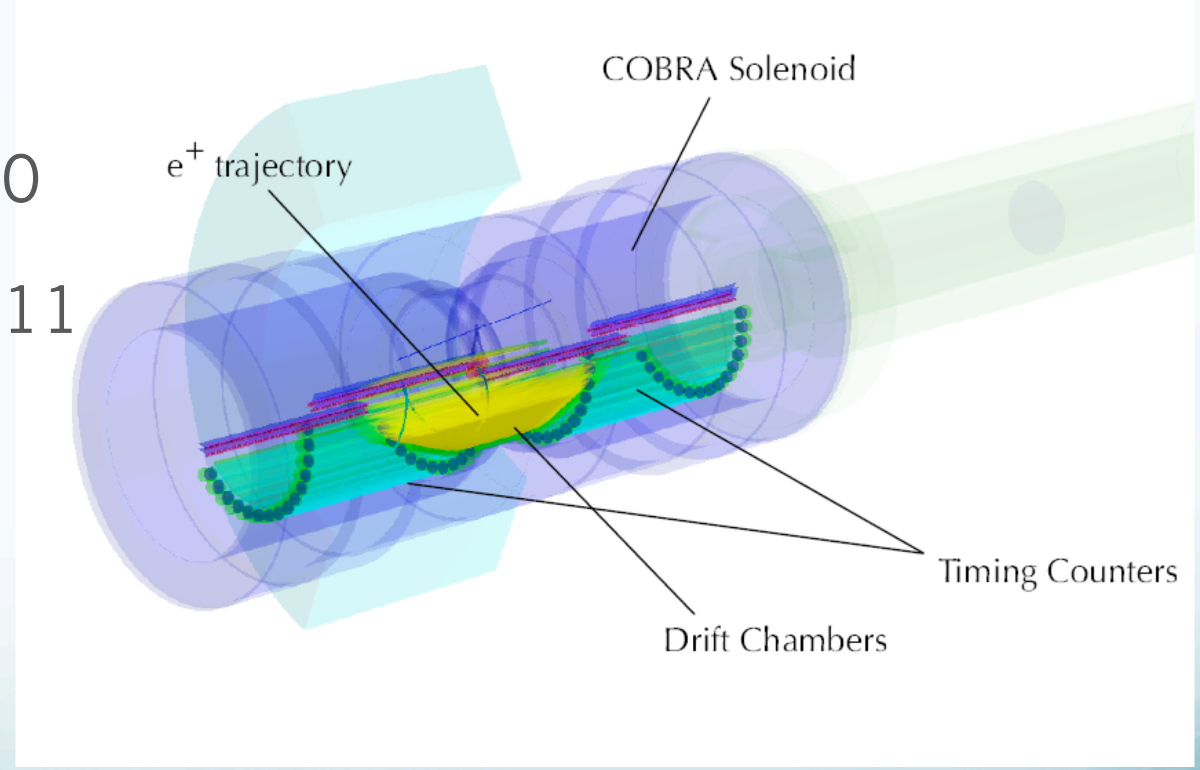
MEG実験
陽電子スペクトロメータの
性能と今後の展望

Yuki Fujii
On behalf of the MEG collaboration
JPS meeting @ Hirosaki University
17th Sep. 2011

Outline

- Introduction
- Run 2009 & 2010
- Status of run 2011
- Noise reduction
- Summary and prospects



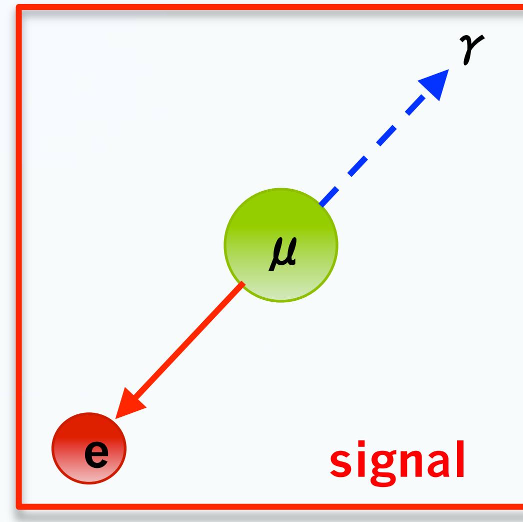
Introduction

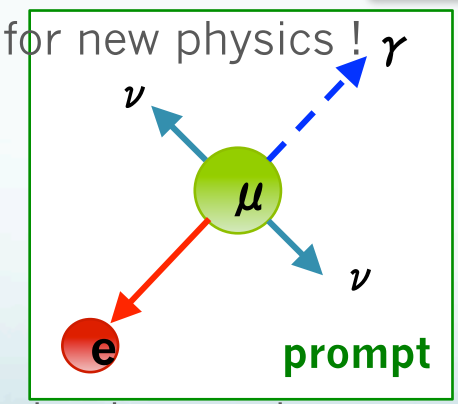
- The decay of $\mu \rightarrow e\gamma$ is strictly forbidden in the standard model because of lepton flavor conservation

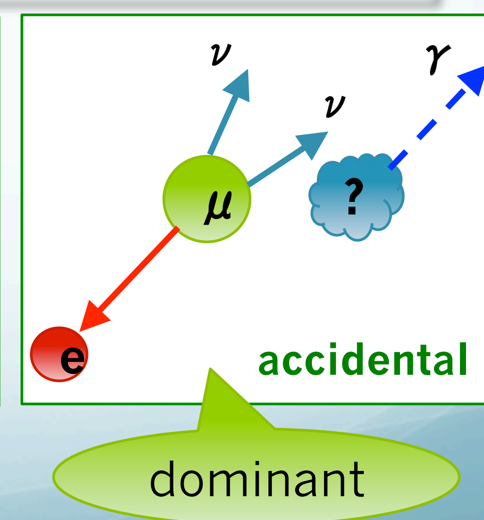
- BUT… some of beyond the SM (e.g. SUSY) predict this decay can happen in the range of 10^{-11}-10^{-15}
  - Previous upper limit is $1.2\text{x}10^{-11}$ (MEGA experiment)
  - $\mu \rightarrow e\gamma$ is a good probe to search for new physics !

- Background
  - Radiative decay (prompt)
  - Michel decay + γ (accidental)

- Experimental requirement
  - **High resolution** detector → reduce background
  - Operation under **high luminosity** → high statistics

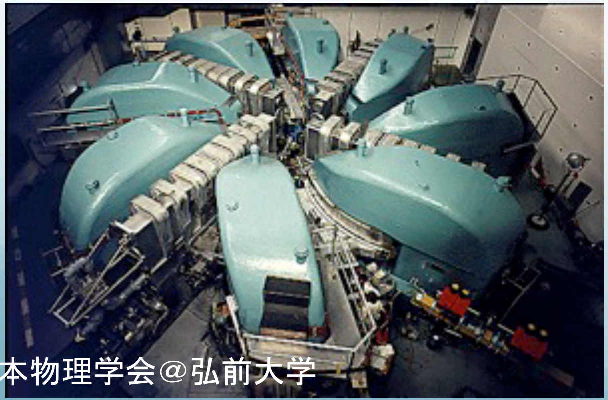


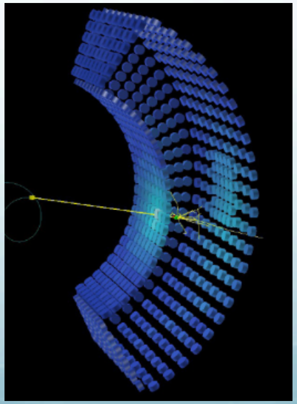


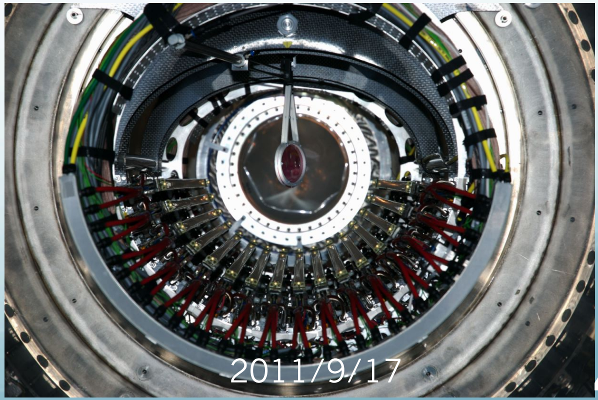


Introduction

- The MEG experiment started to search for $\mu \rightarrow e\gamma$ in 2008
  - World's most intense DC μ^+ beam @ PSI
  - 900 litter large Xenon calorimeter → (白:17pSE2, 金子:17pSE3)
  - **The COBRA (CO**nstant **B**ending **RA**dius) **spectrometer → main topic**
- Result 2009 & 2010 : **Br($\mu \rightarrow e\gamma$) < 2.4x10^{-12}** (90 % C.L.)
  - **5 times lower than previous one**
    → (大谷:18aSJ4, 岩本:19aSD7, 澤田:19aSD8)
- Our sensitivity goal is a few × 10^{-13}
  - **Performance improvement is essential !**

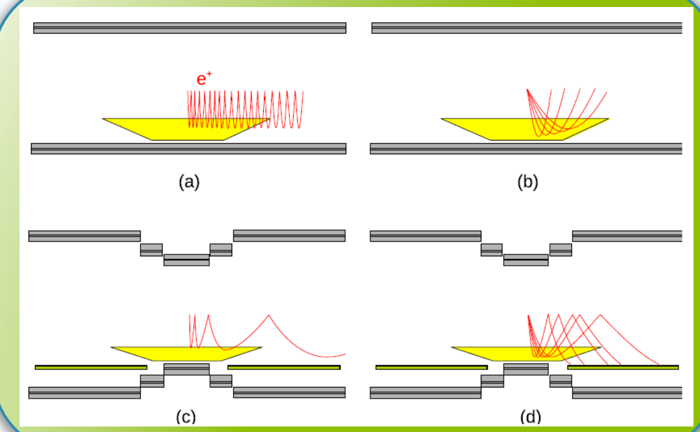






Introduction

- The COBRA spectrometer
  - **COBRA magnet** : fast sweeping low momentum e+ and get uniform angular response for signal e+
  - **Drift chamber** : e+ tracking, low mass materials to reduce the production of background gamma ray
    - Vernier pattern method
    - Waveform data acquisition
  - **Timing counter** : e+ timing, bar counters (ϕ measuring) + fiber counters (z measuring)



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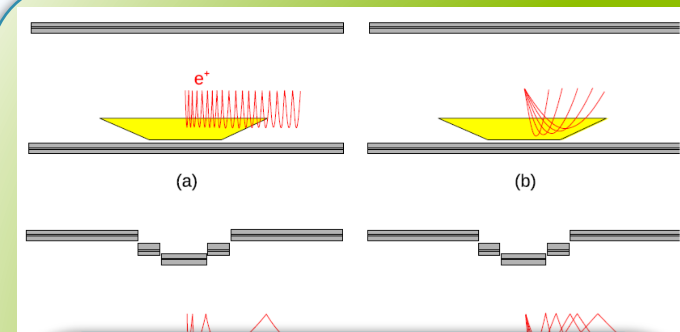

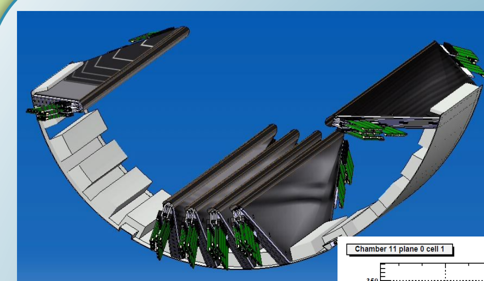

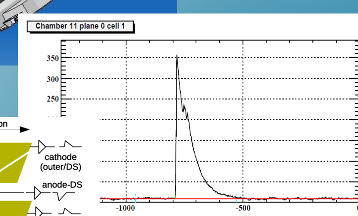

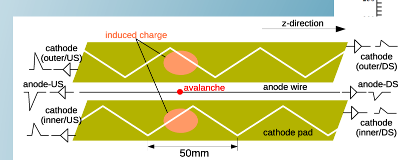

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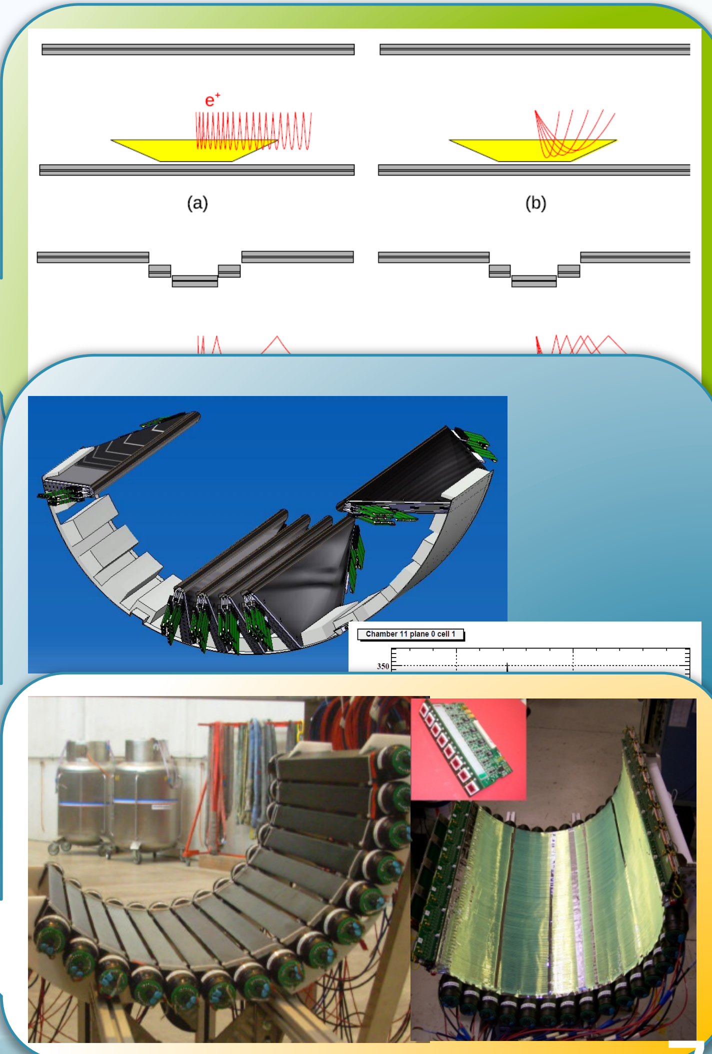
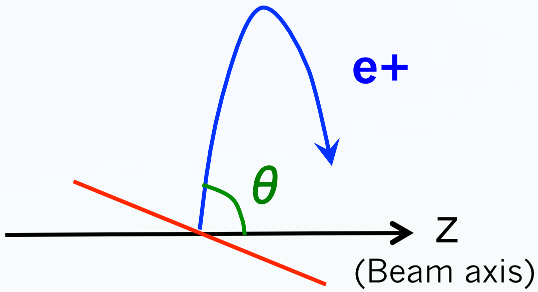
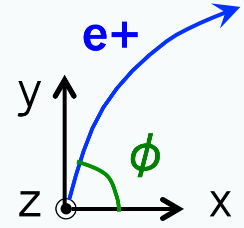
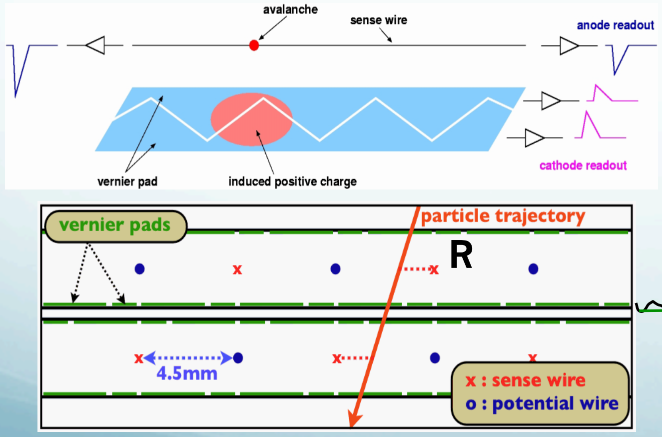


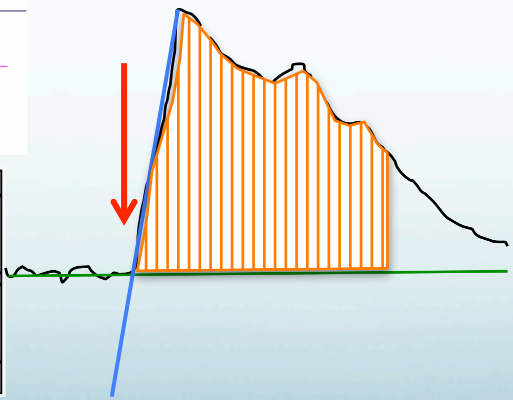
Introduction

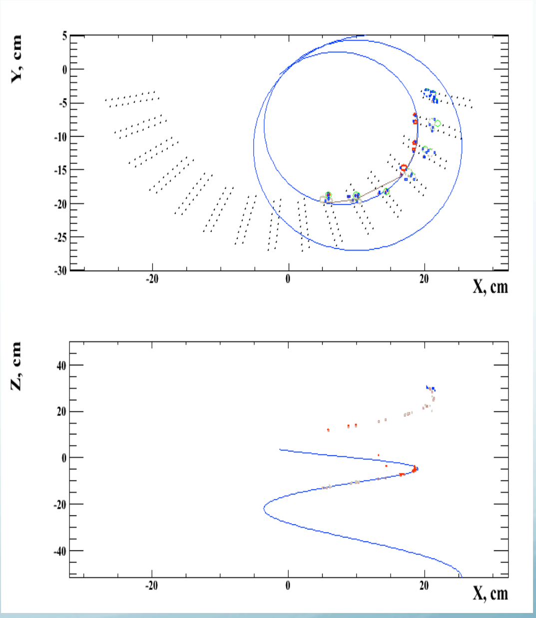
- **Positron measurement**
  - Coordinate system
  - Hit reconstruction
    - R → time reading edge
    - Z → charge division w/ Vernier pad
  - Track reconstruction
    - Kalman filter





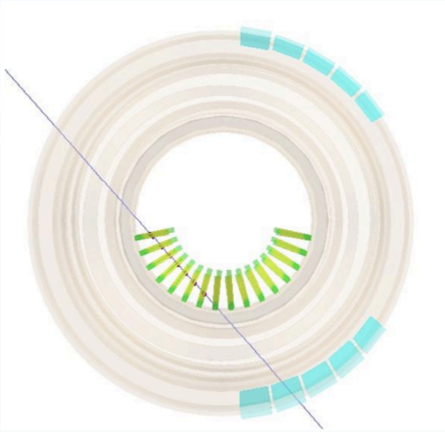


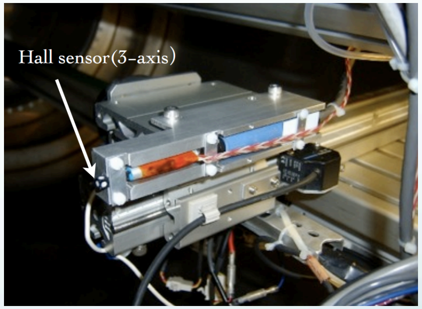




Run 2009 & 2010

- Run and analysis summary of 2009 and 2010
- Drift chamber alignment
  → Millipede using cosmic rays
- COBRA Magnetic field
  → reconstructed field
  - B_{ϕ} and B_r are corrected a possible misalignment of hole probe to conserve the Maxwell's equations from measured B_z
- All APDs off because of noise problem
- Drift chamber waveform in 2010 was a little noisier than in 2009 (σ of pedestal : ~1.8 mV → ~2.0 mV)





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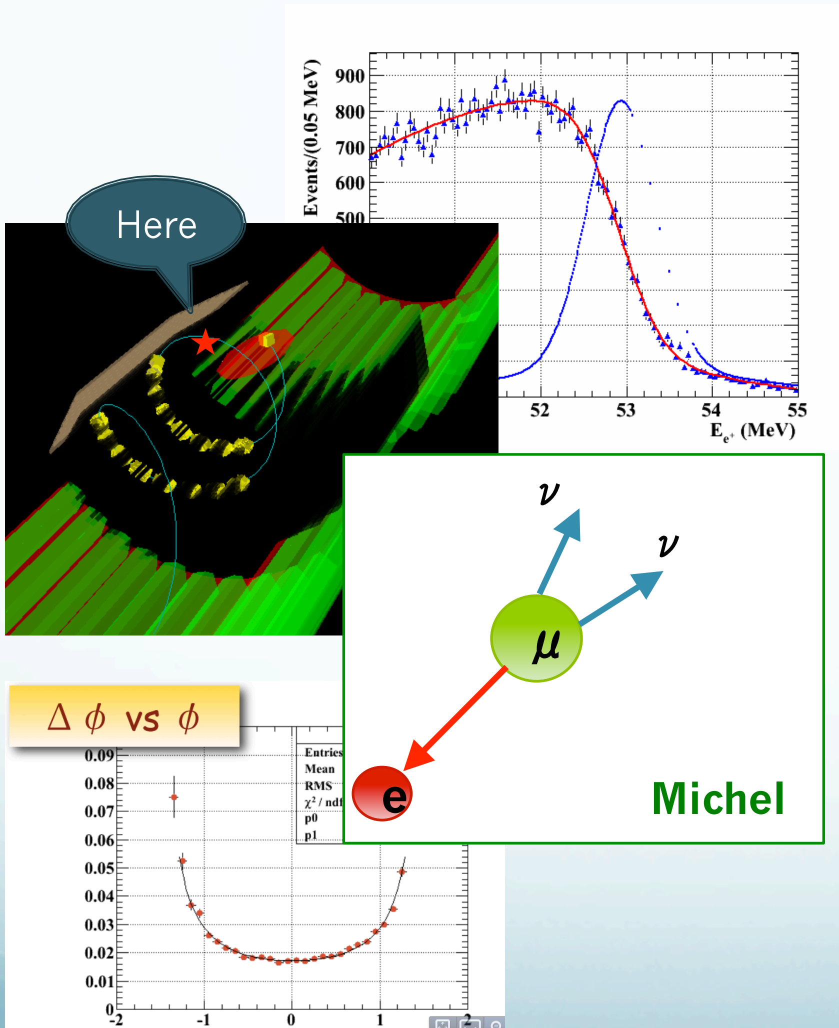

- Performance estimation
  - **Momentum resolution** : Michel edge fitting and double turn events
  - **Angular & vertex resolutions** : Double turn events
  - **Efficiency** : count #of MD
  - **Correlations** : sideband data

Run 2009 & 2010

- All performance of the e+ spectrometer are estimated by data itself (radiative decay events, Michel decay events, and so on)

	2009	2010
E_e	330 keV (core 82 %)	330 keV (core 79 %)
ϕ (at ϕ=0)	6.7 mrad	7.2 mrad
θ	9.4 mrad	11.0 mrad
Z	0.15 cm	0.20 cm
Y	0.11 cm (core 87 %)	0.11 cm (core 85 %)
$T_{e\gamma}$ (RMD)	150 psec	130 psec
ε_{Michel}	40 %	34 %

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Noise
+
increased dead channels

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$T_{e\gamma}$ (RMD)	150 psec	130 psec
$\varepsilon_{\mathrm{Michel}}$	40 %	34 %

Better DRS clock

Increased dead channels

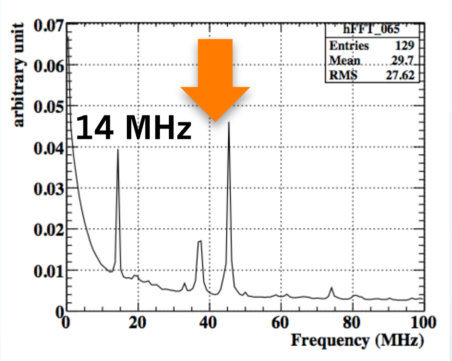
Status of 2011

April	May	June	July	Aug.	Sep.

Detector installation — **Calibration Detector check** — **Physics run** — **CEX**

- 7 drift chamber modules were replaced because of increased remaining current or frequent trip
- Physics data taking started at the end of June
- In 2009 and 2010, only 14 MHz noise is dominant

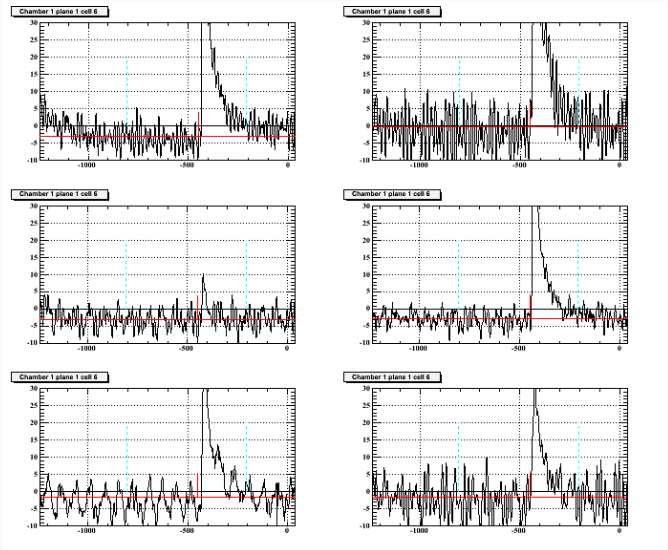
  → reduced by adjusting charge integration time

  - other noise components appeared (>30 MHz from APD fiber counters)
- Working of hardware noise reduction was done in the middle of July
  - Change HV module for drift chambers and turn off noisy APD channels

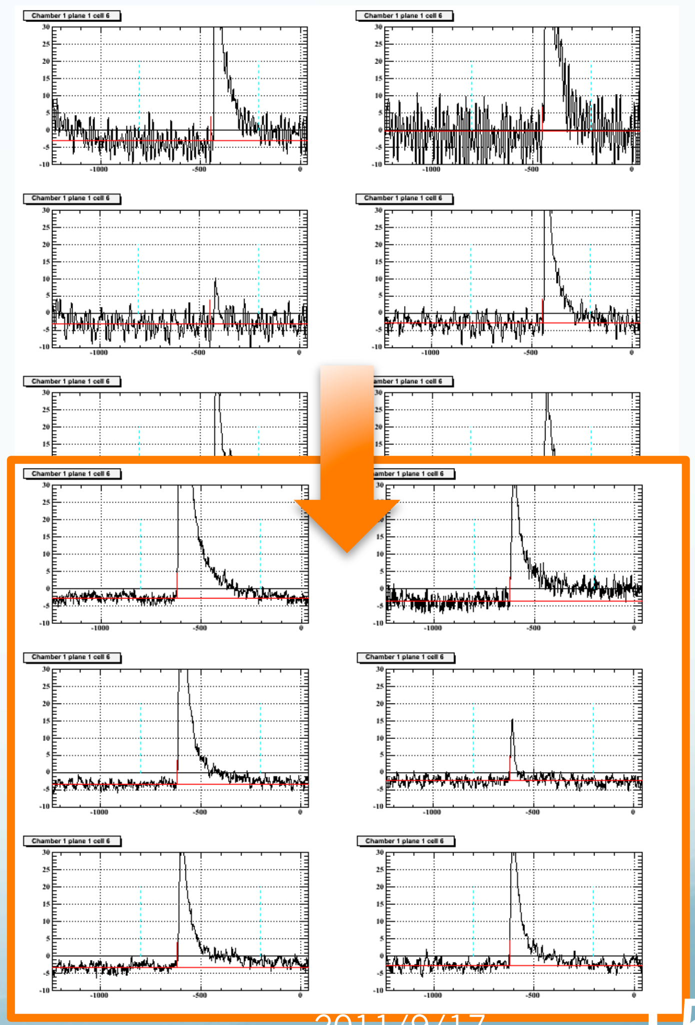
Status of 2011

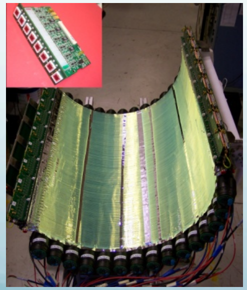
- At the beginning of 2011 run, noise situation was the worst…
- **But**



Status of 2011

- At the beginning of 2011 run, noise situation was the worst…
- **After hardware modifications, the lowest noise condition realized !**
- The APD fiber counters are partially operational now (not all)
  - Data quality to be checked





Noise reduction

- Performance of noisy runs and low noise runs
  - compare 2 condition by checking single hit resolutions (residuals between reconstructed wire hit and reconstructed track)
  - Single hit resolutions are estimated from double Gaussian fitting

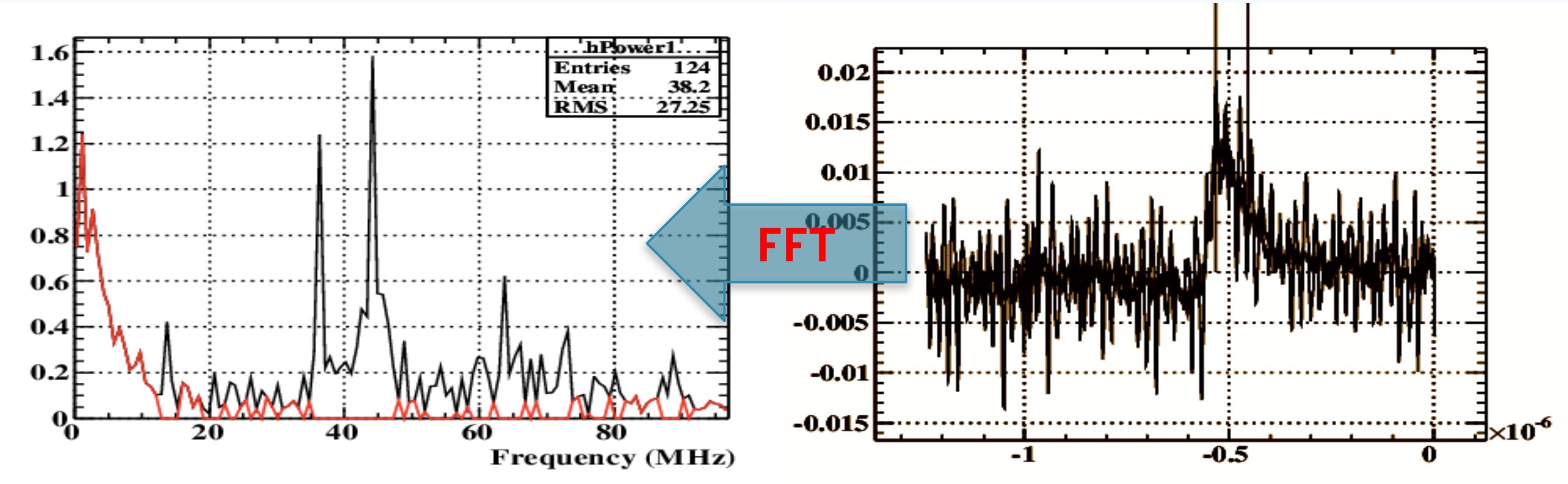
~ 1 month data taking

	2010	2011 (noisy)	2011 (low noise)
Intrinsic Z (um)	668 (core 56 %)	758 (core 52 %)	710 (core 56 %)
Intrinsic R (um)	209 (core 66 %)	233 (core 66 %)	197 (core 67 %)

- Give up noisy data to improve ? → **OF COURSE NO !**
- Filtering
  - Low pass filter → small contribution
  - High pass filter → distort the shape of signal pulse
  - FFT

Noise reduction

- Large periodical noises are eliminated in FFT power spectrum from DCH waveform
- After that, filtered spectrum is transformed inverse to the waveform
  - Charge integration done for filtered waveform



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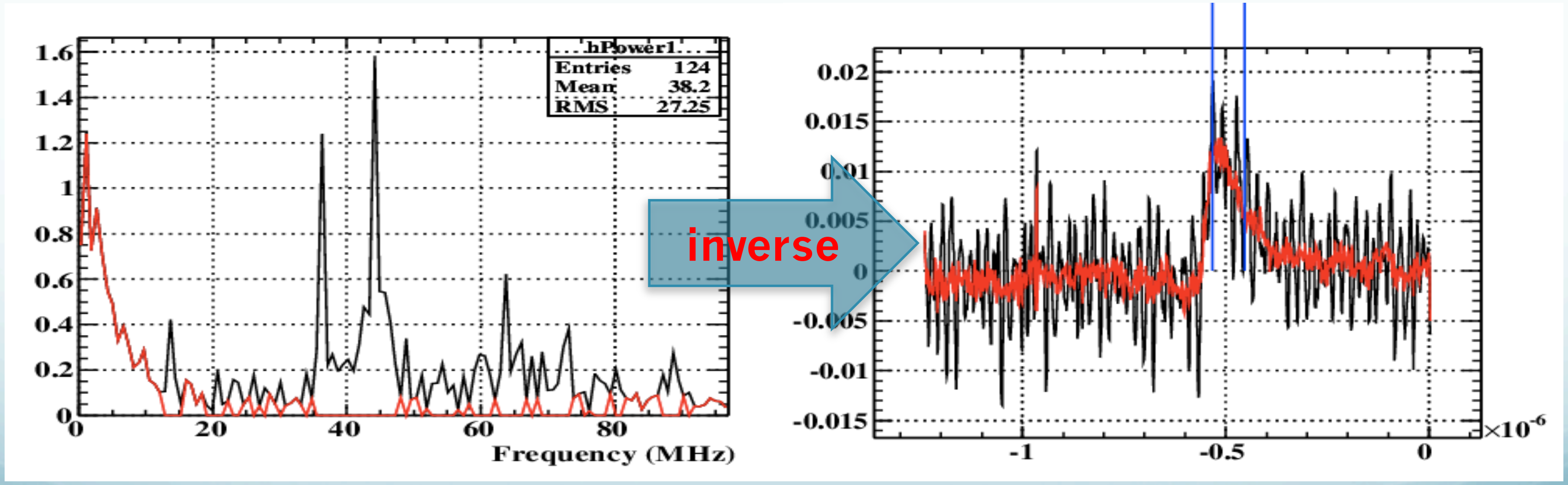
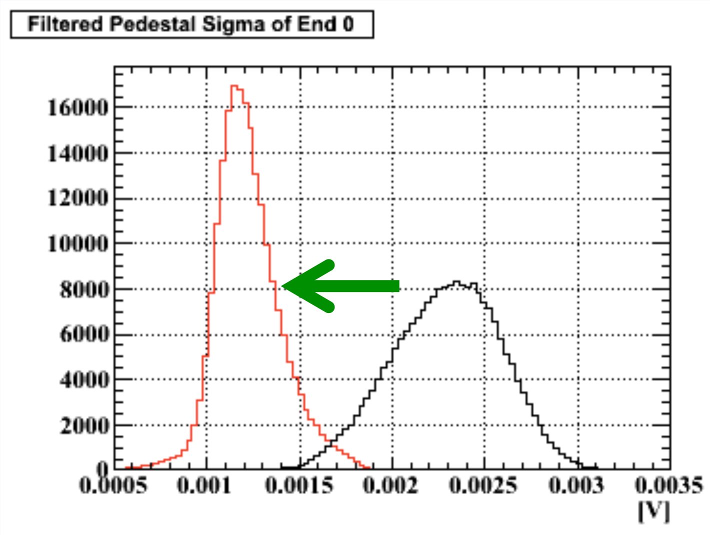


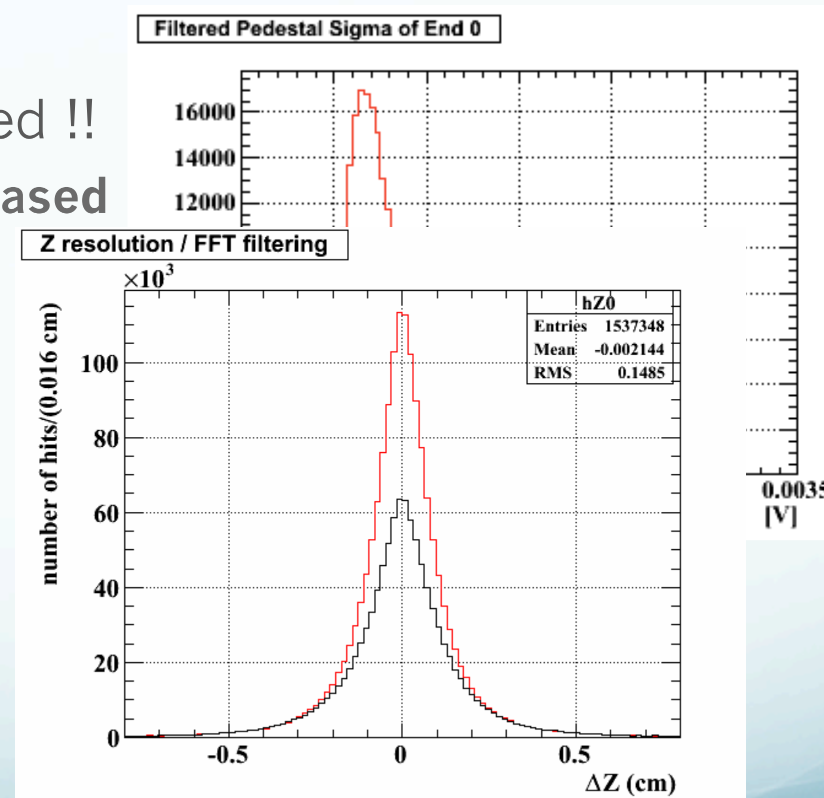
Noise reduction

- Thanks to offline noise filtering, twice better σ of pedestal realized (2.4 mV→**1.2** mV)



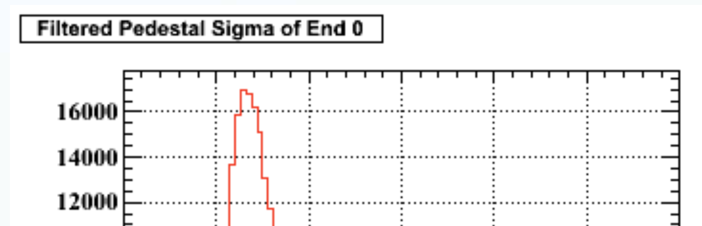
Noise reduction

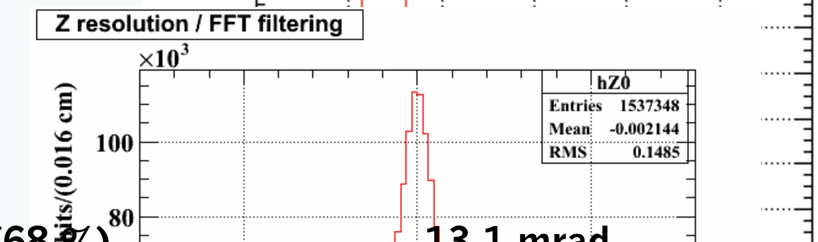
- Thanks to offline noise filtering, twice better σ of pedestal realized (2.4 mV→**1.2** mV)
- Single hit Z resolution improved !!
  - **758 → 664 um, #of hits increased**



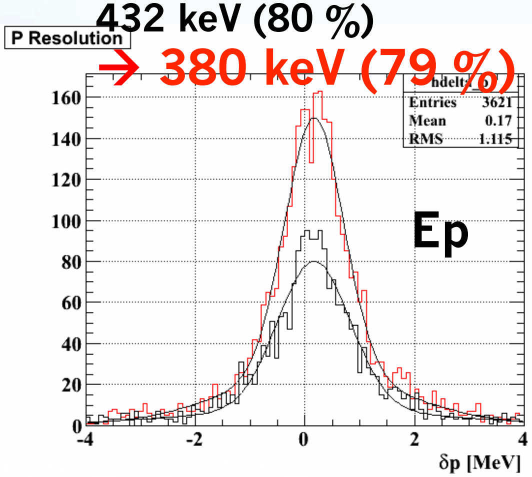
Noise reduction

- Thanks to offline noise filtering, twice better σ of pedestal realized (2.4 mV→**1.2** mV)
- Single hit Z resolution improved !!
  - **758 → 664 um, #of hits increased**
- Efficiency & resolutions
  - **Very good !**

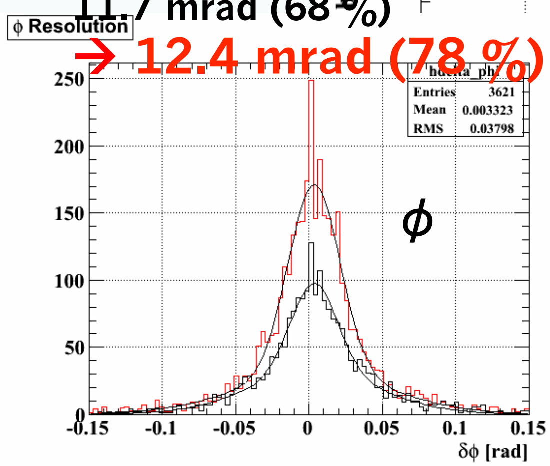




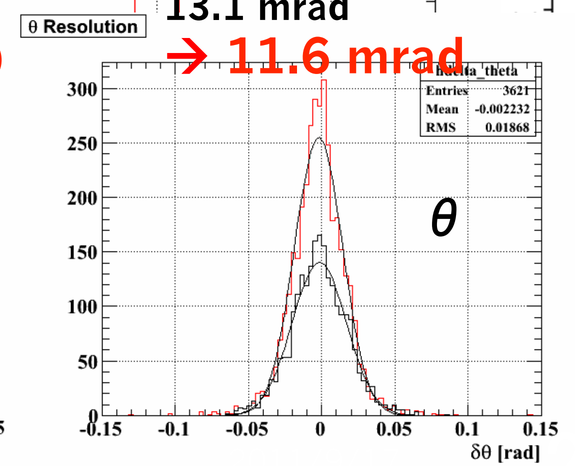
432 keV (80 %)
→ 380 keV (79 %)



11.7 mrad (68 %)
→ 12.4 mrad (78 %)

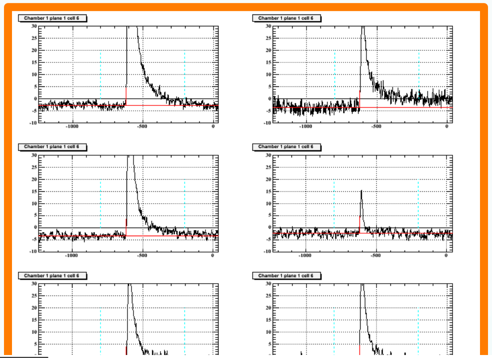


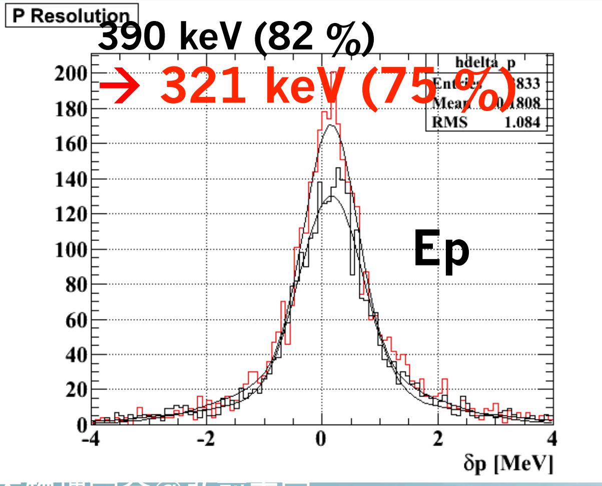
13.1 mrad
→ 11.6 mrad

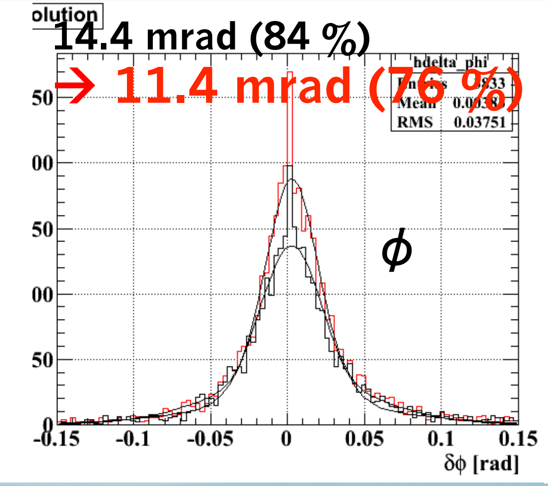


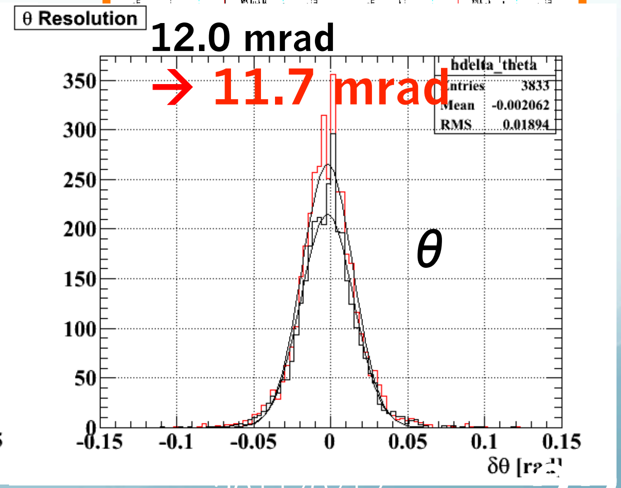
Noise reduction

- Filtering for waveform in low noise condition
  - What happen if FFT filtering used in low noise condition ?
  - Single hit Z resolution
    - Only a few % better (710 → 697 um)
    - #of hits increased
  - **Efficiency and resolutions improved, too**









Performance summary

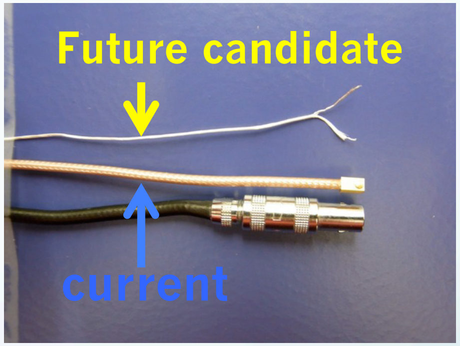
- 2011 performance summary (Preliminary)
  - Only parts of data were analyzed
  - Correction for resolutions in 2011 not yet done
  - **Calibrations still ongoing**

Preliminary !

	2010	2011 noisy	2011 low noise
Intrinsic Z (um)	668 (core 56 %)	664 (core 57 %)	697 (core 56 %)
Intrinsic R (um)	209 (core 66 %)	237 (core 65 %)	201 (core 68 %)
E_e (keV)	330 (core 79 %)	380 (core 79 %)	321 (core 75 %)
ϕ (mrad)	7.2 (core, ϕ=0)	12.4 (core 78 %)	11.4 (core 76 %)
θ (mrad)	11.0	11.6	11.7
#of 2 turn e+	-	2499 → **4019**	3184 → **3833**

Summary and prospects

- Summary
  - **Thanks to FFT noise filtering, data quality of noisy runs achieved to the level of low noise situation !**
    - Further check needed
      - Transformation accuracy
      - Check with more data
      - Single hit R resolution
- Prospects
  - **Calibrations for the spectrometer in preparation now**
    - Better resolutions and efficiency expected
  - Monochromatic calibration source for the spectrometer
    - Mott scattering with e+ beam (energy tunable)
  - Hardware improvement for ε_e (≒ reduce materials between DC and TC)
    - **Readout cable exchange to thinner one (40 % → 50 + x %)**
    - According to changing cables, the support structure system for drift chambers will be updated



backup

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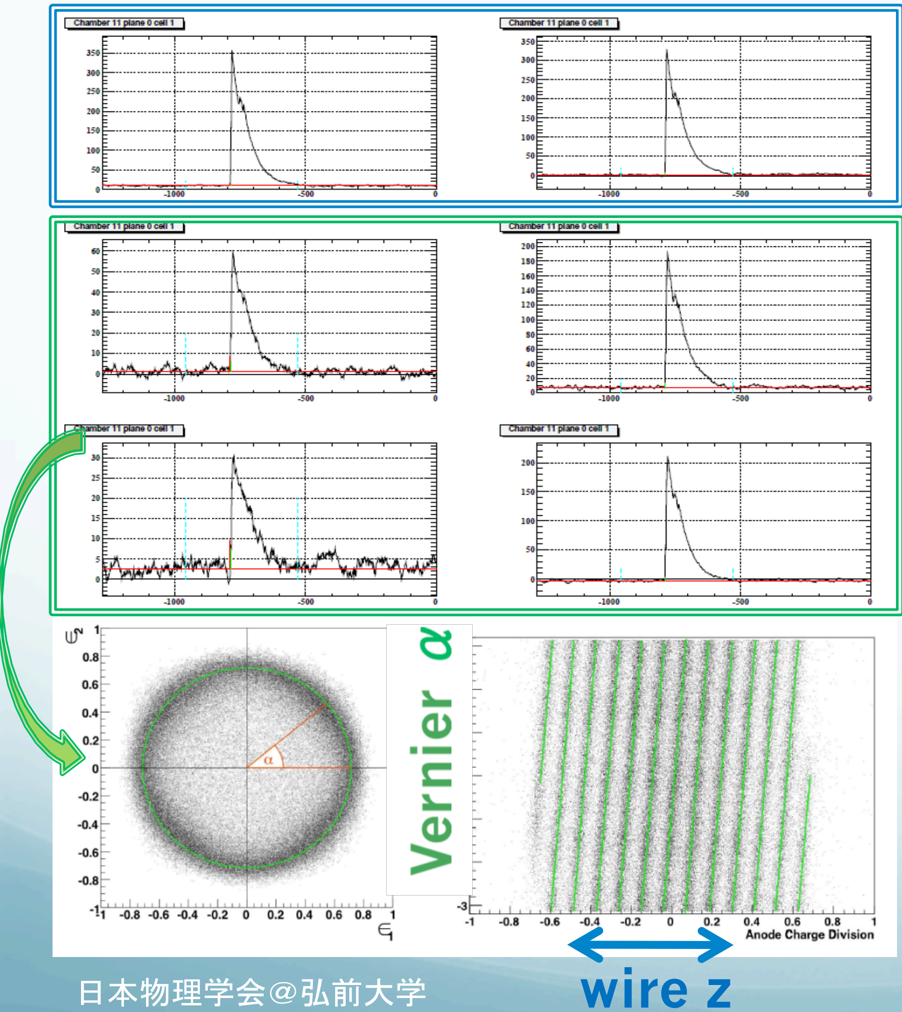
Vernier method



Vernier α is defined as

$$\alpha = \tan^{-1}(\epsilon_1/\epsilon_2)$$

where

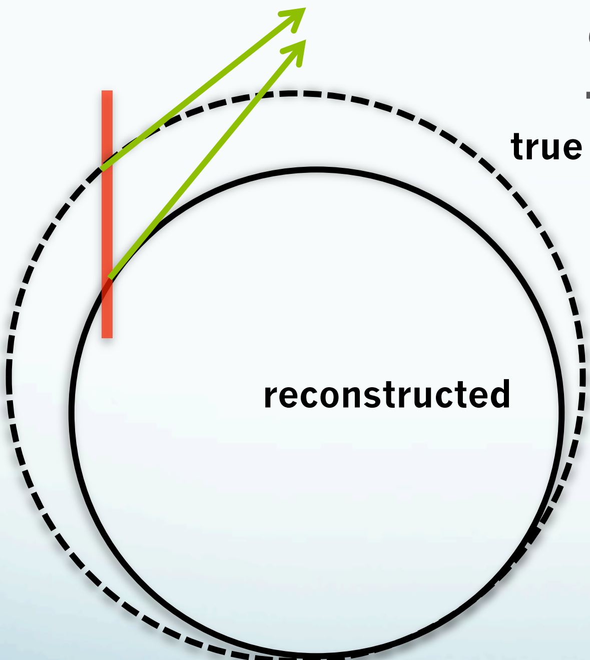
$$\epsilon_a = \frac{Q_U - Q_D}{Q_U + Q_D}.$$

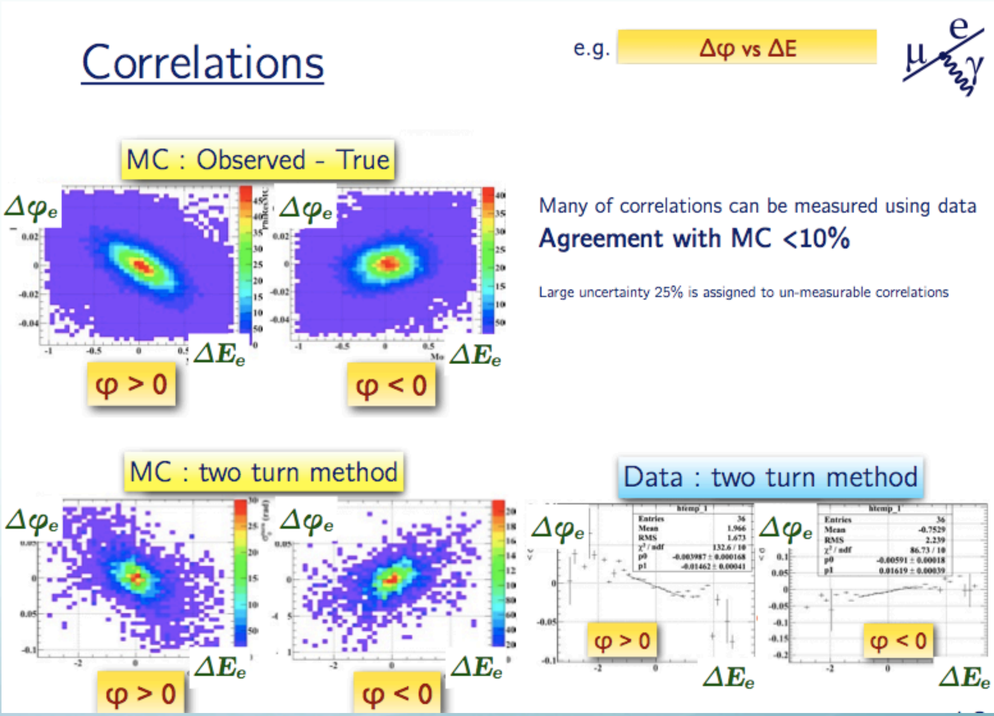
- Compare α to reconstructed z position, we can decide z more precisely

Positron correlations

- Correlations

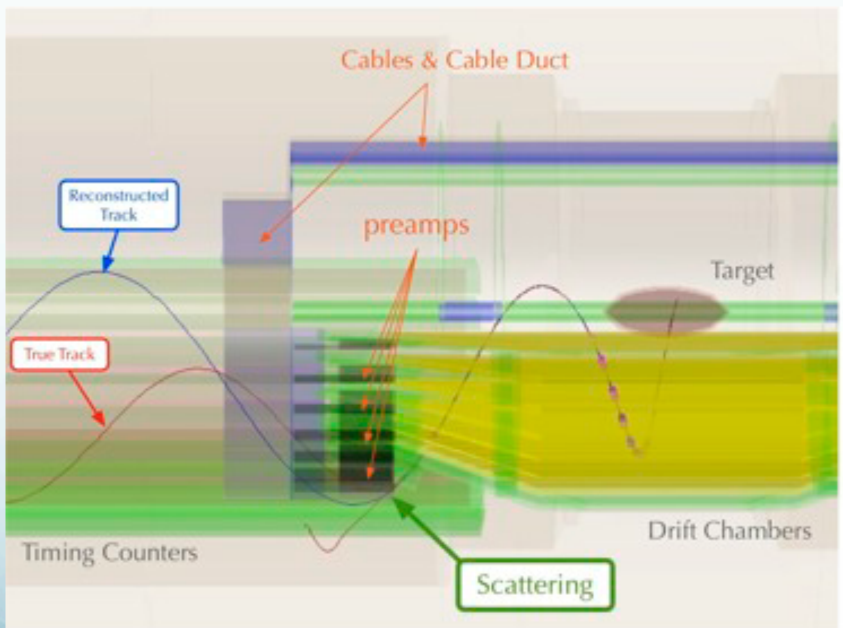
Case : $E^{meas} < E^{true}$
$Y^{meas} < Y^{true}$
$\phi^{meas} > \phi^{true}$
…

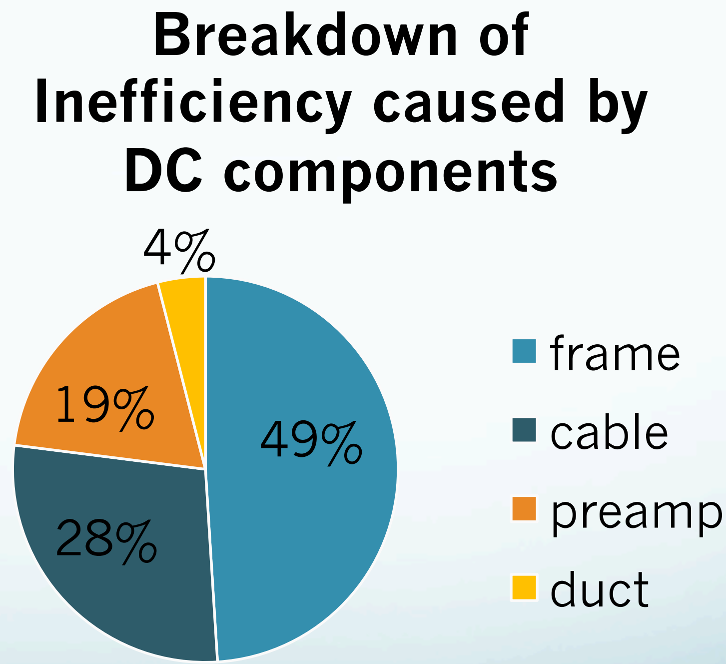




Efficiency

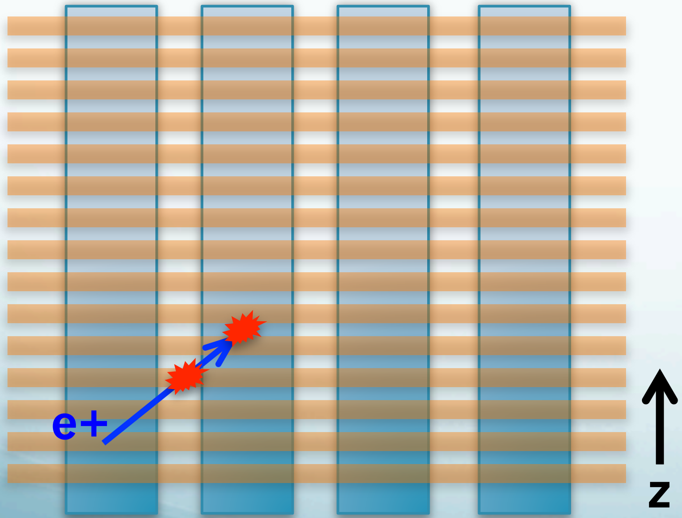
- Material between drift chambers and timing counters make lower efficiency because of multiple scattering

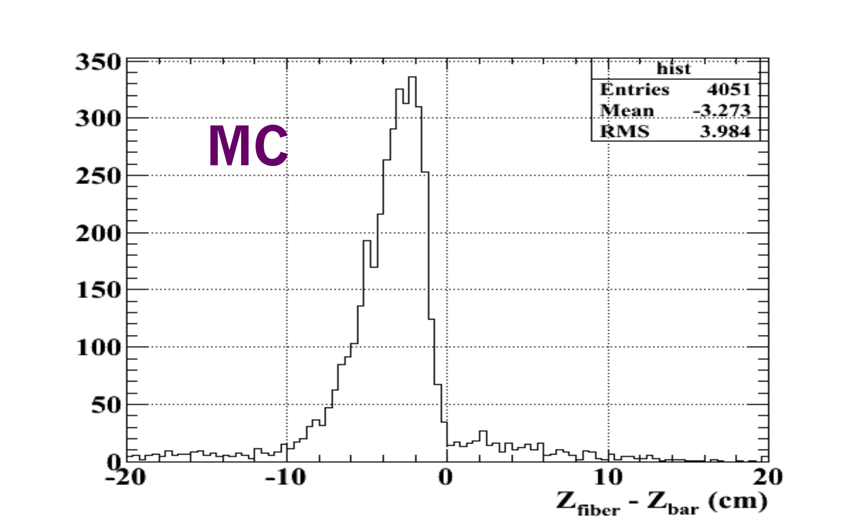




Check for APD data

- Quality check for APD outputs
- **First step**
  - Matching between hit z at fiber and e+ track at timing counter bars
  - Only downstream of APDs are working now





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Check for APD data

- Quality check for APD outputs
- **First step**
  - Matching between hit z at fiber and e+ track at timing counter bars → peak position is same, but large tail found
  - Only downstream of APDs are working now