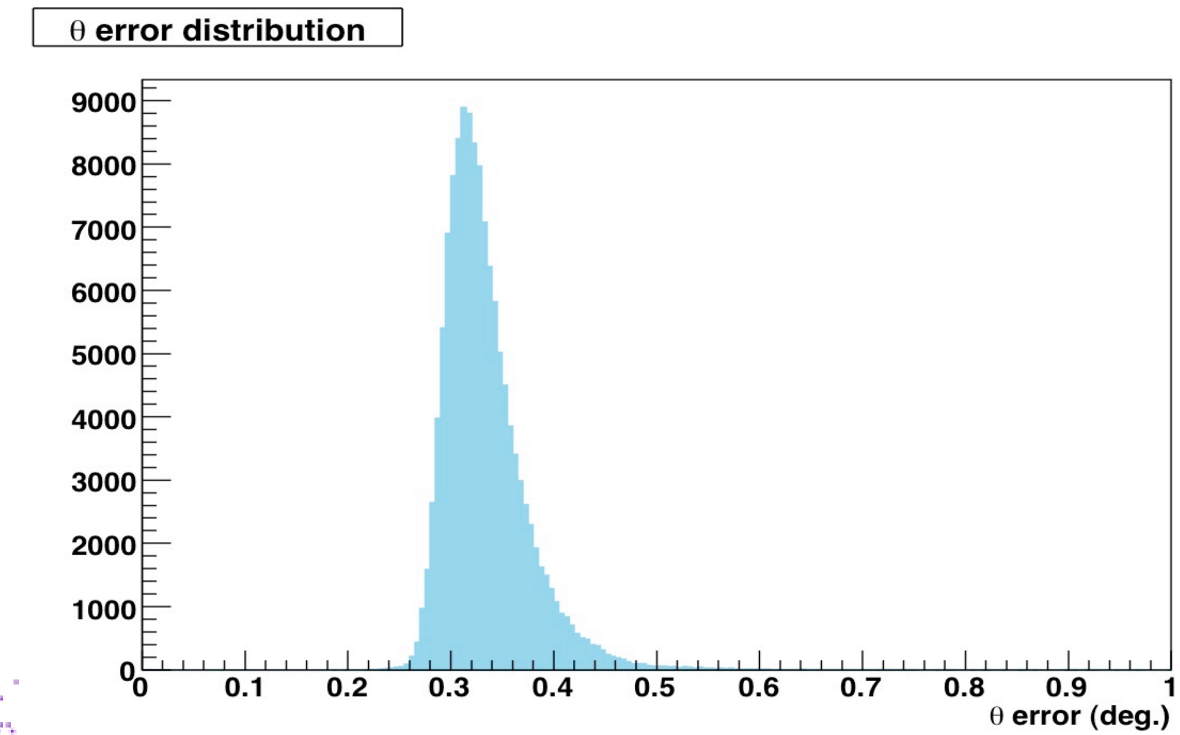


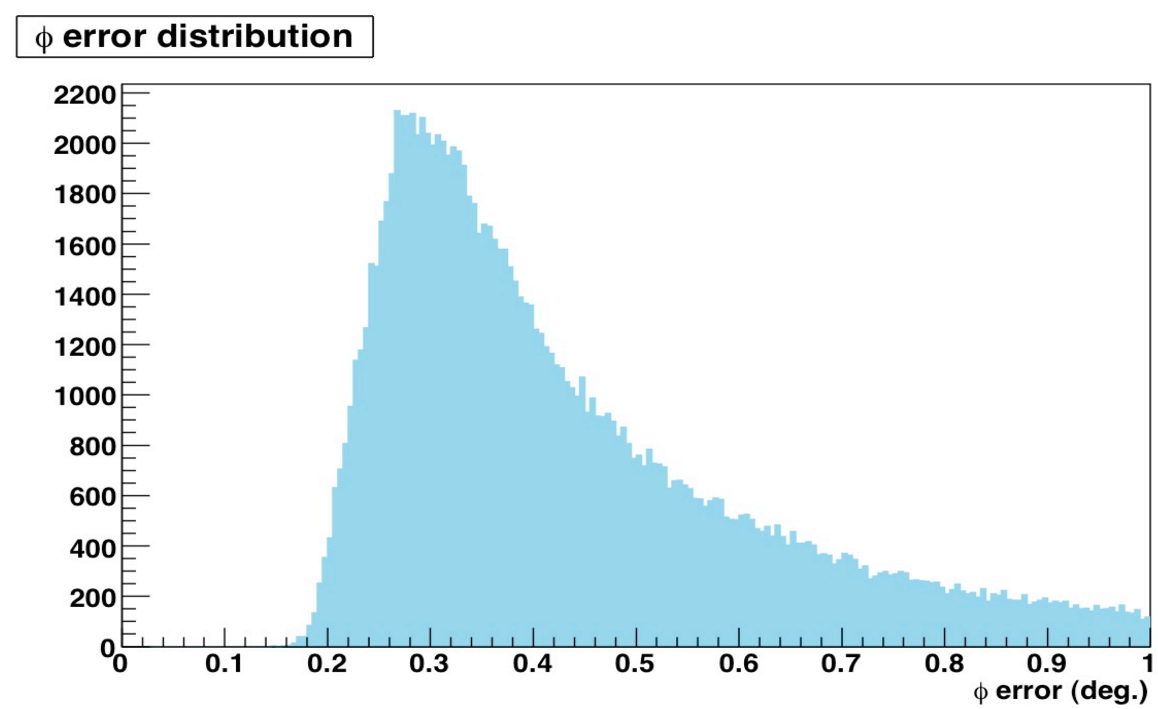


MC



data





- $\sigma_{x,y}$ = 1~2 mm
- σ_{φ} = 5.23 mrad , σ_{ϑ} = 5.76 mrad