CLAS12 First Experiment workshop
June 13 2017

The CLAS12 Forward Tagger

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… et (many) al.

Quark and gluon confinement: hybrids and exotics

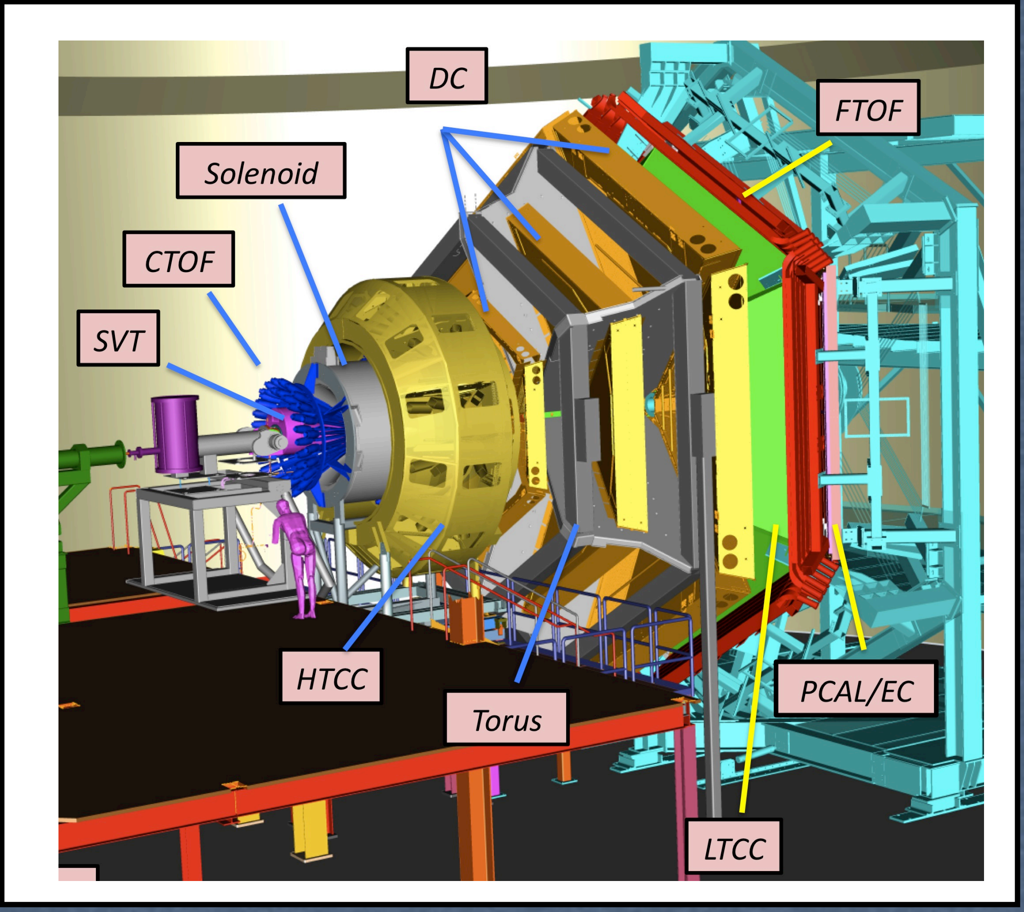
We propose to study the light meson spectrum in a photoproduction experiment using CLAS12

★ Meson provide an easier access to inter-quark potential, strong interaction dynamics, and gluonic degrees of freedom

★ Photoproduction should be favorable to excite exotic quantum number and photon polarisation helps in extract the information suppressing the bg

JLab PAC41 granted A^- to E12-11-005 MesonEx proposal

- E12-11-005A Photoproduction of the Very Strangest Baryons on a Proton Target in CLAS12
- E12-16-003A Light meson decay
- E12-16-010 A Search for Hybrid Baryons in Hall B with CLAS12



Requirements:

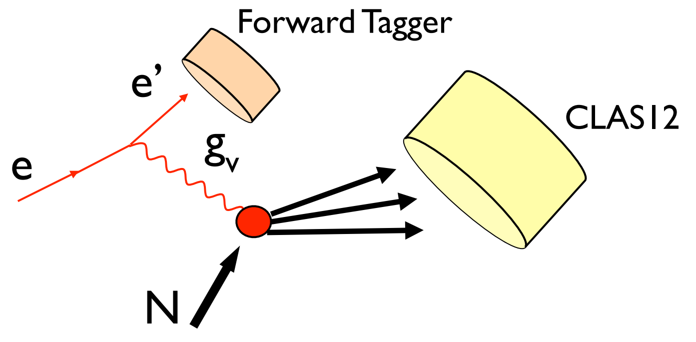
★ Large acceptance detector:

CLAS12

★ Intense, tagged, polarized photon beam in the energy range 5-10 GeV

CLAS12 Forward-Tagger

Quasi-real photoproduction with CLAS12 (Low Q^2 electron scattering)



$E_{scattered}$	0.5 - 4.5 GeV
θ	2.5^o - 4.5^o
ϕ	0^o - 360^o
ν	6.5 - 10.5 GeV
Q^2	0.01 - 0.3 GeV^2 ($< Q^2 >$ 0.1 GeV^2)
W	3.6 - 4.5 GeV

★ Electron scattering at "0" degrees (2.5^{O} - 4.5^{O})

low Q^2 virtual photon ⇔ real photon

★ Photon tagged by detecting the scattered electron at low angles

High energy photons $6.5 < E_g < 10.5$ GeV

★ Quasi-real photons are linearly polarized

Polarization ~ 70% - 10% (measured event-by-event)

★ High Luminosity (unique opportunity to run thin gas target!)

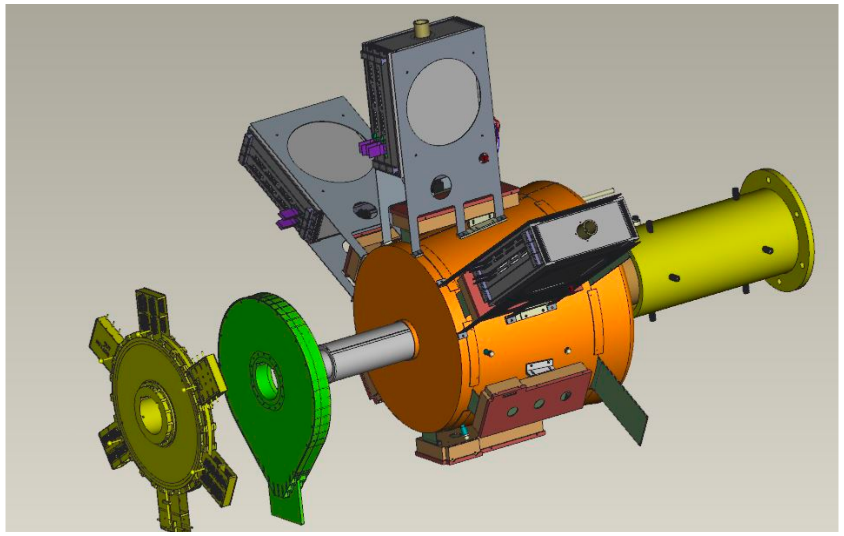
Equivalent photon flux $N_\gamma \sim 5\ 10^8$ on 5cm H_2 ($L=10^{35}$ cm^{-2}s^{-1})

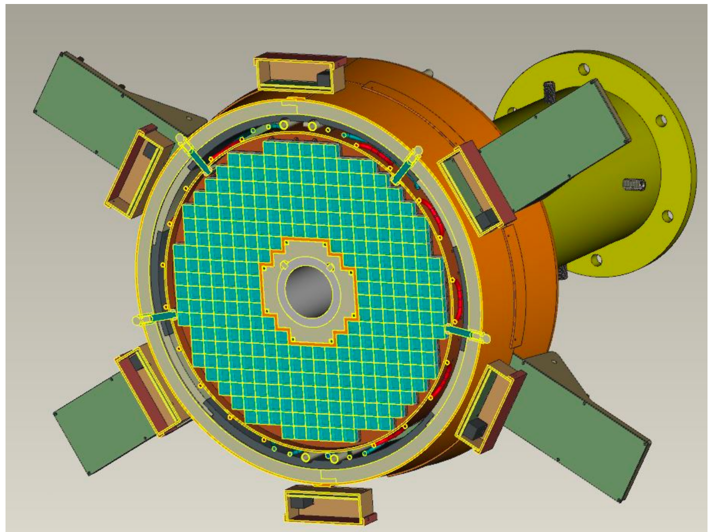
★ Multiparticle hadronic states detected in CLAS12

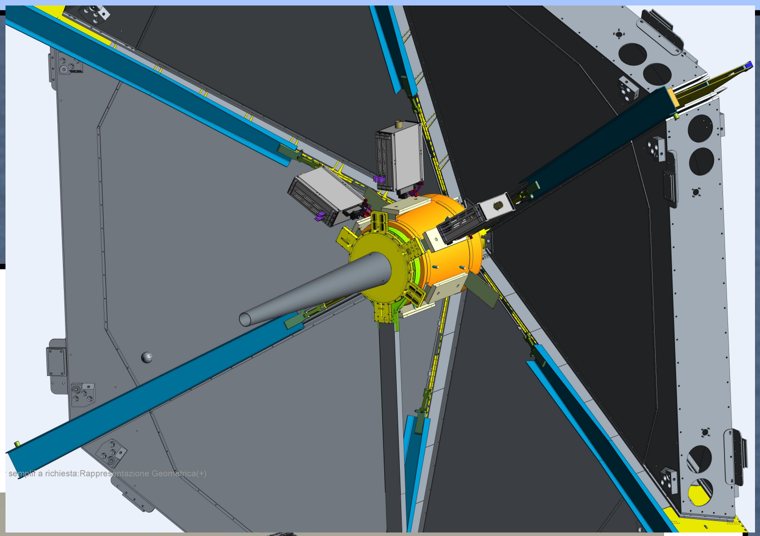
High resolution and excellent PID (kaon identification)

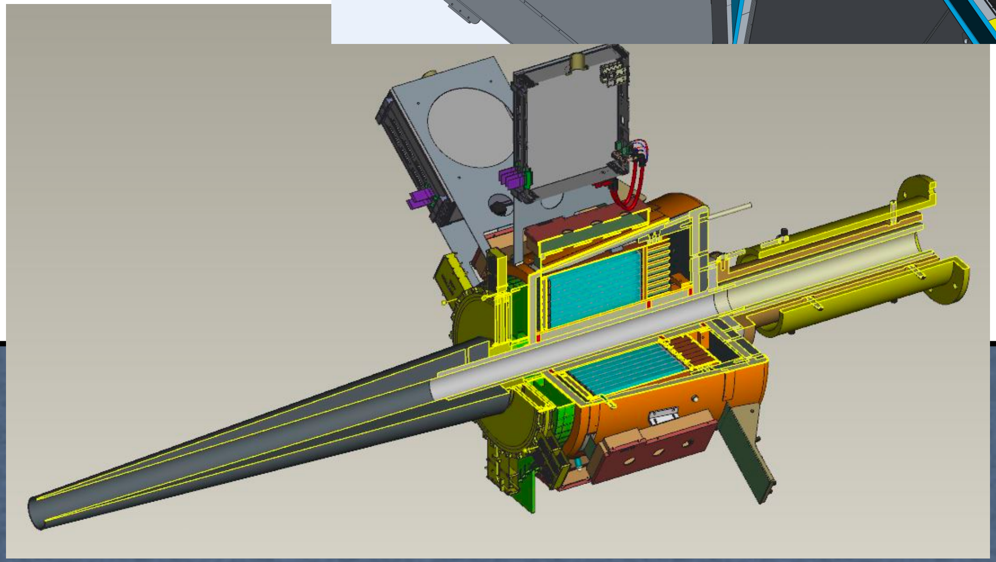
High energy low Q2 photon beam in CLAS12!

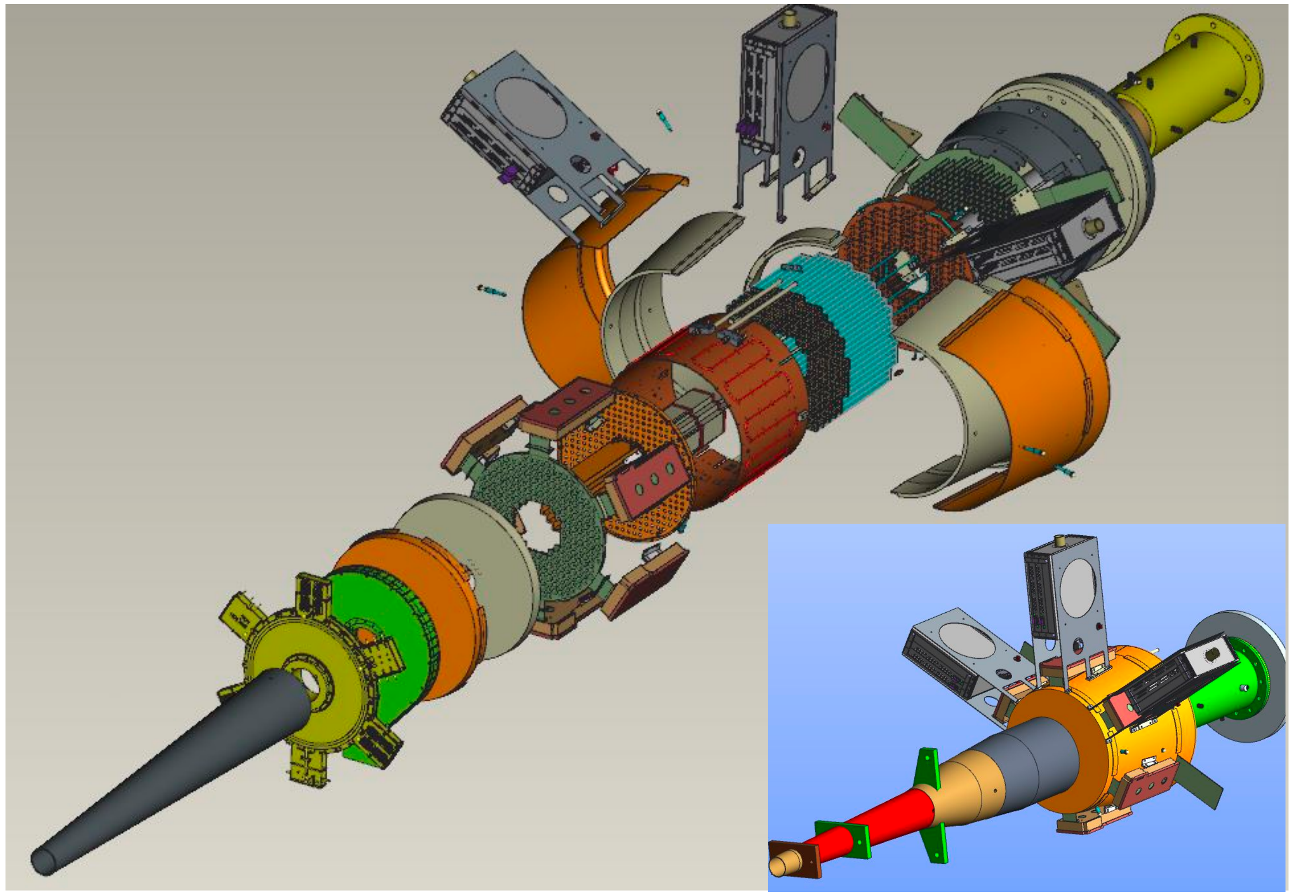
The Forward Tagger for CLAS12











FT-Cal: $PbWO_4$ calorimeter

electron energy/momentum

Photon energy (ν=E-E')

Polarization $\varepsilon^{-1} \approx 1 + \nu^2/2EE'$

INFN-GE, INFN-RM2, INFN-TO

FT-Hodo: Scintillator tiles

veto for photons

EdinburghU+JMU+NSU

FT-Trck: MicroMegas detectors

electron angles and polarization plane

Saclay + OhioU

FT-Cal

Calorimeter + hodoscope + tracker

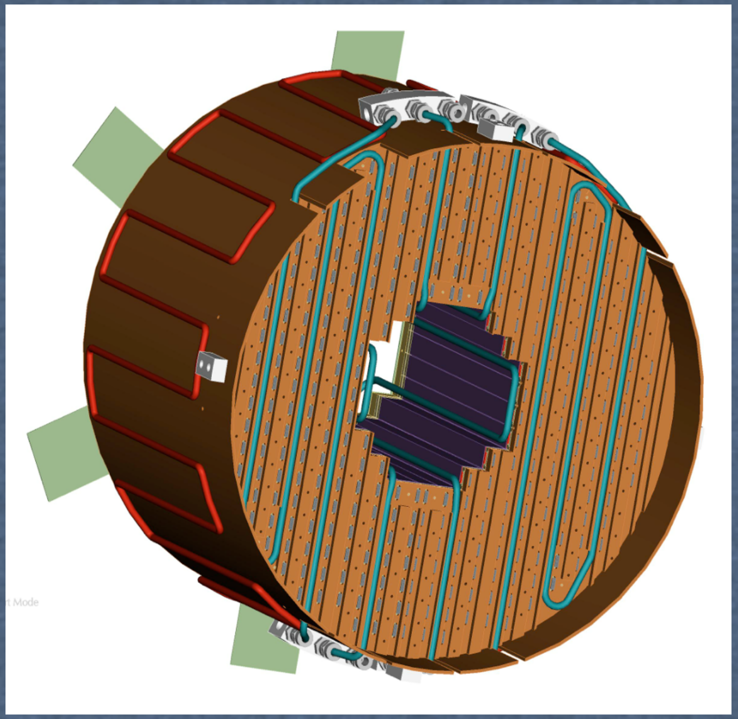
Electron energy/momentum

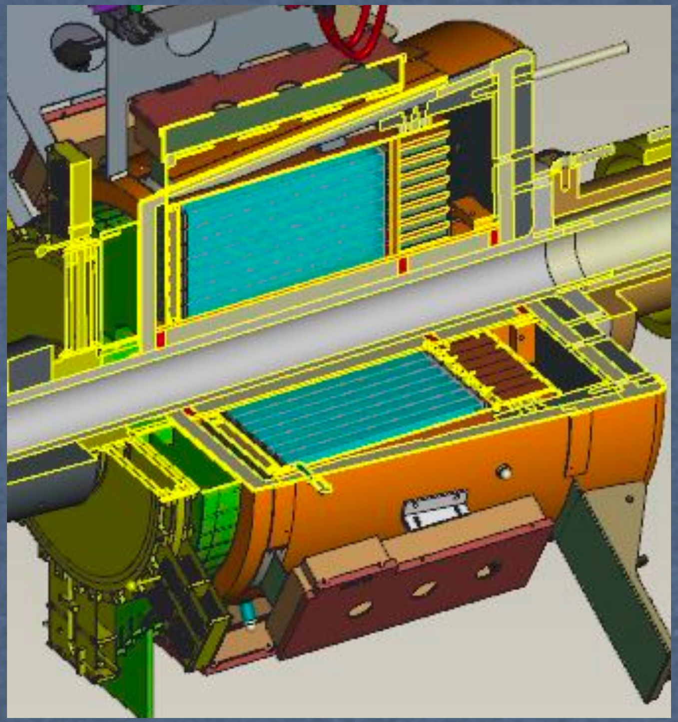
$\delta\nu / \nu = \delta E'/(E-E')$

Photon energy (ν=E-E')

Polarization $\varepsilon^{-1} \sim 1 + \nu^2/2EE'$

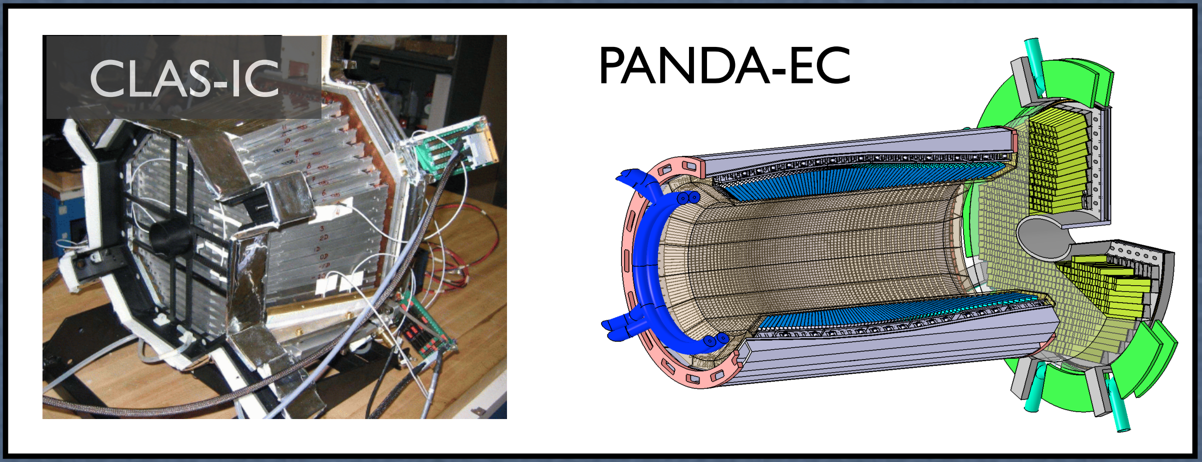
Homogeneous, fast, dense, inorganic-crystals: PbWO4 Type-II

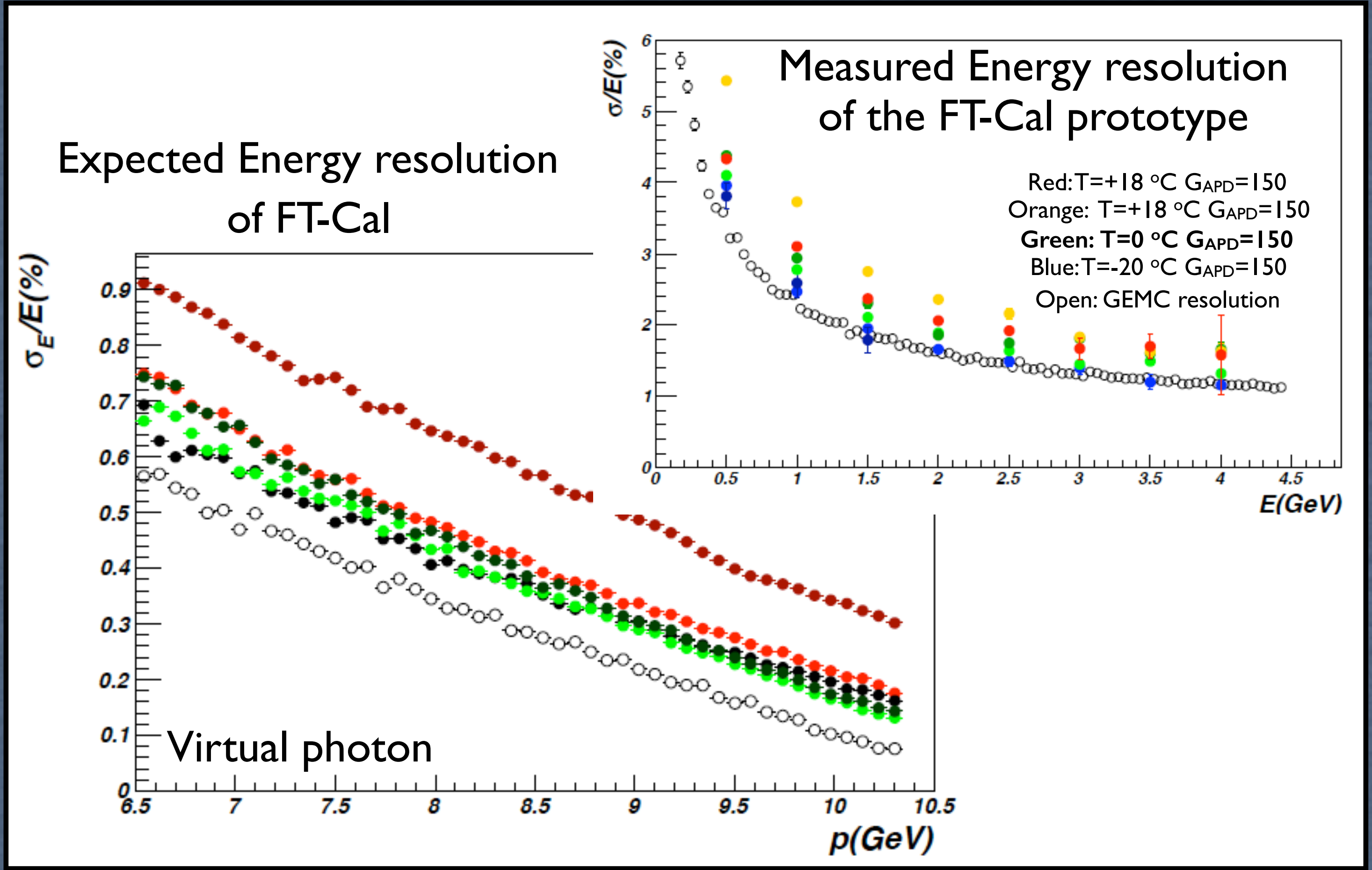




Requirements

- ✳ Radiation hard
- ✳ Good light yield
- ✳ Energy resolution
- ✳ Time resolution
- ✳ Light read-out (APD/SiPM)





FT-Cal Specs

- ✳ Crystals: 332 15x15x200 mm3 BTCP/SICCAS PbWO4 Type II
- ✳ Light sensors: Hamamatsu LAAPD s8664-1010
- ✳ FE electronics: FT-Orsay preamps
- ✳ Working temperature: 0 °C, +18 °C
- ✳ Energy range: 5 MeV (Threshold on single crystal) to 8 GeV
- ✳ Energy resolution: $2.3\%/\sqrt{E(GeV)} \oplus 0.5\%$

FT-Hodo

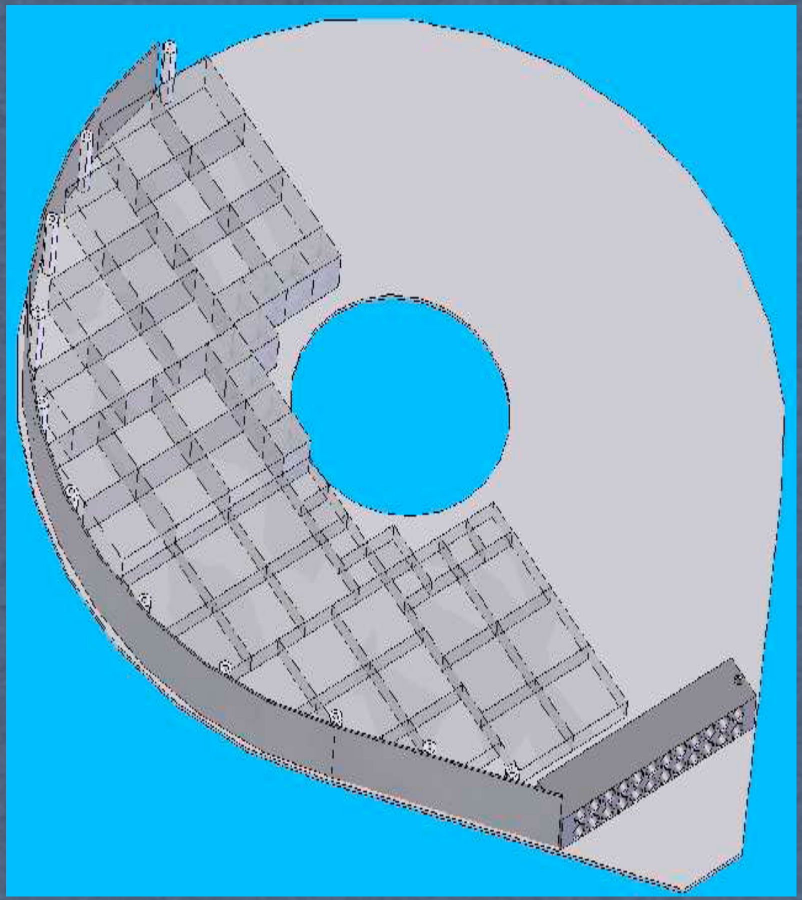
Calorimeter + **hodoscope** + tracker

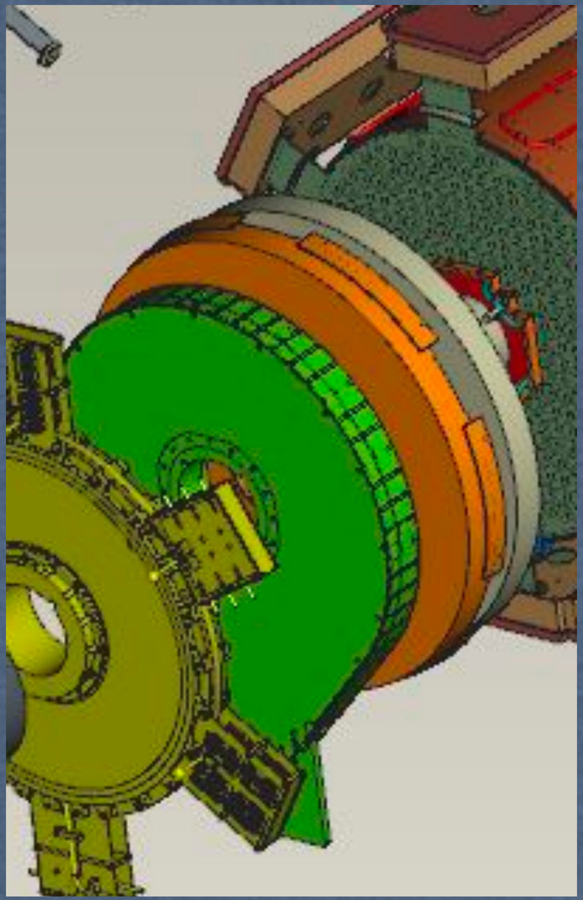
veto for photons

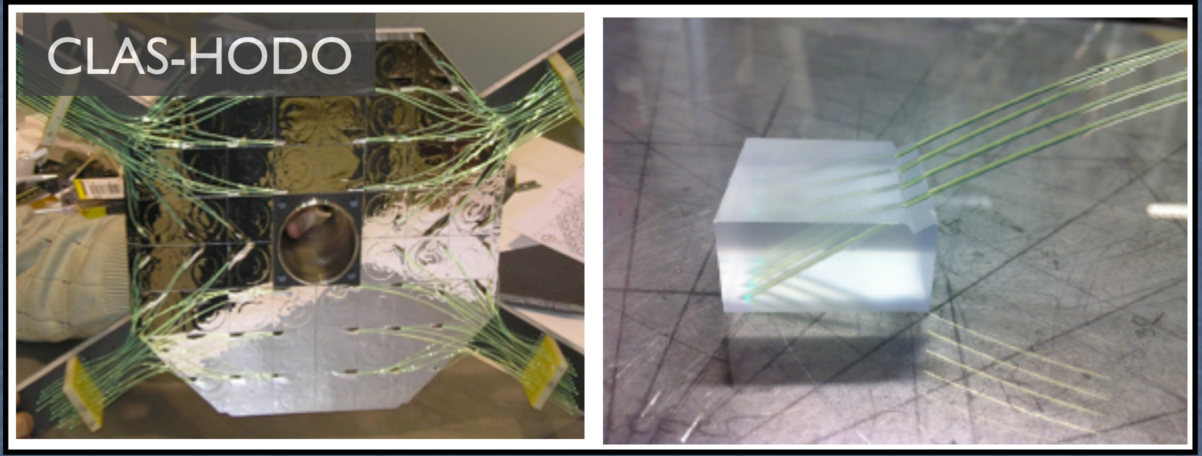
Plastic scintillators tiles with WLS fibres coupled to SiPM

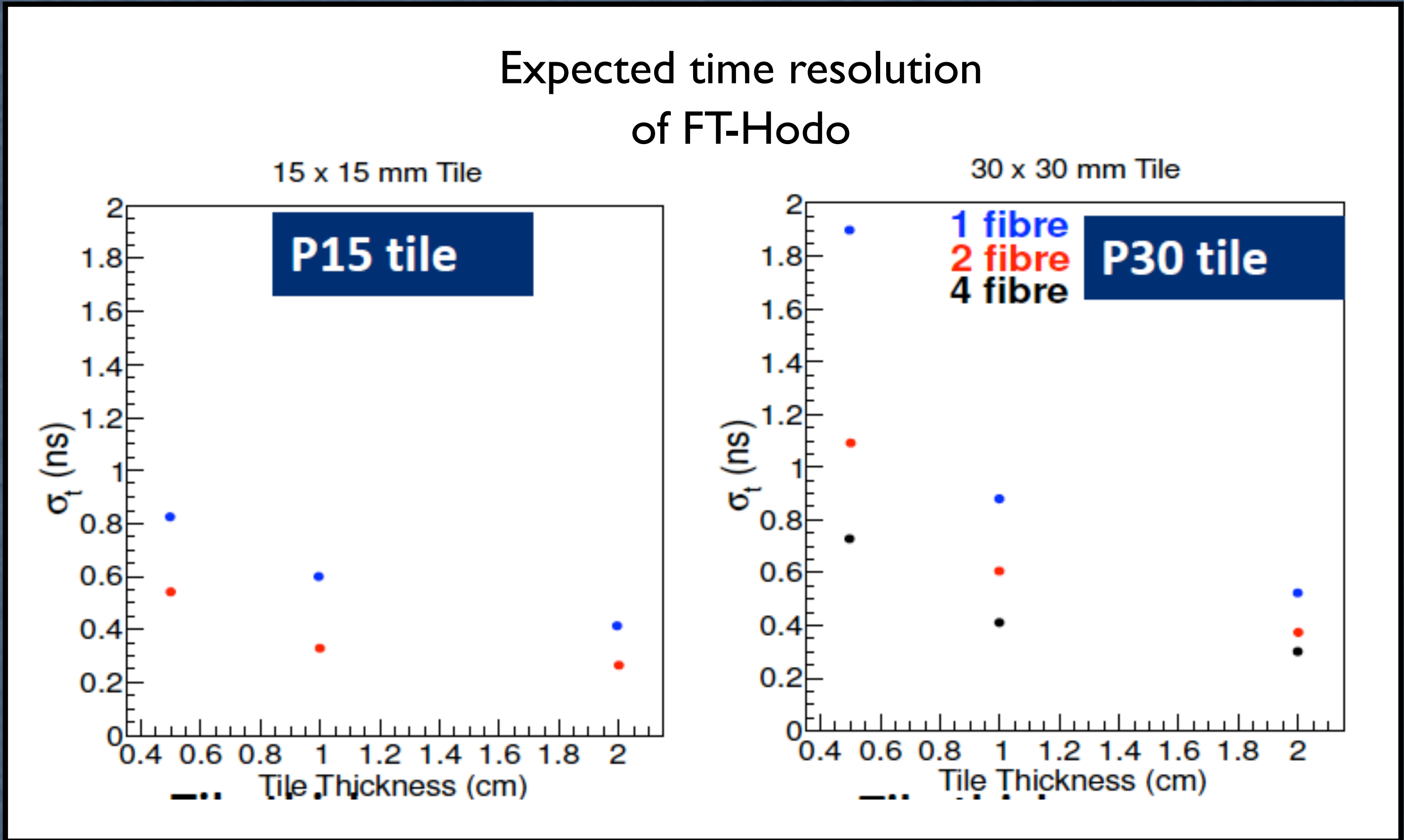
Requirements

- ✳ Good timing (<ns) for MIPs
- ✳ High segmentation
- ✳ 100% efficient for charged particles









FT-Hodo Specs

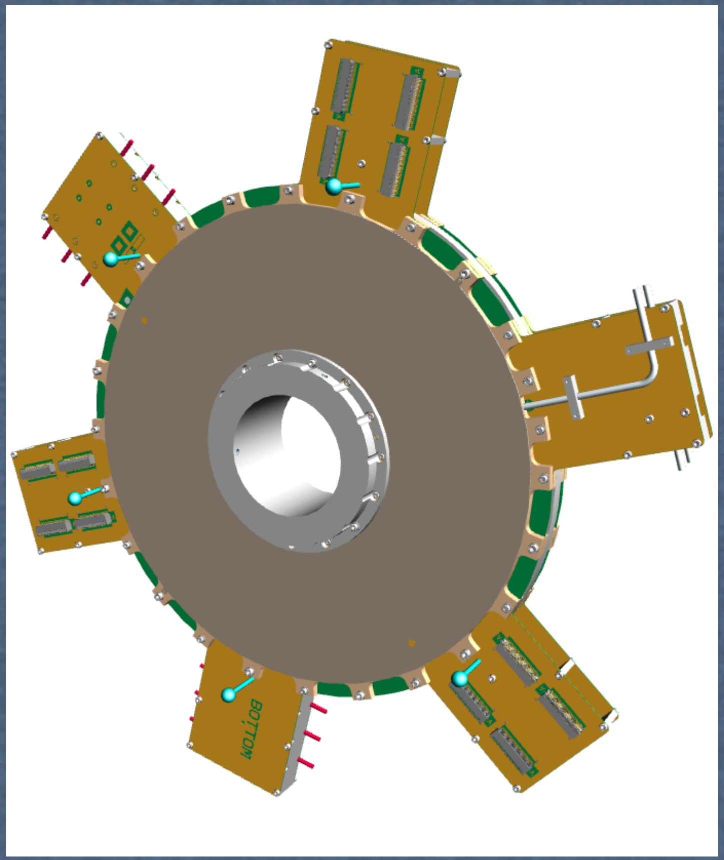
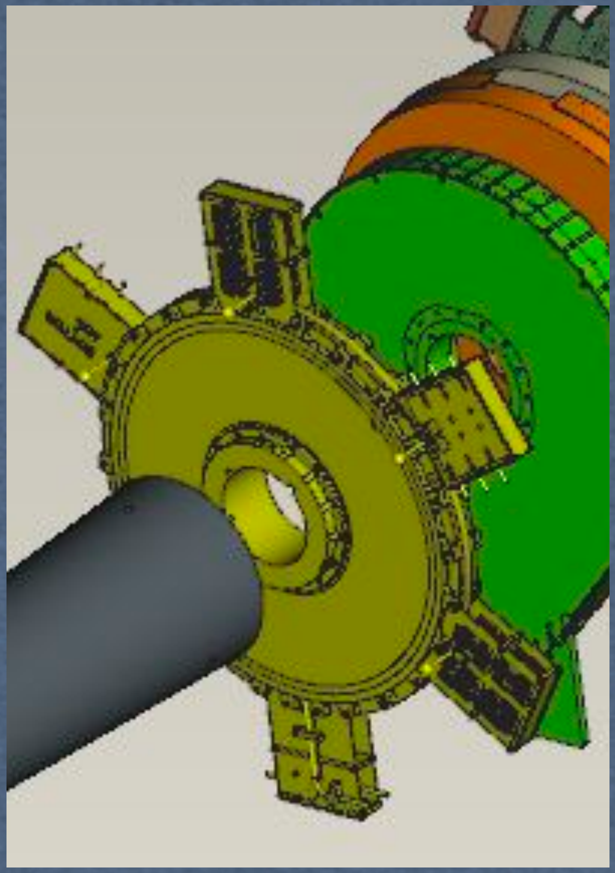
- ✳ Segmented array, 2 layers of tiles to minimize photons misid
- ✳ Tiles: 74 30x30x15 mm2 + 42 15x15x7 mm3 EJen 204 per layer
- ✳ WLS: (4x74 + 2x42)x2 = 380 d=1mm Kuraray K11
- ✳ Light sensors: Hamatsu S10362-33-100 3x3mm2, 100um SiPM
- ✳ FE electronics: 232 channels FTh-Orsay preamps
- ✳ Time resolution: <1ns

FT-Trck

Calorimeter + hodoscope + **tracker**

$Q^2 = 4\,E\,E' \sin^2 \vartheta/2$

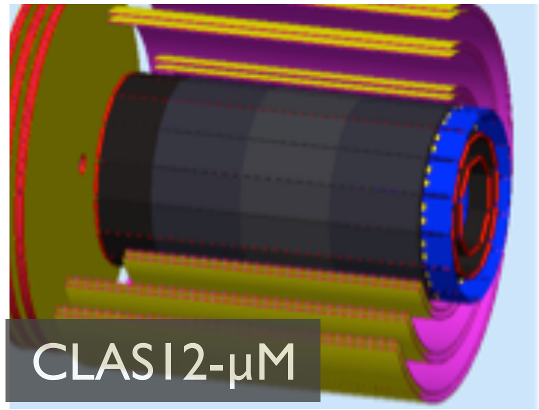
Scattering plane

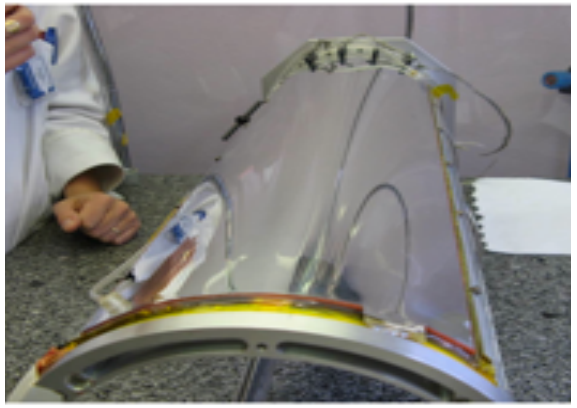



Requirements

- ✳ High pixel density (FW)
- ✳ 100-300 µm resolution
- ✳ Integrated in the CLAS12 base equipment

Sustain high rate, moderate resolution, low material budget: Micromegas



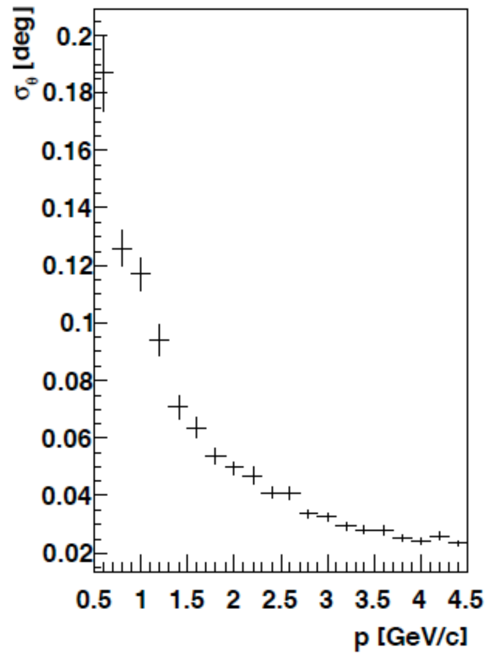


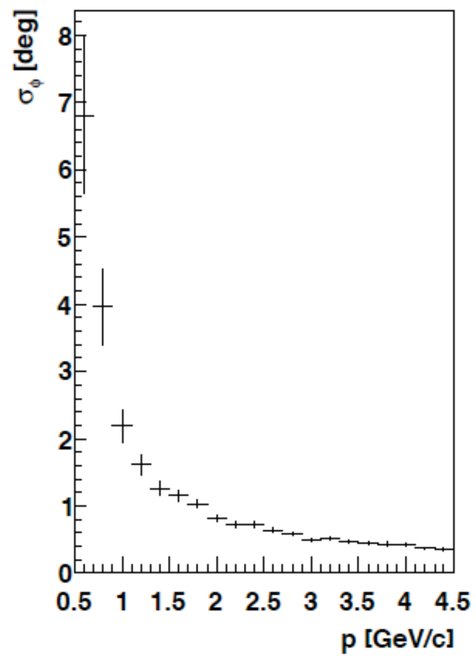
FT-Trck Specs

- ✳ Two double layers of bi-face bulk Micromegas
- ✳ Pitch: 500 µm
- ✳ FE electronics: 3392 channels, same FE used for MCT
- ✳ Services and slow controls shared with MCT
- ✳ Spatial resolution: < 150 µm

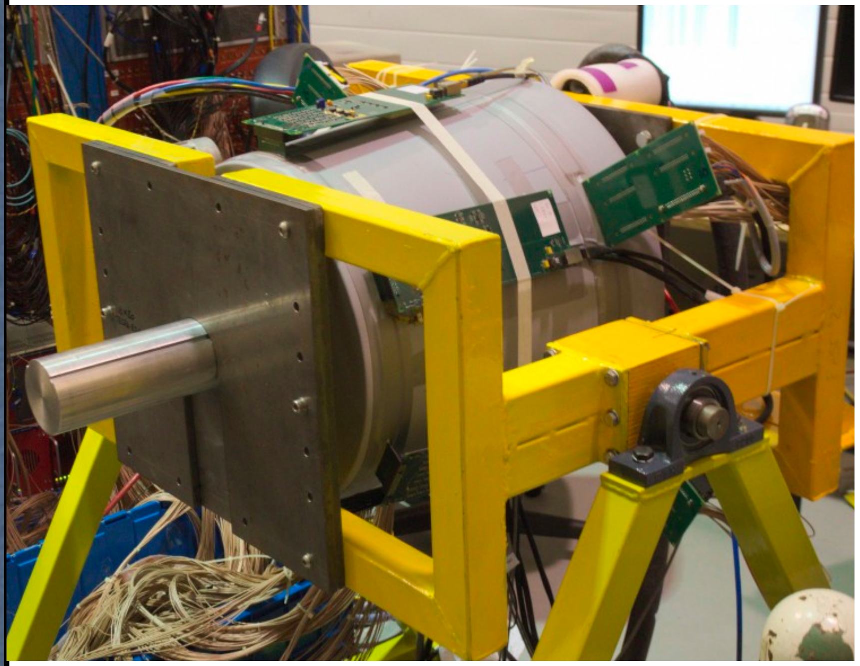
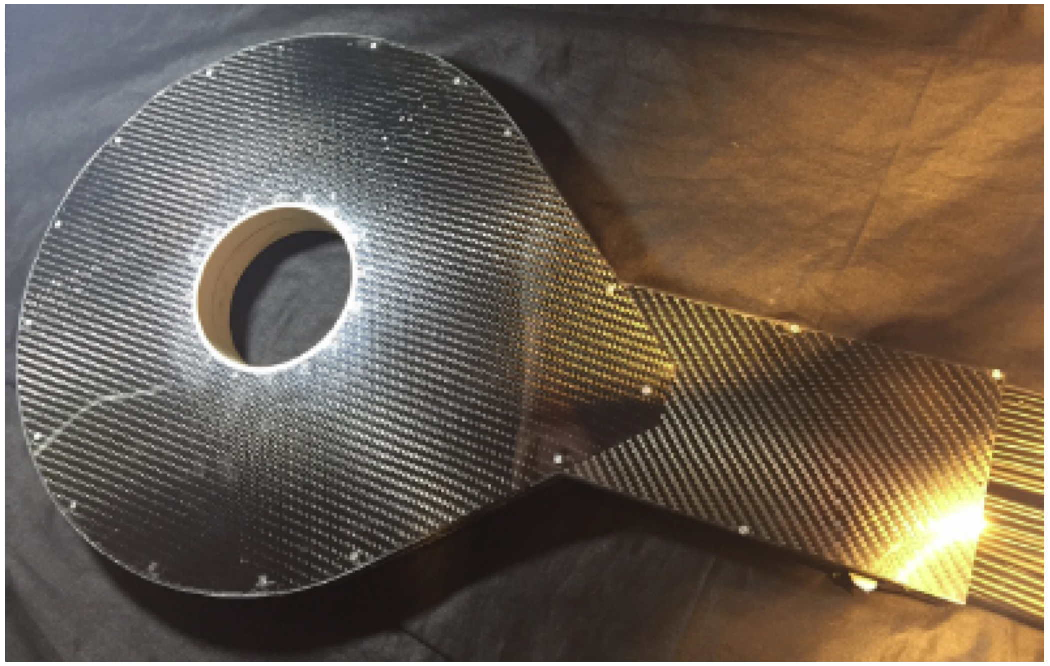
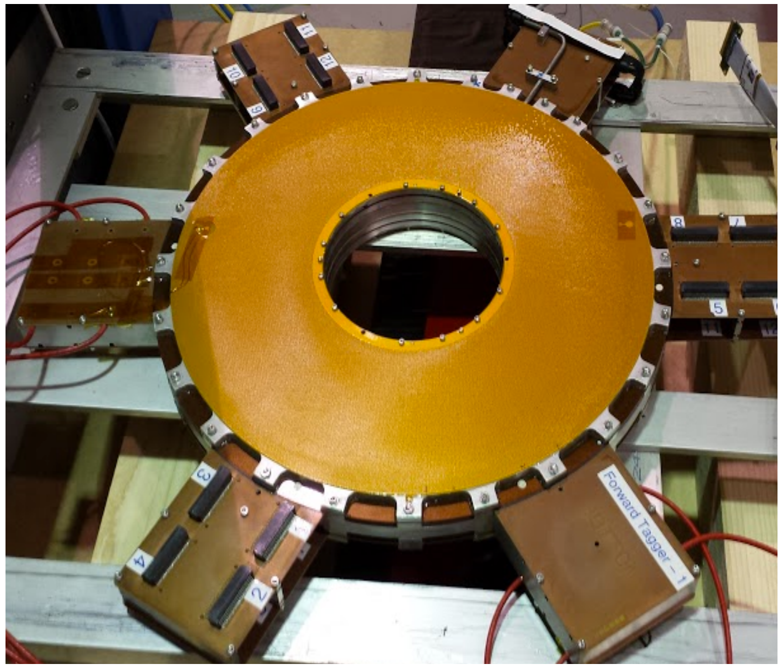
Expected angular resolution of FT-Trck

Exploiting the solenoid kick a single tracker close to the FT suffices



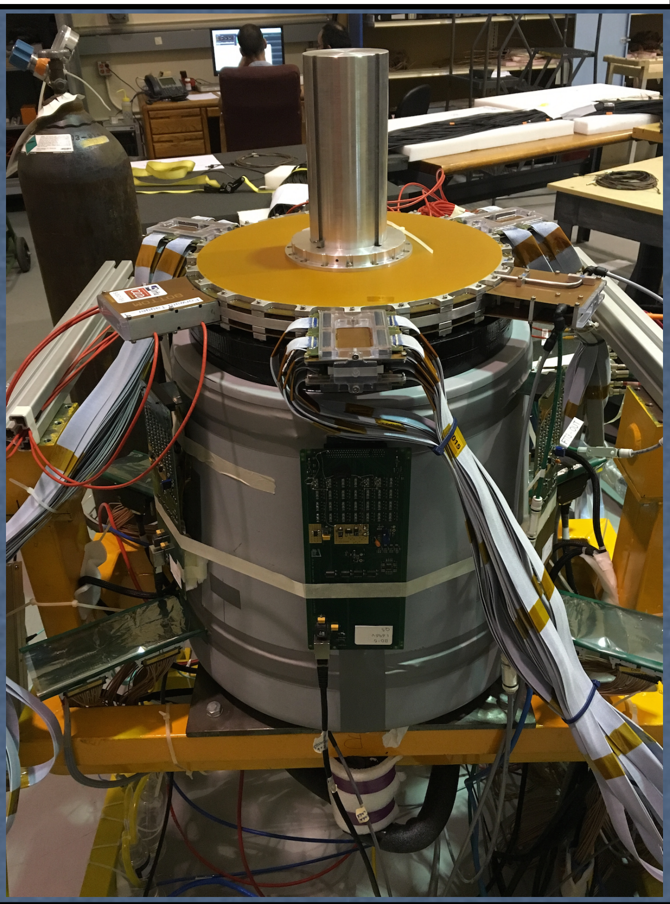


FT current status

FT-Cal	FT-Hodo	FT-Trck
		

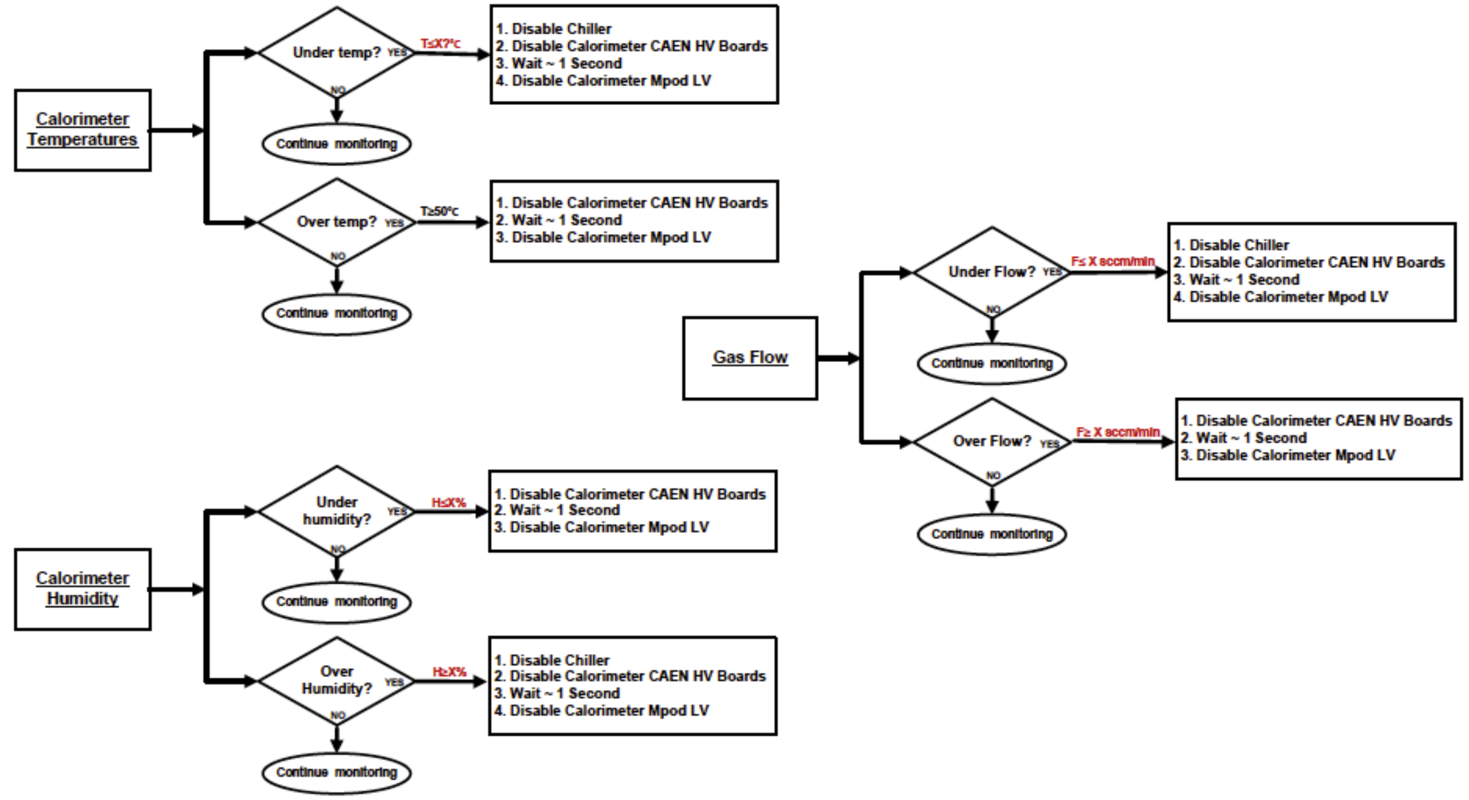
- FT-Cal, FT-Hodo and FT-Trck assembled at JLab, cabled and connected to DAQ, taking cosmic data

JLab
EEL building



- Inner W pipe used to hold the Moeller cone during KPP
- FT reassembled and sealed

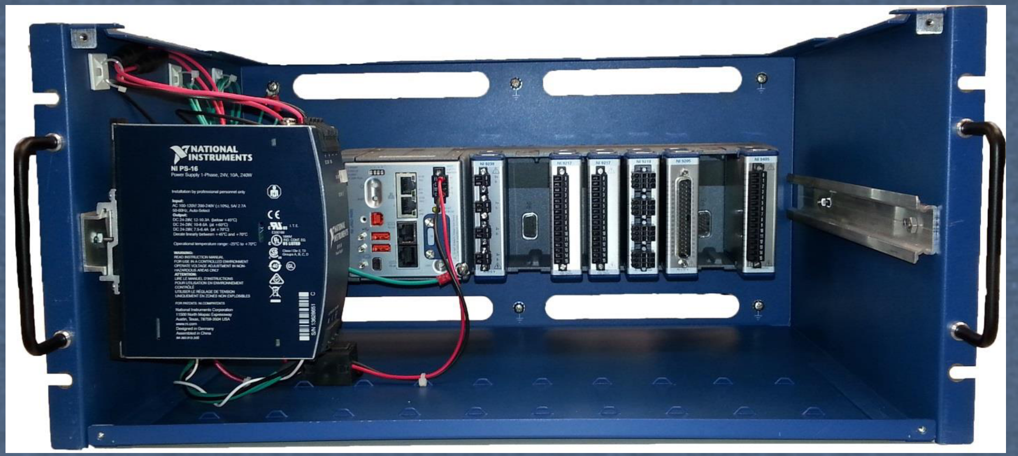
FT interlocks

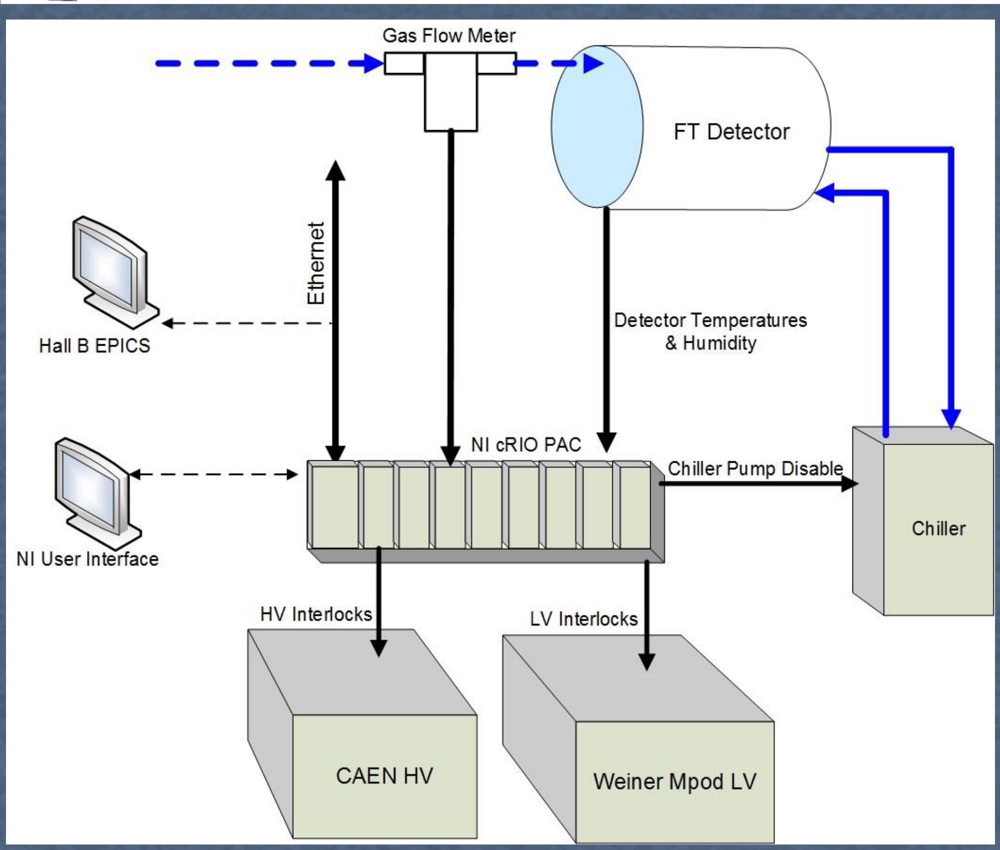


FT Calorimeter Hardware Interlock System Fault Chart

Revision Date 2/08/2017

Hardware interlocks for all three FT detectors designed and implemented to ensure safe operation during data taking



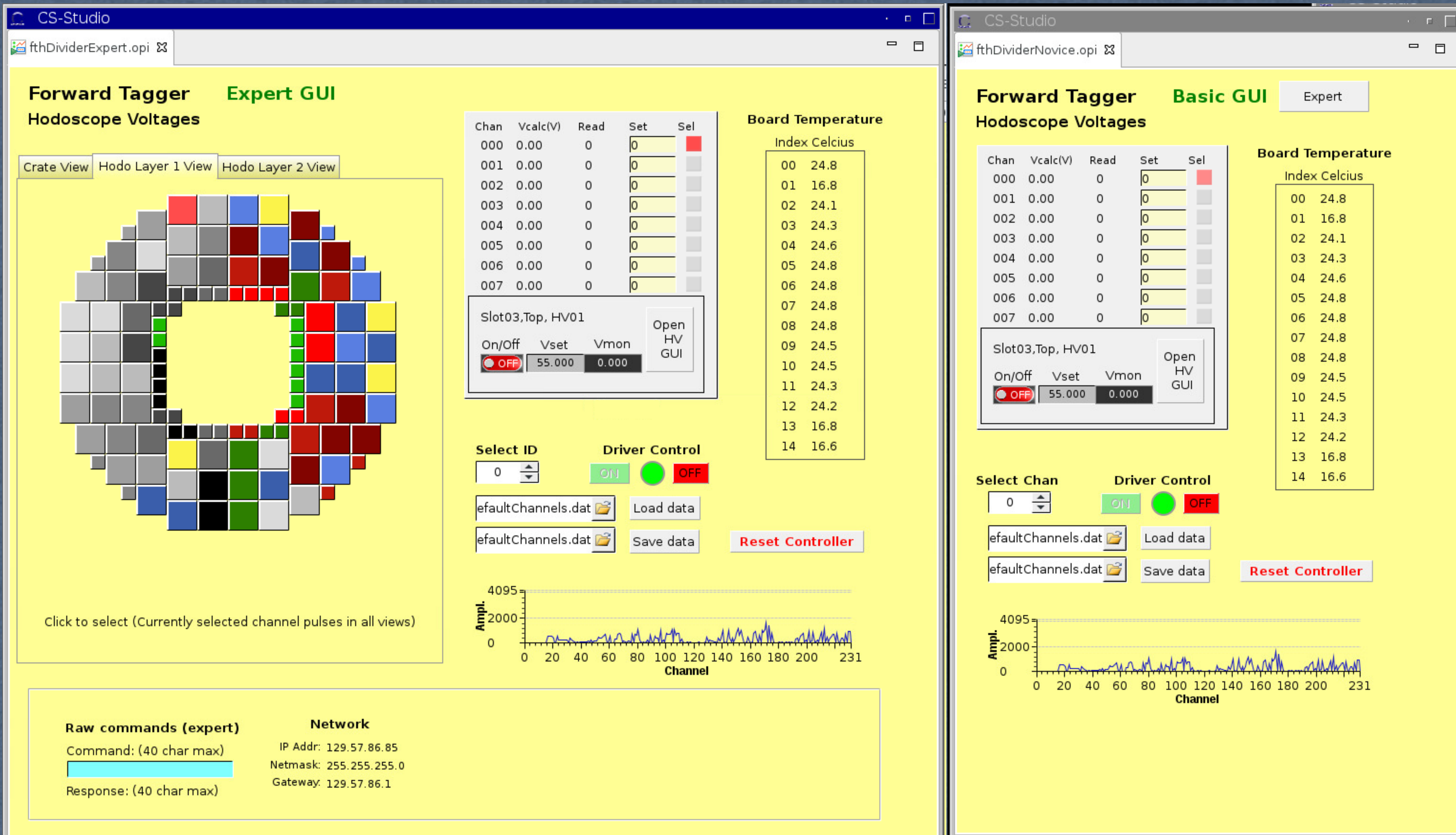


- NI-cRIO for FT-Cal and FT-Hodo:
  - Monitoring of temperature, humidity, nitrogen flow and chiller parameters
  - HV and LV enable/disable functions
  - Chiller enable/disable functions
  - Full shutdown if unsafe conditions detected
- Siemens PLCs for FT-Trk
  - Monitoring of gas pressure and flows in inlet and outlet
  - Stop gas flow if overpressure or leak detected

Status:

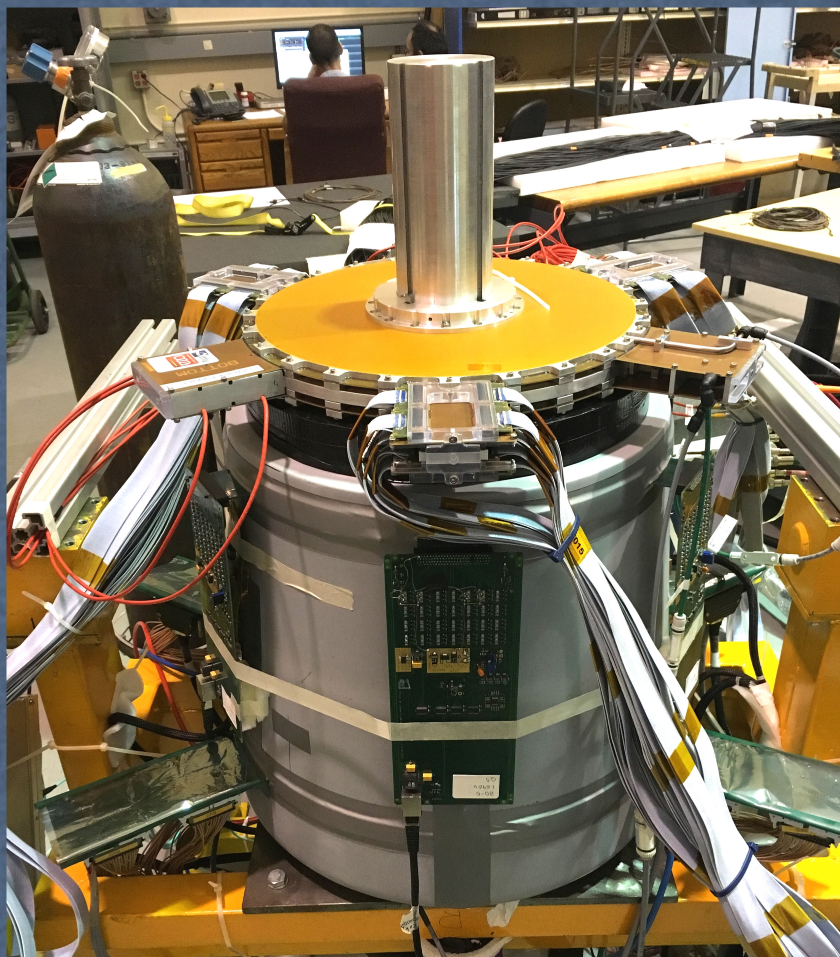
- All hardware purchased and available
- Interlocks systems assembled and tested
- Controls integration in EPICS (slow control system) completed for cRIO interlocks

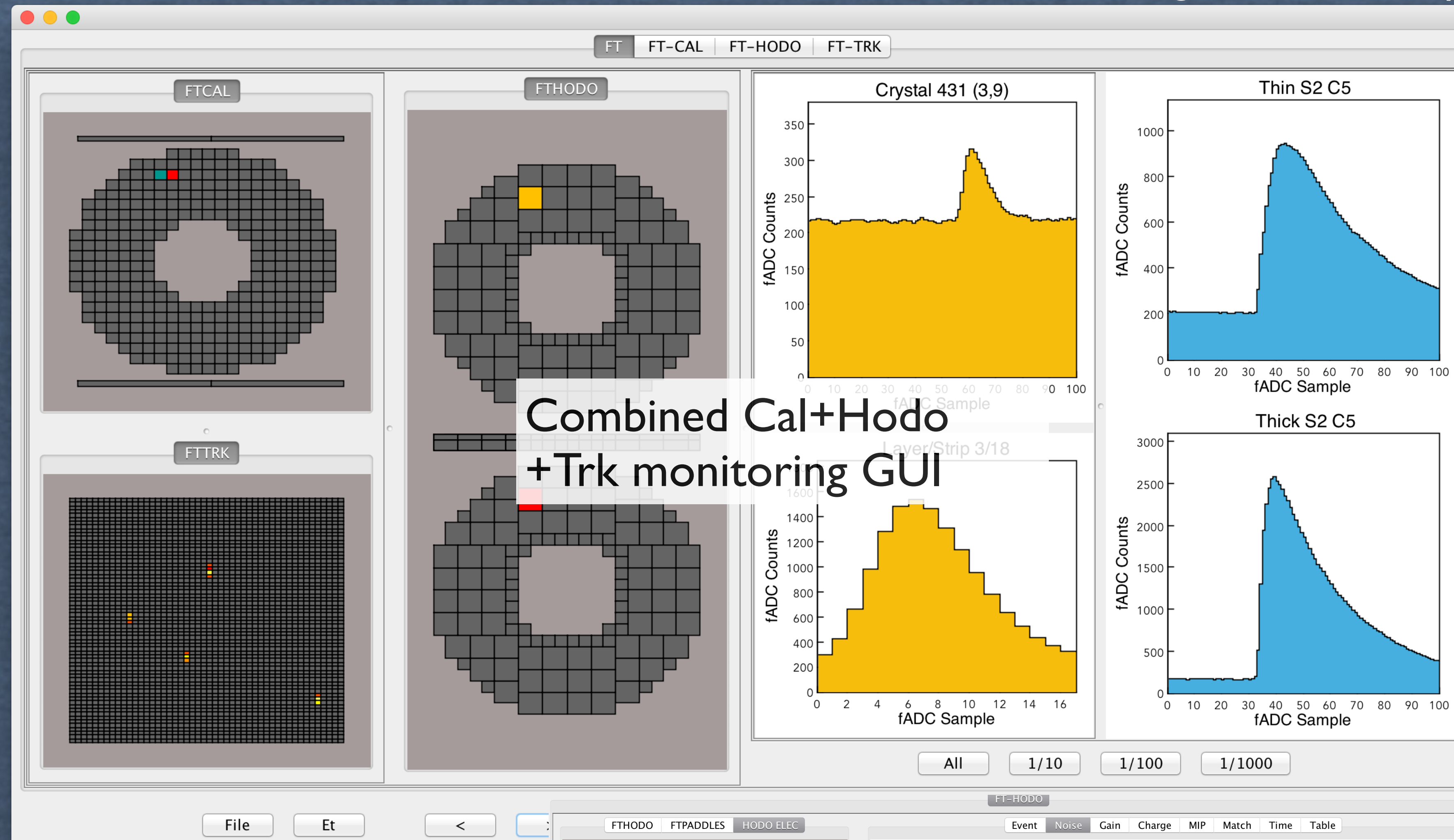
FT-Hodo slowcontrol



FT Monitoring

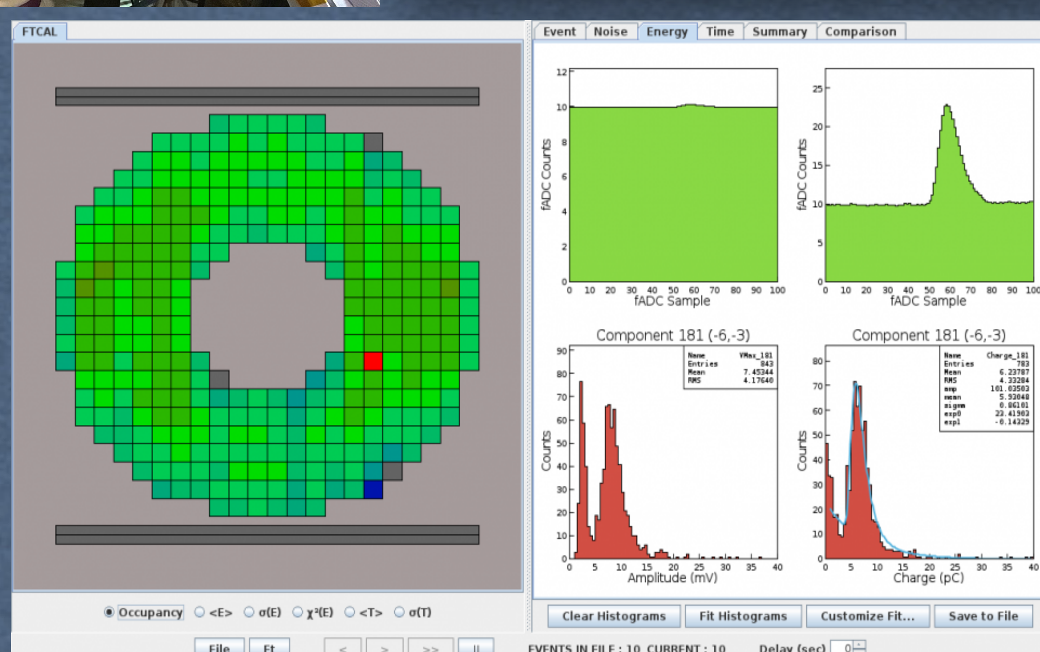
INFN – Genova, Edinburgh U., CEA-Saclay

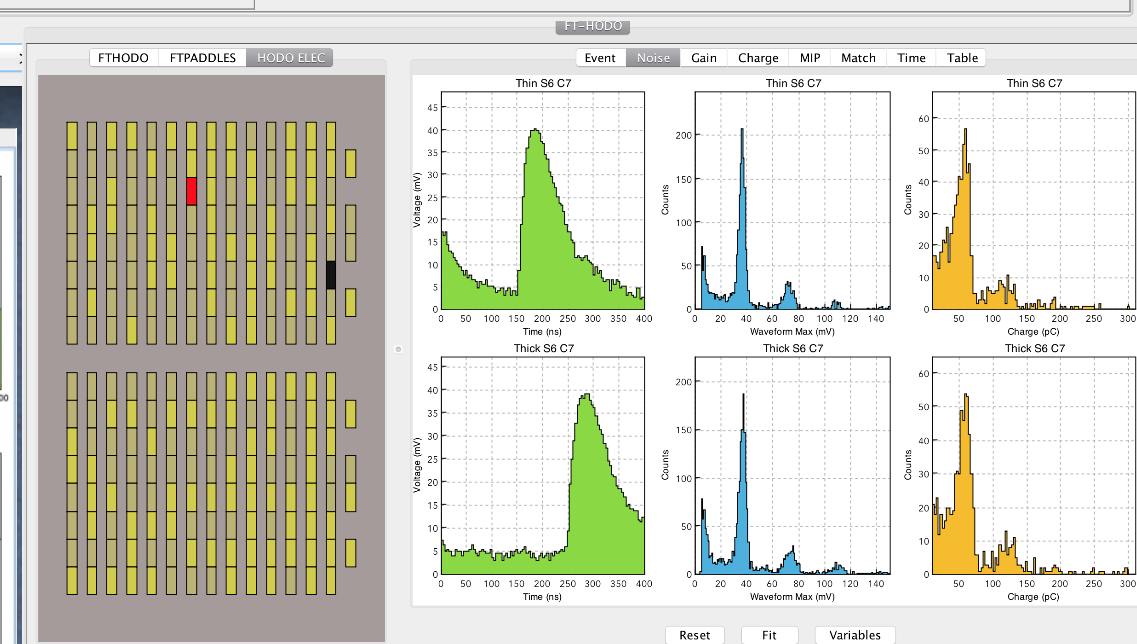




Combined Cal+Hodo +Trk monitoring GUI

System checkout and commissioning with cosmic rays

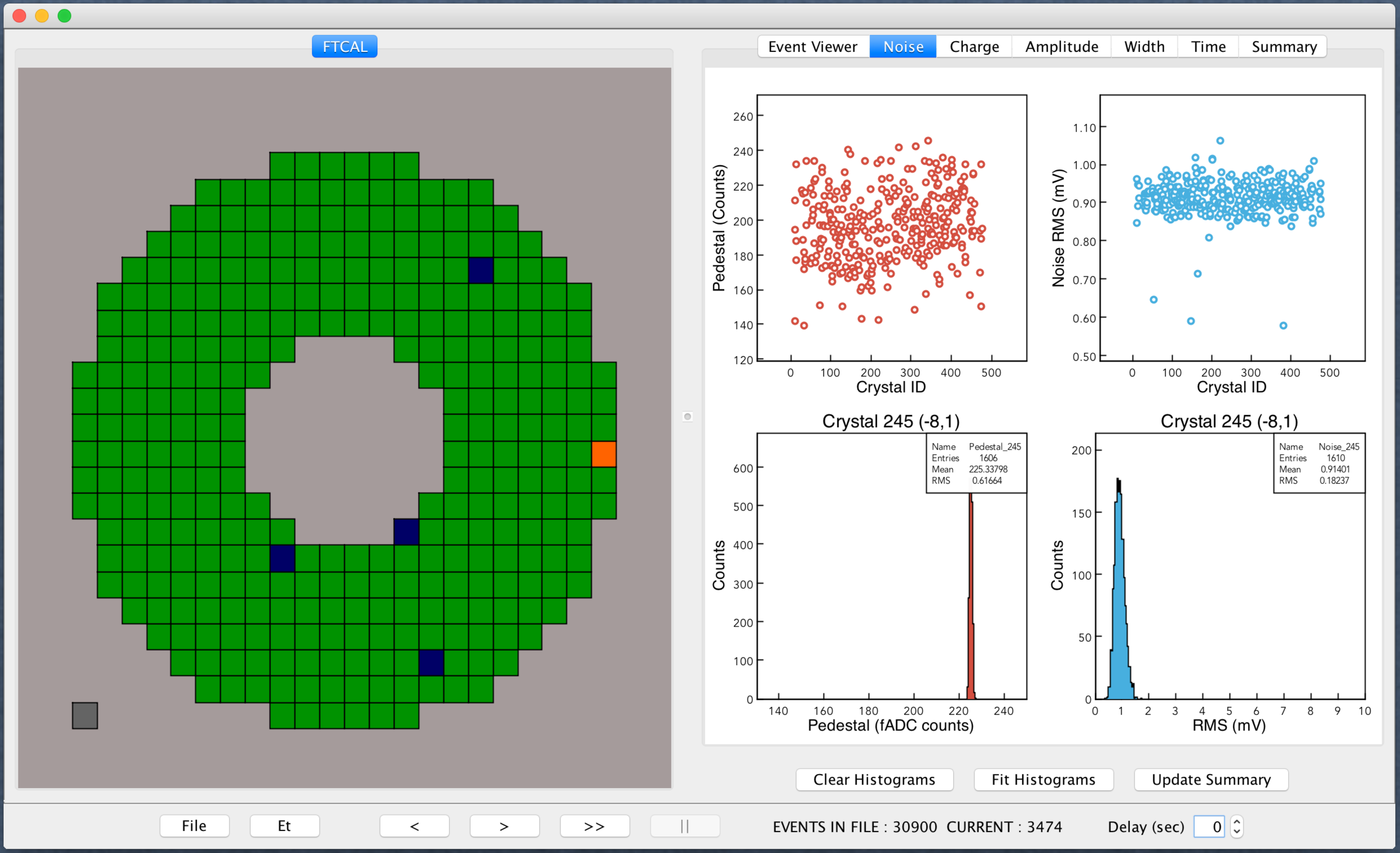




Now upgrading to latest COATJAVA

FT Diagnostic

Crystal "status" determined in real time for the analysis of output signal "noise"

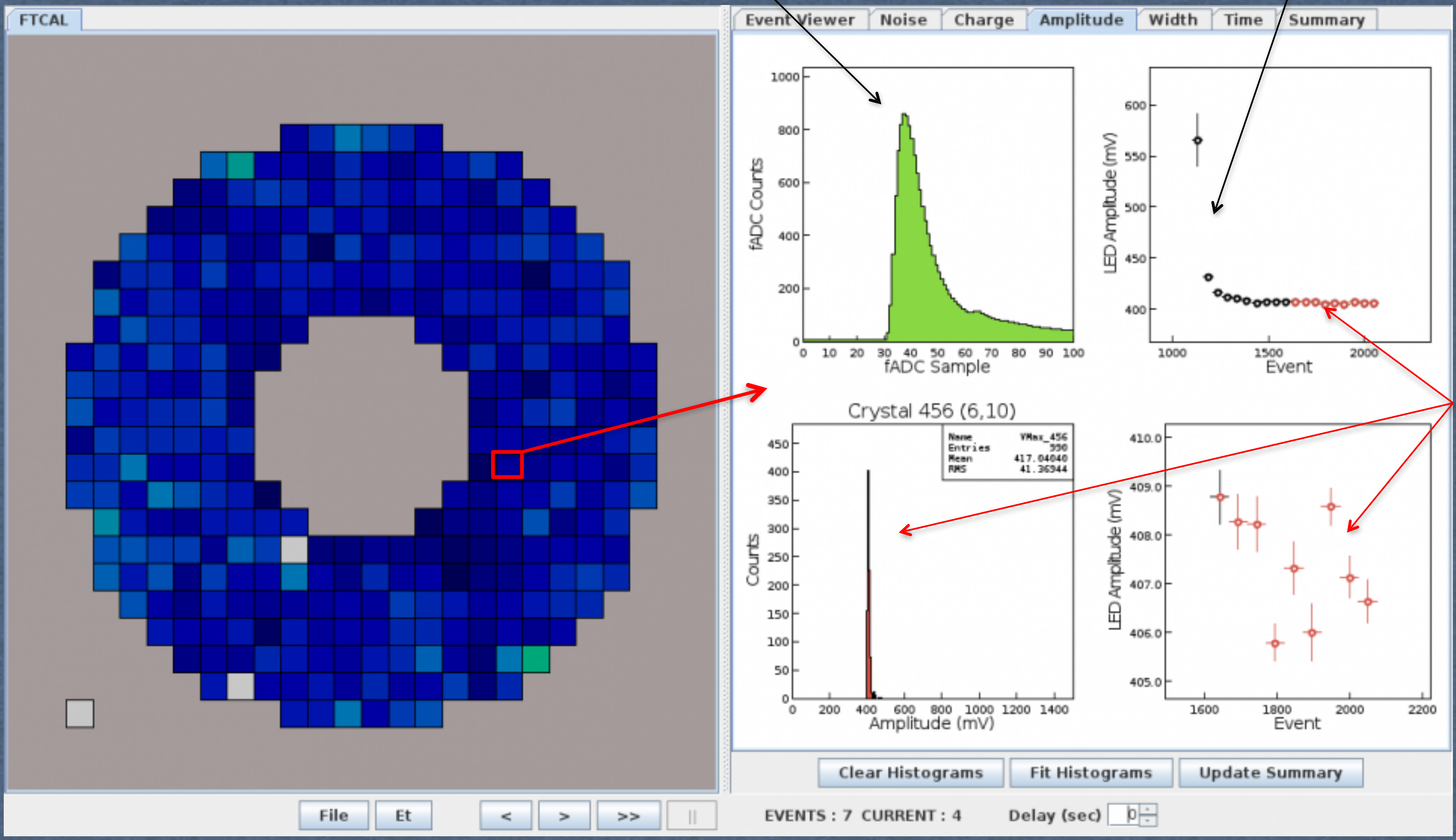


- "healthy" channels identified by signal RMS in the pedestal region of 0.75-1.05 mV
- RMS<0.75 mV indicates channel is dead (bad preamp, no connection with APD, disconnected cable, …)
- RMS>1.05 mV indicates issues with HV (APD on properly polarised)

FT-Cal LED Monitoring System

Averaged pulse

Pulse amplitude as a function of time



Asymptotic level is used to monitor system stability

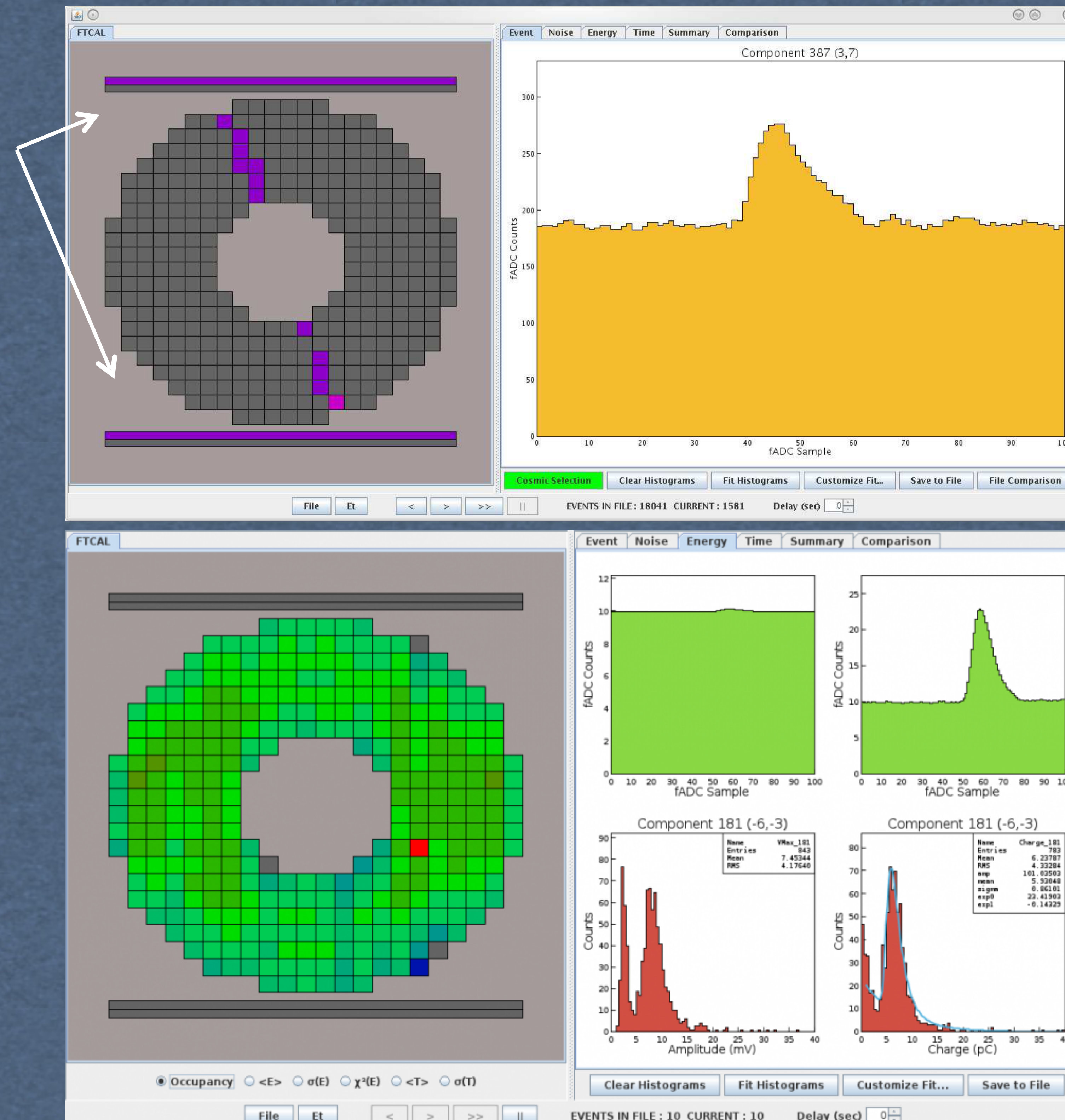
FT-Cal Cosmic ray calibration

Calibration performed using:

- external trigger scintillators
- self-triggering based on fADC (majority of pulses over threshold in a board above selectable value)

Analysis:

- For each crystal, select events with at least 4 crystals with signal above threshold among the adjacent crystals in the same column
- Integrate waveform in fixed range and extract waveform maximum
- Plot charge of amplitude and fit distribution to extract Landau peak position

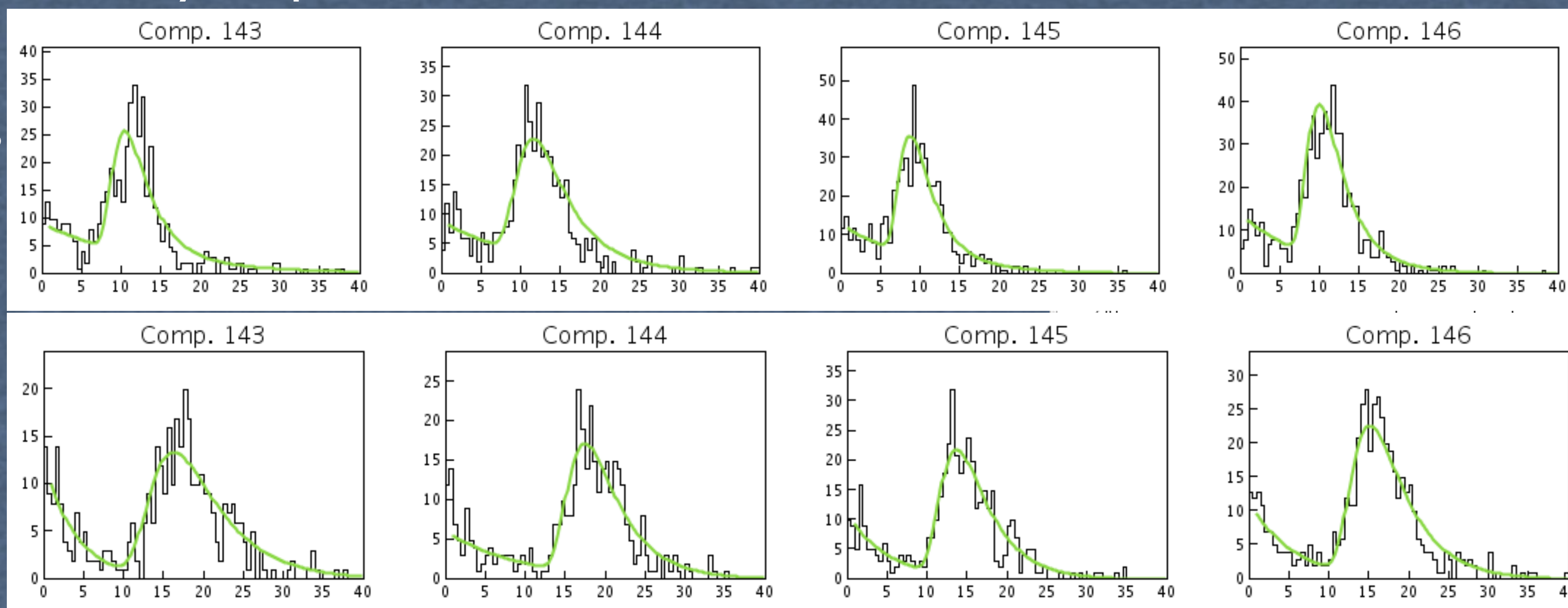


FT-Cal Cosmic ray calibration

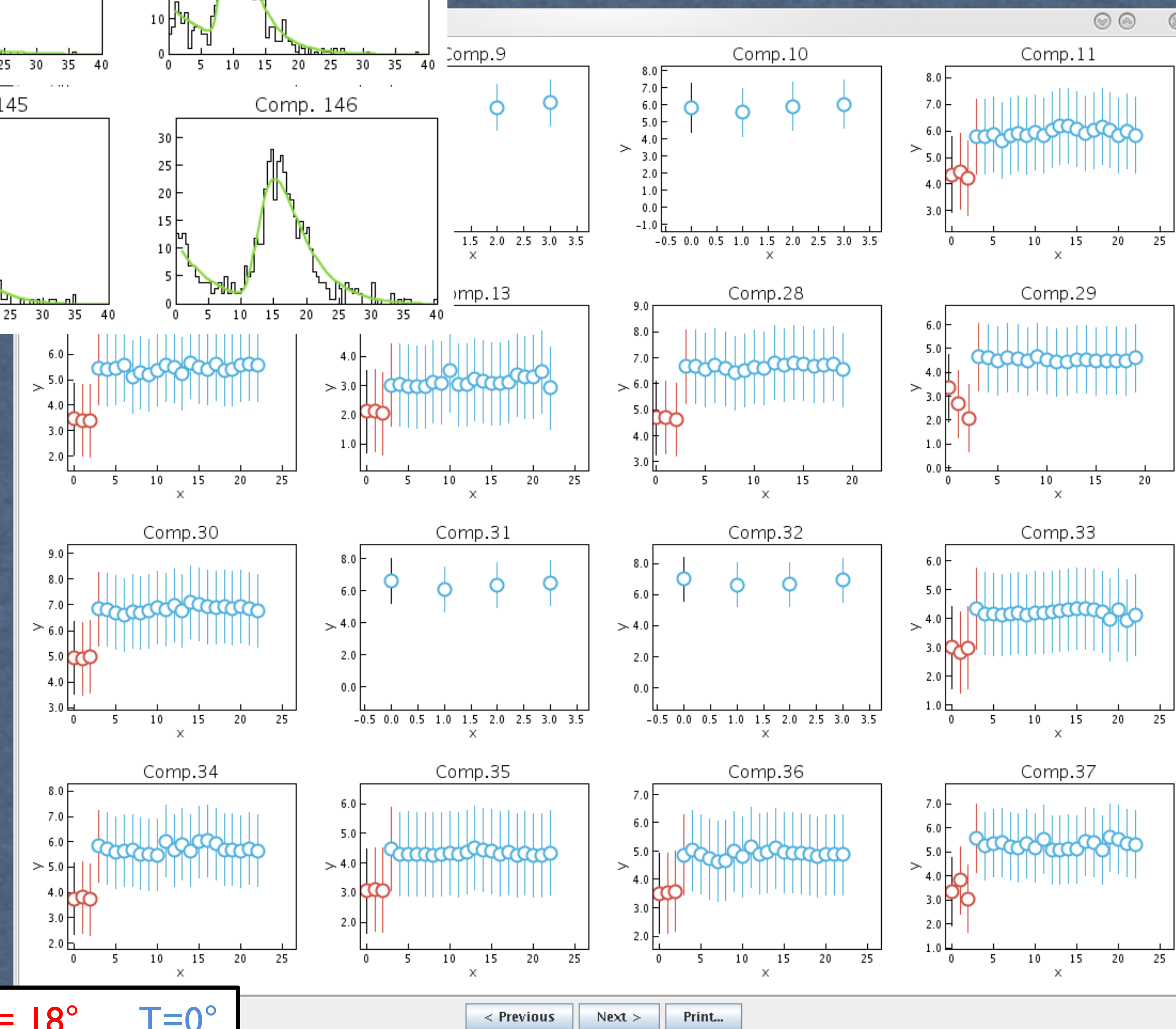
Cosmic ray response monitored as a function of time for both 18° C or 0° C operation

T=18°

T=0°



CLAS12 notes: CLAS12-2016-005 and CLAS12-2017-006



T= 18° T=0°

- Cosmic ray response provides first calibration of charge to energy conversion factor
- Second level calibration from real data using pi0 mass peak

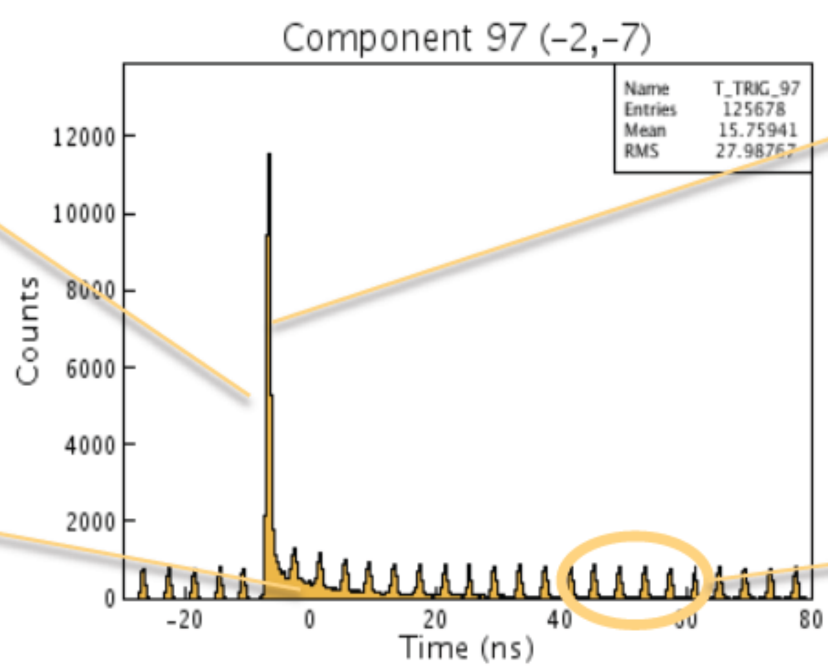
FT-Cal Timing Calibration

Tested during December 2016 calibration challenge using pseudo-data (Pythia events at 10^{34} luminosity):

- Select events with electron in CLAS12 forward detector
- Use event start time from electron as a reference
- Study the time distribution of hits in each crystal from fADC pulse analysis
- No need of information from other FT detectors

Photon: fastest component => composition of the main peak

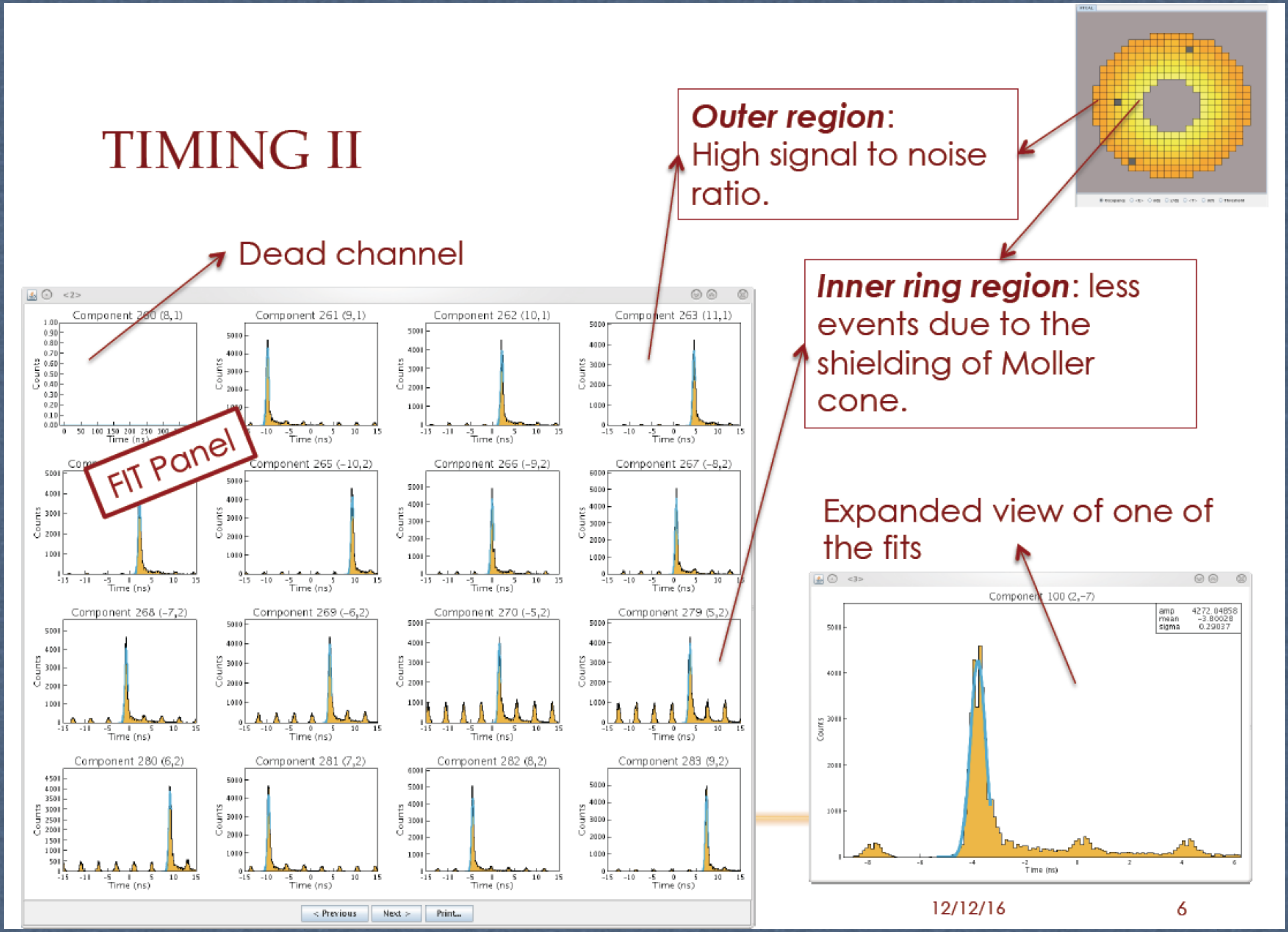
Pion: The exponential contribution



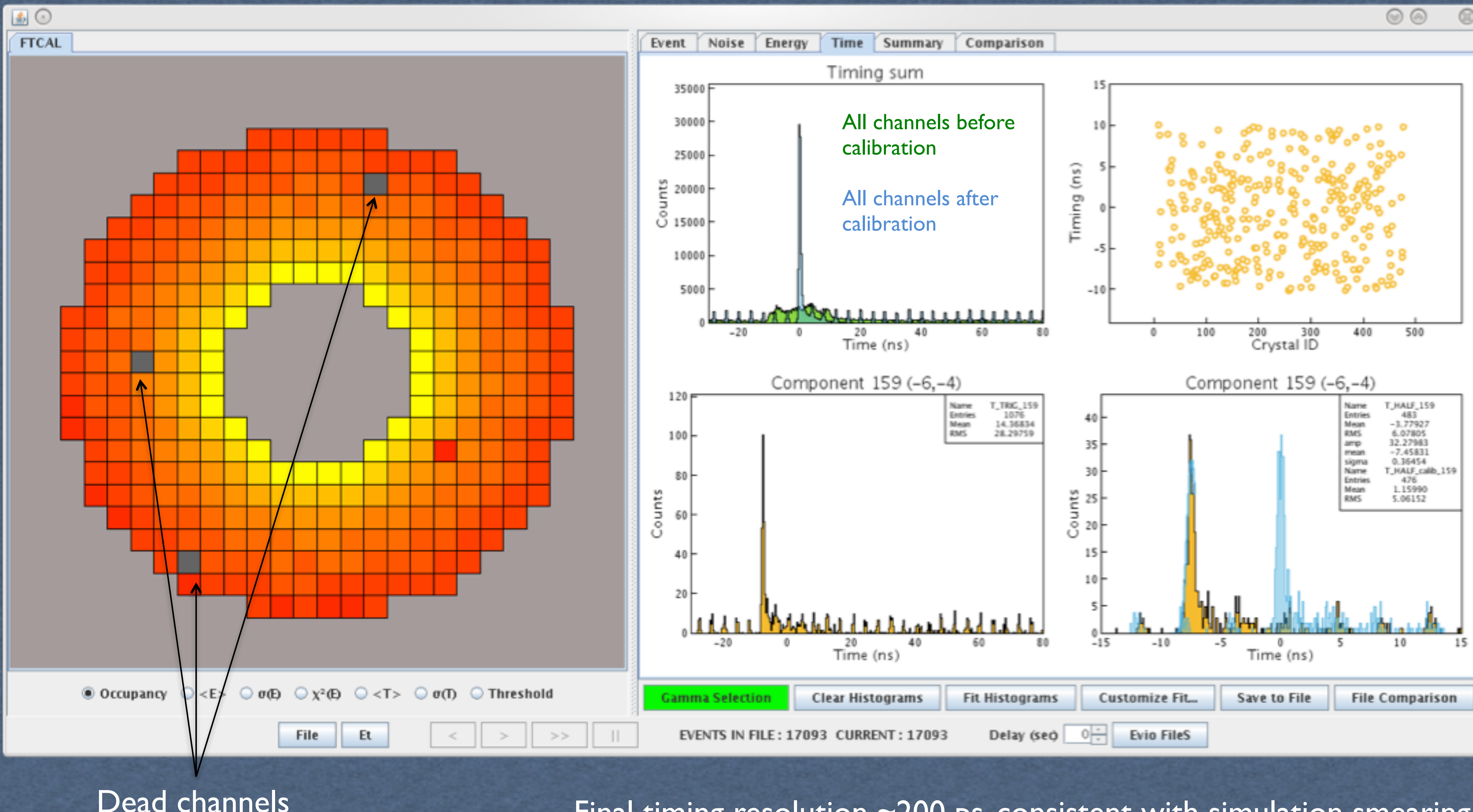
The peak is not at 0 => miscalibration

4.008 beam structure at 11 GeV

FT-Cal Timing Calibration

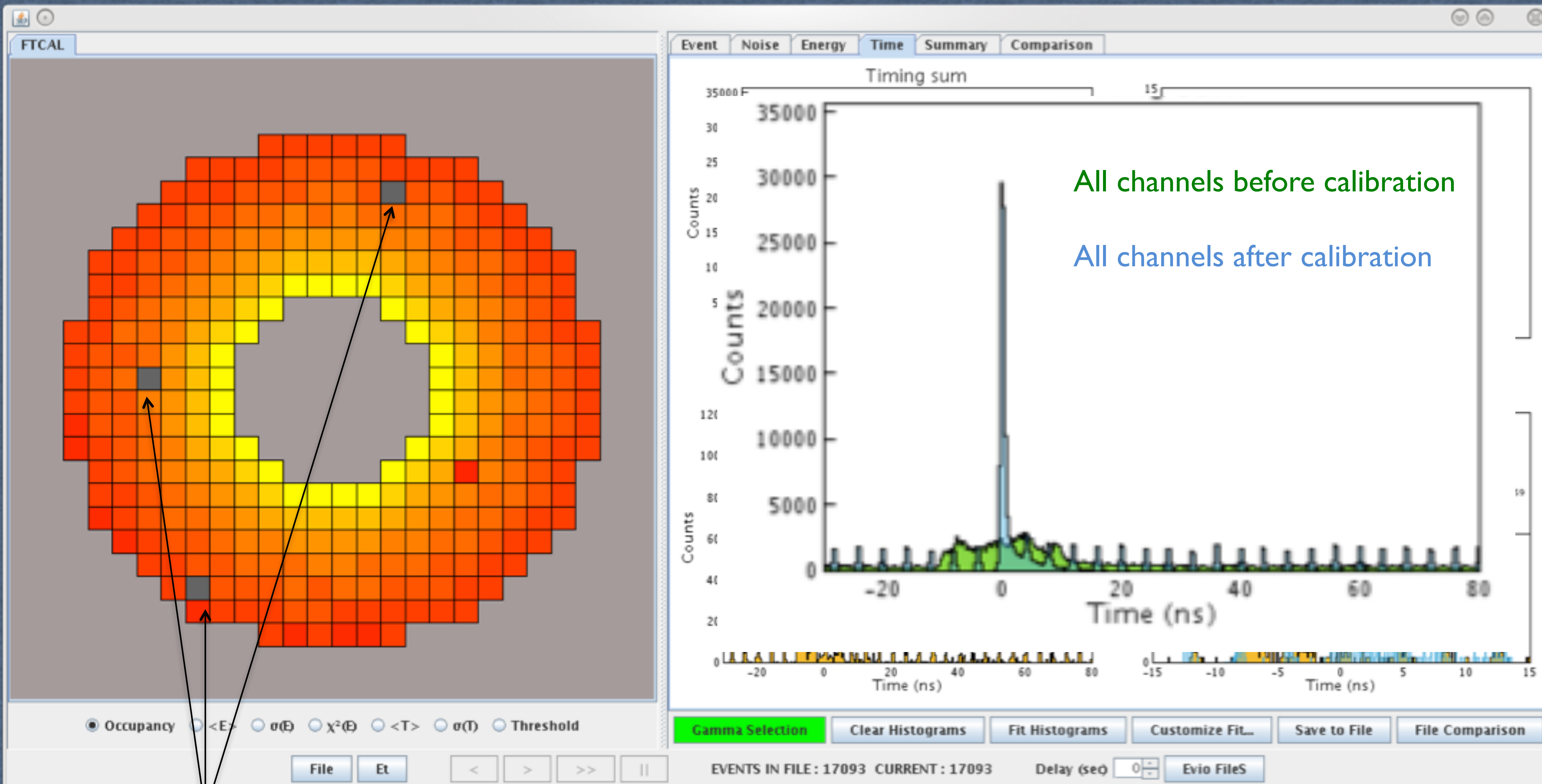


FT-Cal Timing Calibration



Final timing resolution ~200 ps, consistent with simulation smearing

FT-Cal Timing Calibration

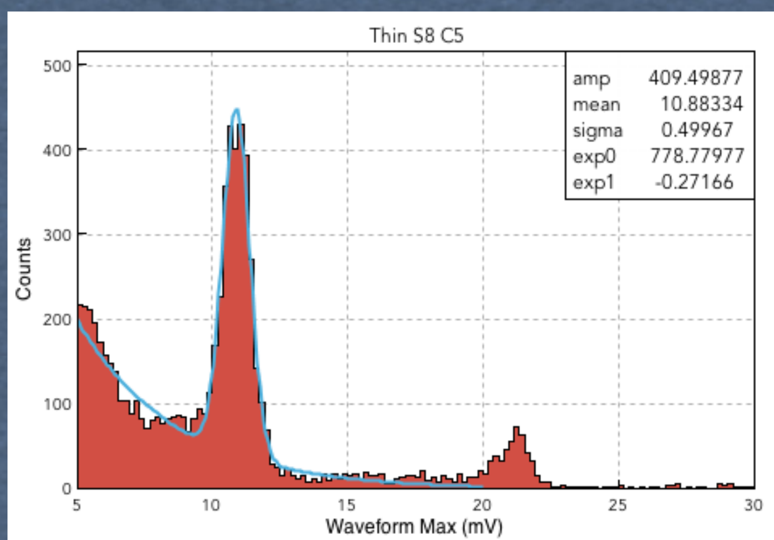


Dead channels

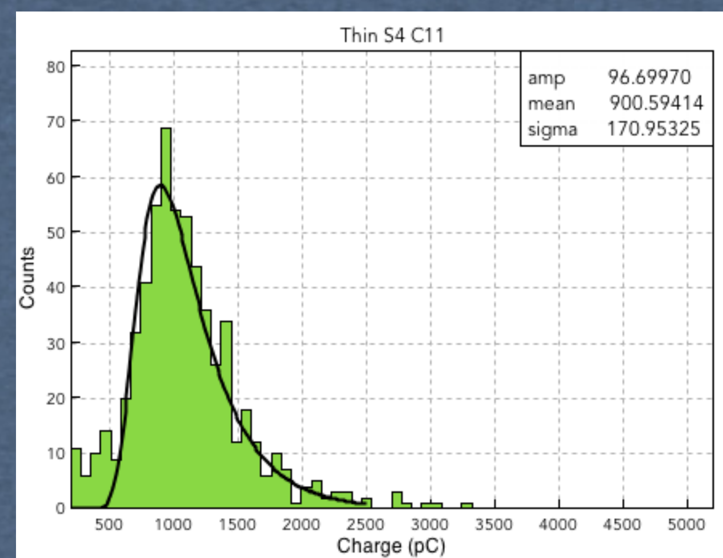
Final timing resolution ~200 ps, consistent with simulation smearing

FT-Hodo Calibration

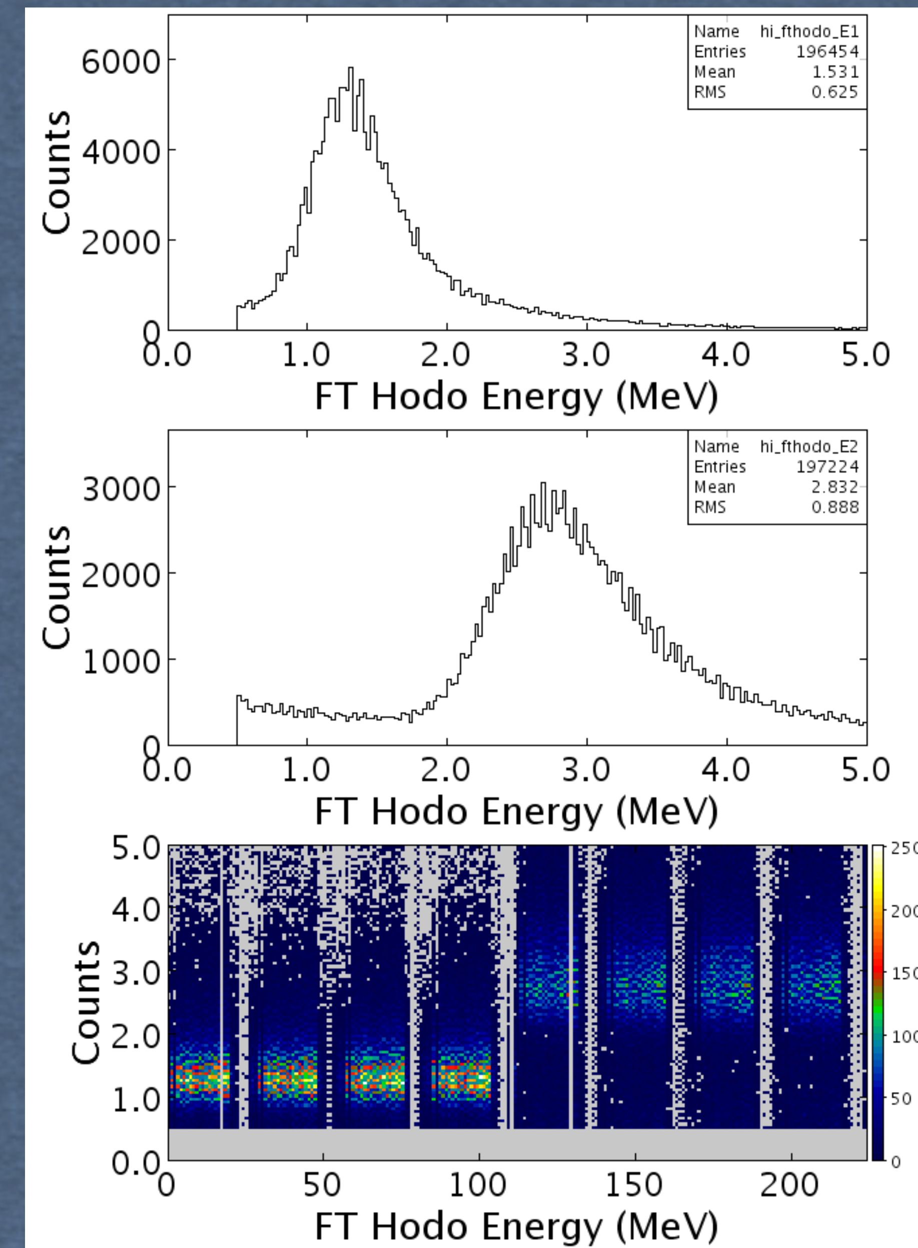
- Complete set of electronics - one sensor board replaced in April
- Slow controls suite
- **Timing fits in calibration software for individual channels**



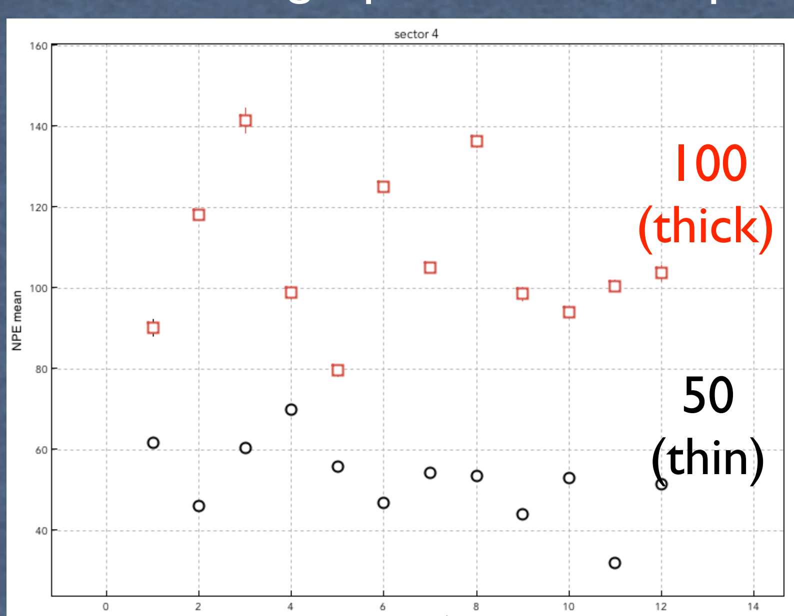
Gain from fit to single photoelectron spectrum



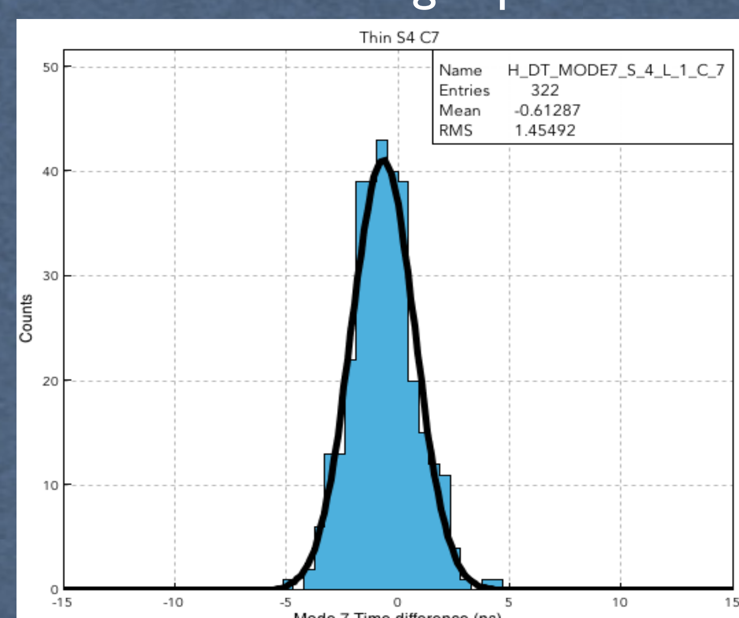
Landau fit to charge spectrum



FT-Hodo charge2energy constants consistent with simulated ones with small systematics (3%) due the Landau parameterization



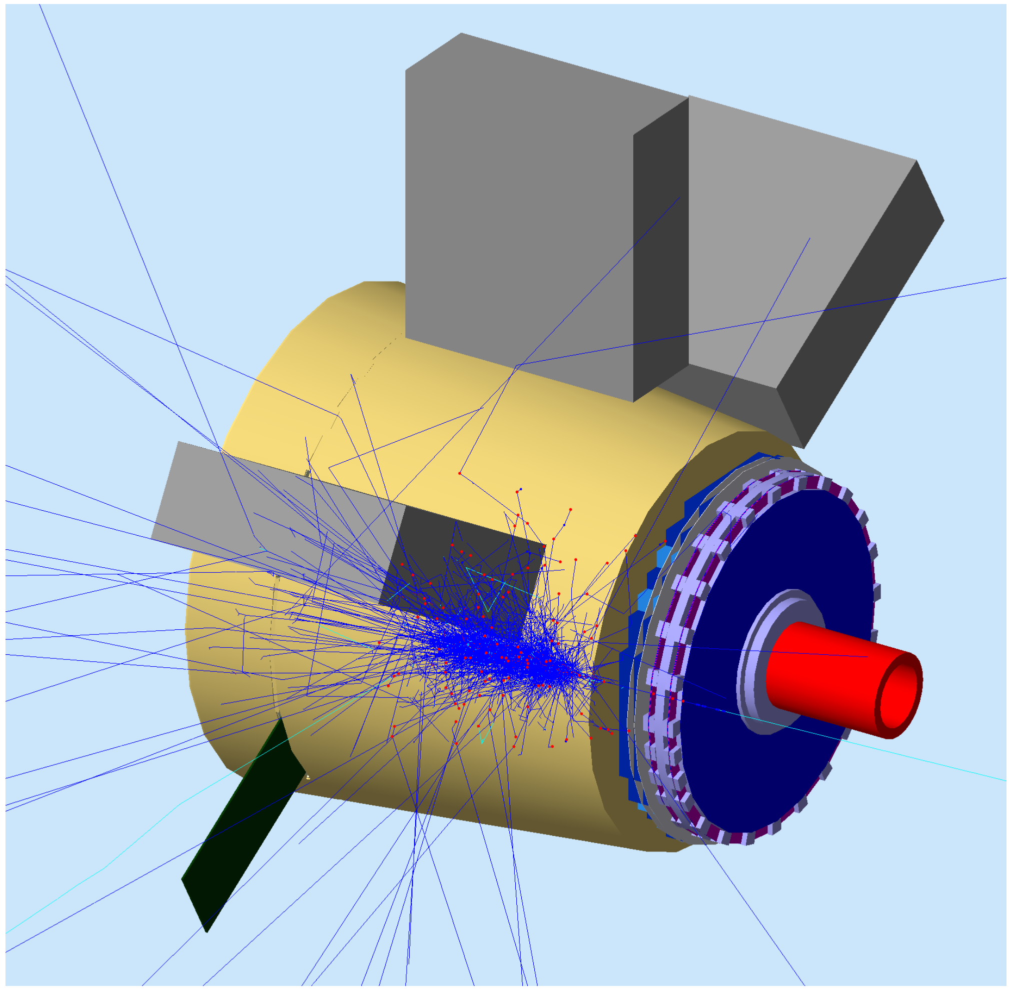
Number of photoelectrons

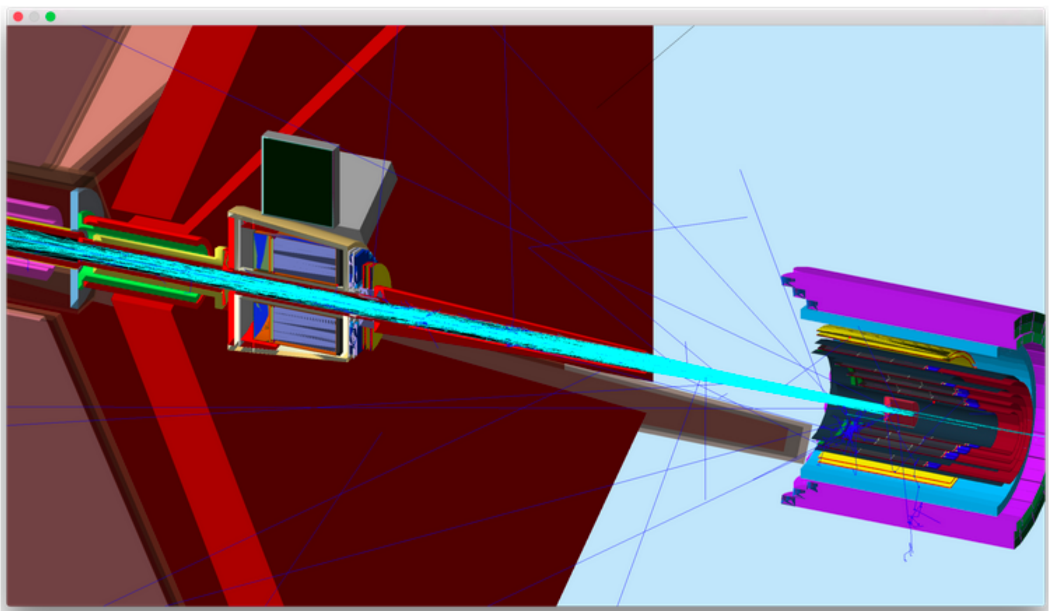


Gaussian fit to timing difference $\Delta t = (t_{thin} - t_{thick})$

FT simulations

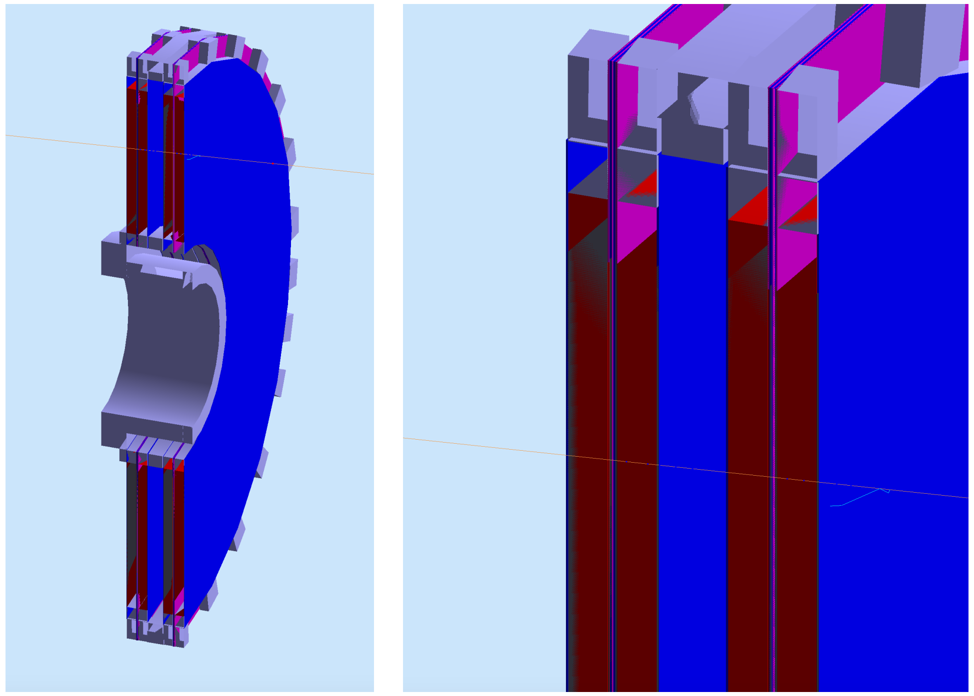
FT in GEMC



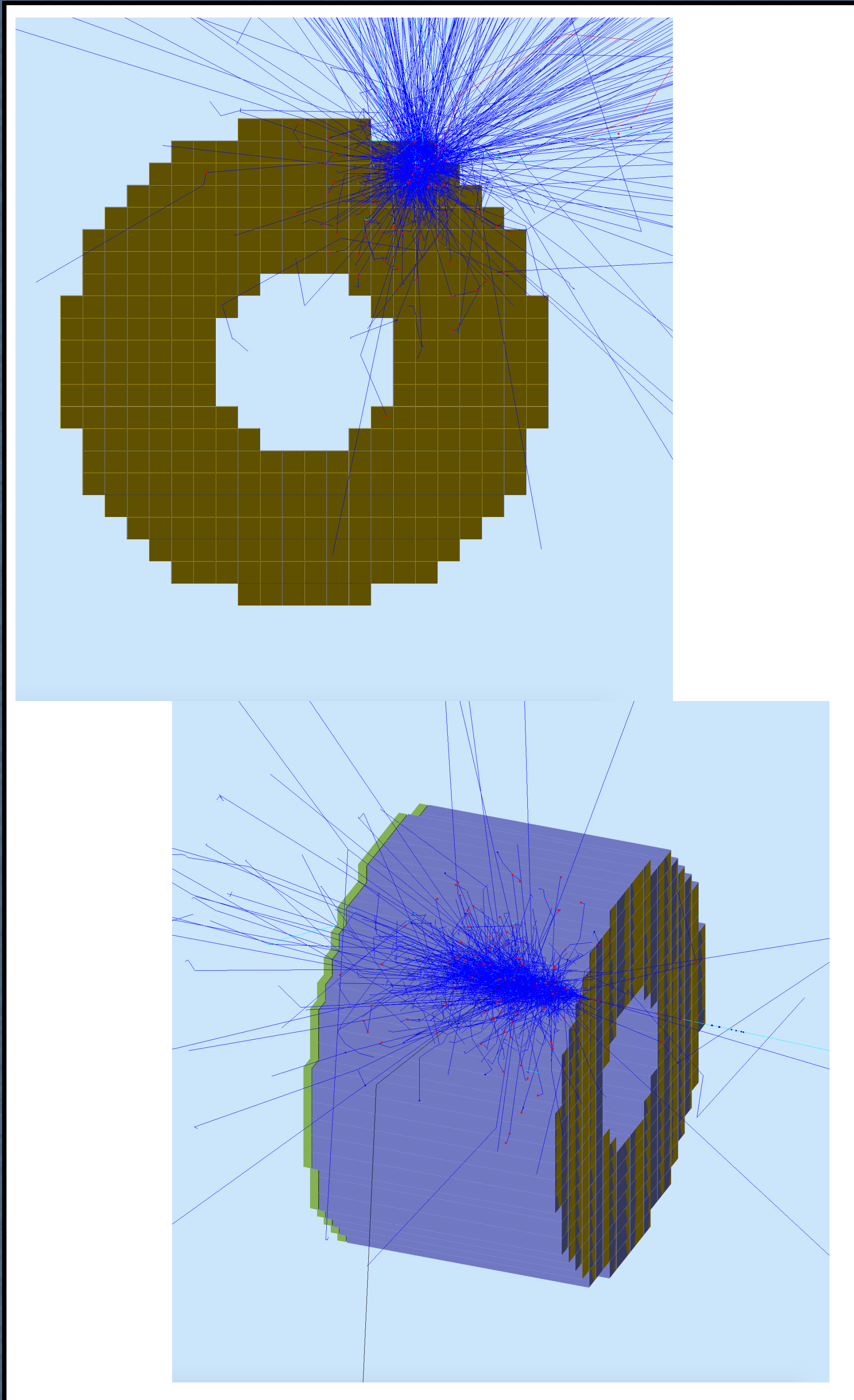


Geometry
- correct z position
- correct FT-cal insulation and FT-Trk crates position
- Full FT-Hodo geometry (Edinburgh+Genova)
- Full FT-Trk geometry (M. Garcon)

FT hitprocess
- Digitization based on calibration constants read from CCDB
- FT-Cal and FT-Hodo tuned to match cosmic ray calibration data
- FT-Trk hit-process based on correct strip numbering and first estimates of the cluster size (M. Defurne and R. De Vita)
- Available in GEMC 4a.1.0

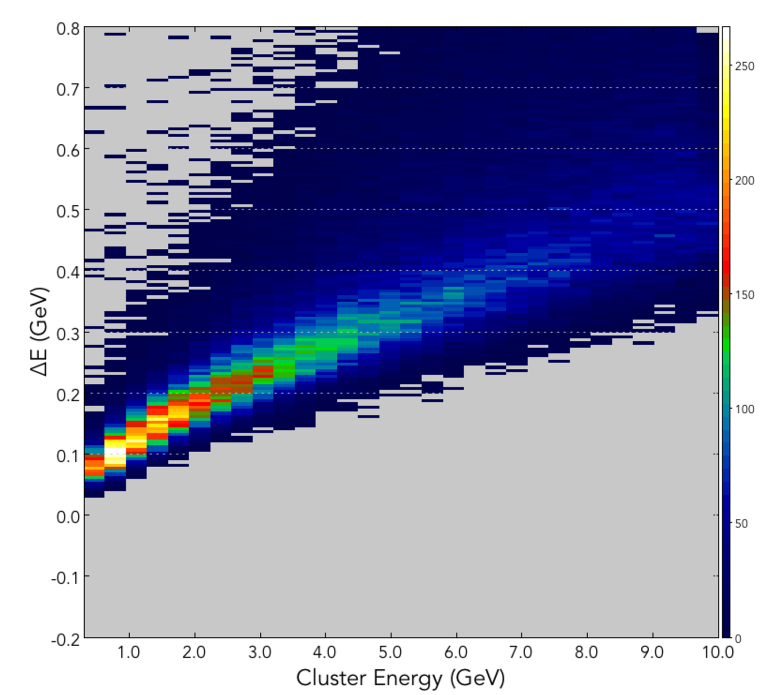


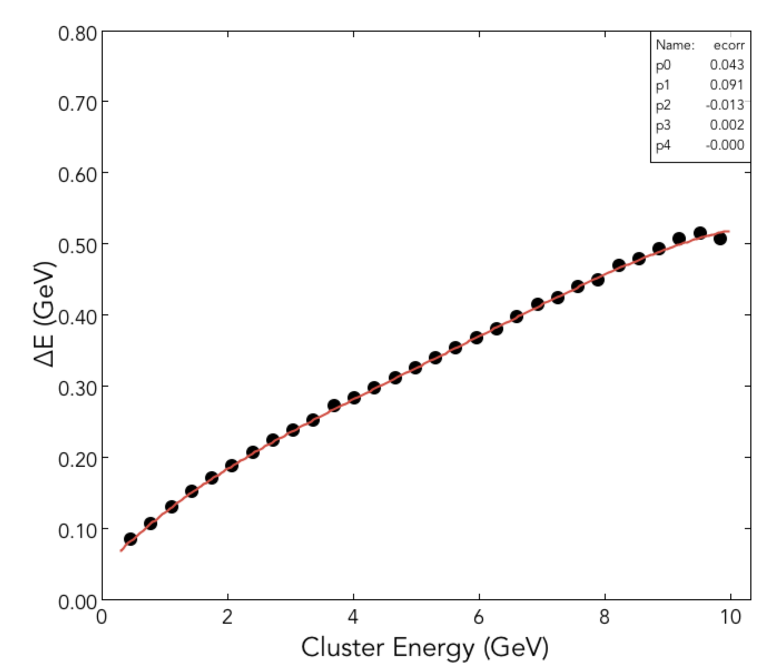
FT reconstruction



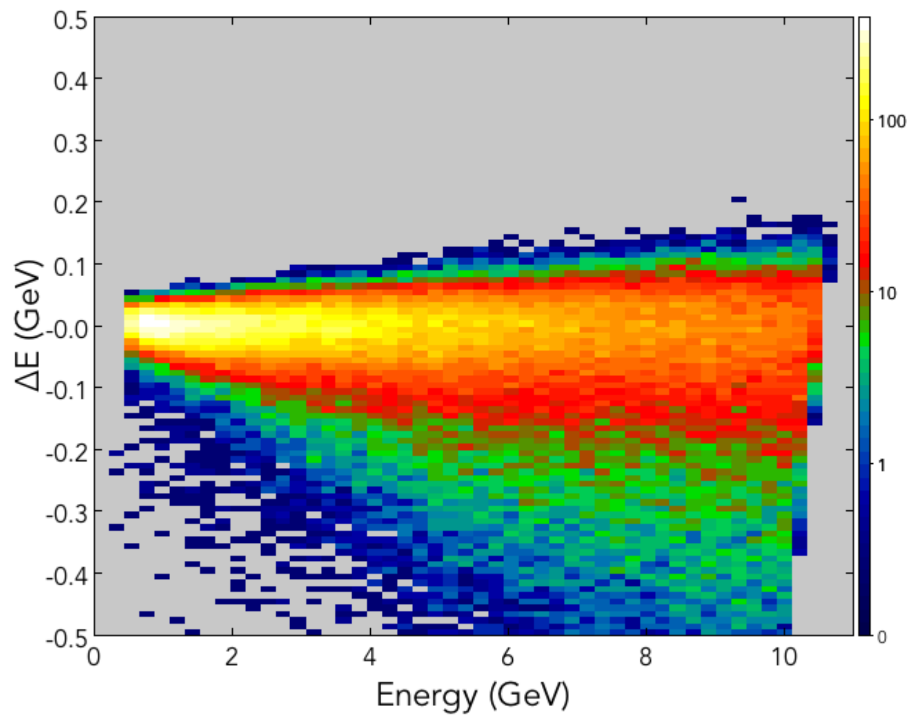
FT-Cal: shower leakage corrections:

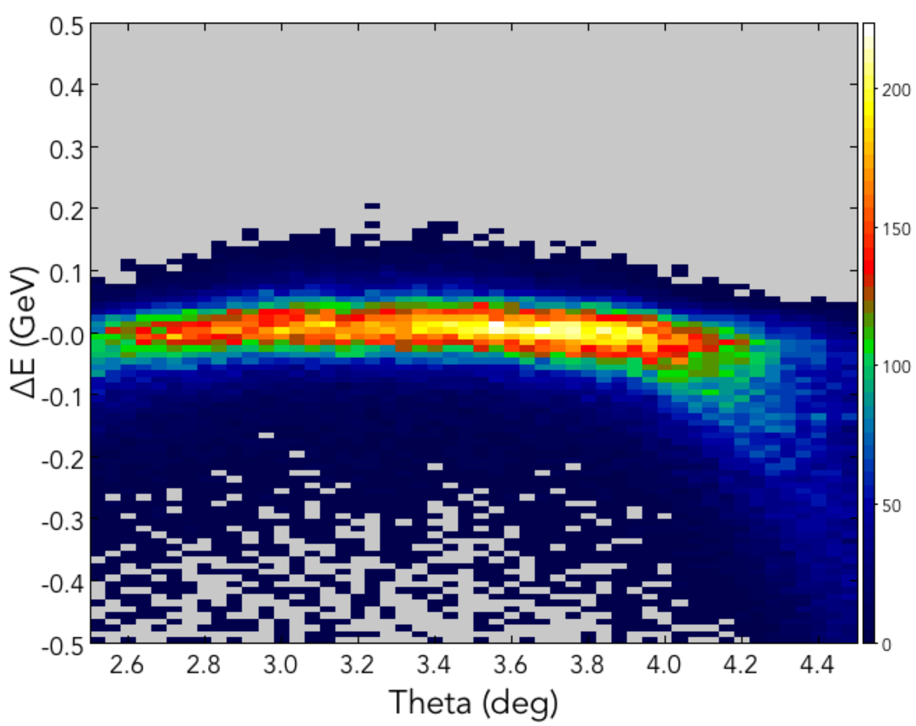
- Deposited energy is less than incident particle energy because of finite size of the detector and readout
    - longitudinal containment (FT-Cal thickness = 20 cm ~ 25 r.l.)
    - lateral containment
    - readout threshold





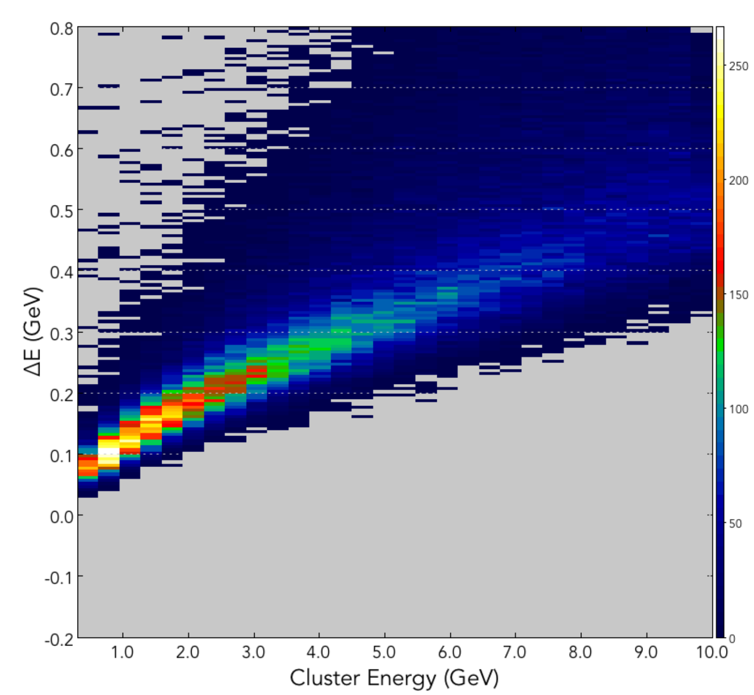
FT reconstruction

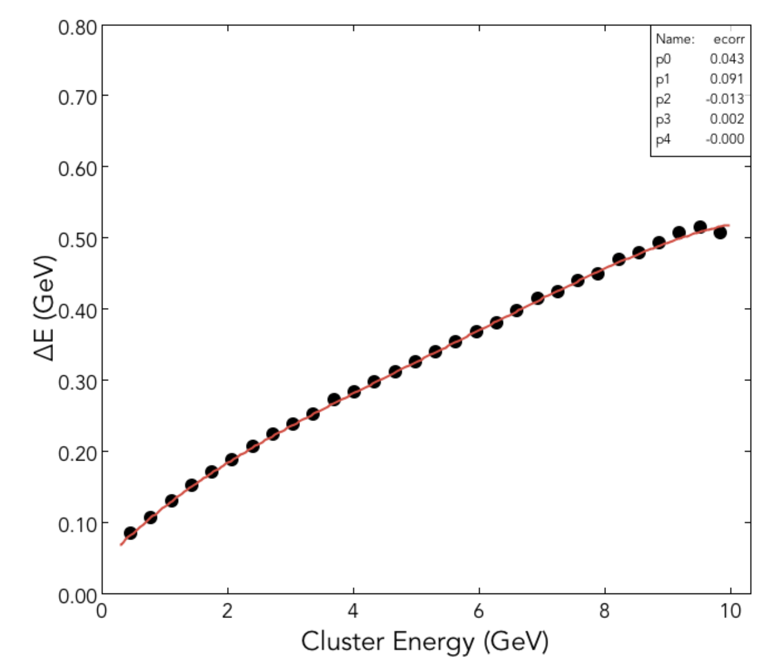




FT-Cal: shower leakage corrections:

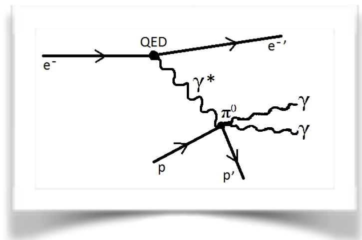
- New correction for longitudinal leakage implemented and tested up to electron/photon energy of 10 GeV
- New correction dependent on cluster seed position under development:
  - Account simultaneously for both shower leakage and readout threshold

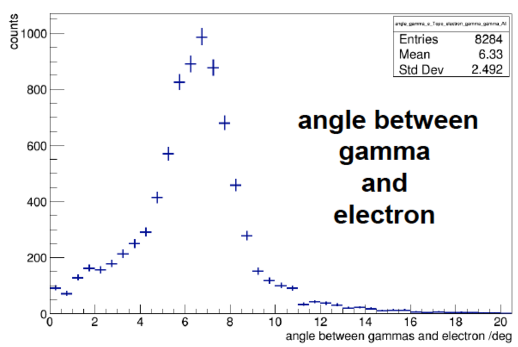


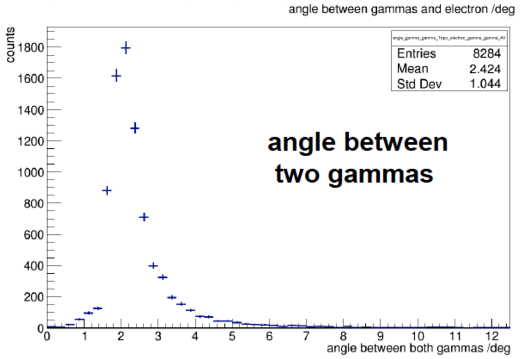


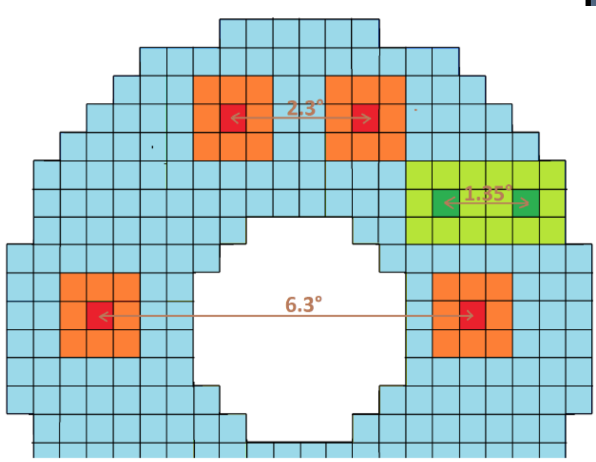
$e\,p \to e'\,p\,\pi 0$ ($\gamma\,p \to p\,\pi 0$)

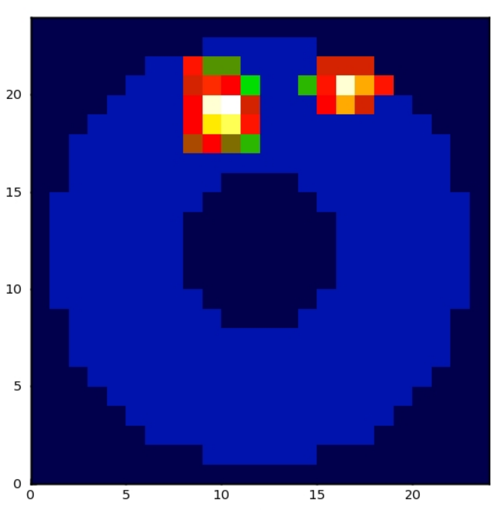
- **S.Diehl (U Giessen)**
- Full CLAS12 (+FT) GEANT4 sim/rec
- JPAC e-production amplitudes (V.Mathieu)
- AMPTOOLS

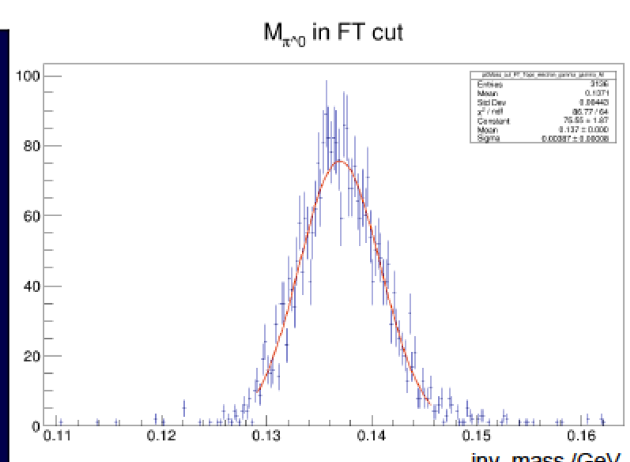












137 MeV/c² reconstrcuted (lit.: 134,98 MeV/c²)

Resolution: 3.9 MeV/c²

FT reconstruction

Reconstruction

FT-Cal:

- Read raw hits from hipo bank
- Read calibration constants from DB
- Create hits, converting from digitized info to E and T
- Reconstruct cluster and determining cluster E, T and pos

FT-Hodo:

- Read raw hit from evio bank
- Read calibration constants from DB
- Create hits, converting from digitized info to E and T
- Match hits in the hodoscope layers

FT-Track:

- started based on algorithm developed by G. Charles

FT-Match:

- Match reconstructed clusters with hits in hodoscope
- Output of final reconstructed particles

Code available in present COATJAVA distribution

FT Trigger simulation (S.Diehl at the HSWG meeting on Thur)

Schedule of remaining tasks

FT final assembly and test in the EEL building	JLab EEL building	
• FT-Cal sealing		May
• FT-Cal + FT-Hodo ready for cosmic checkout		
• Interlocks + Gas system tested in EEL building		June
• FT-Trck integration (interlocks + gas system)		

FT detector ready to be installed in CLAS12

FT installation in CLAS12	JLab Hall-B	
• Move the electronics to the Hall		July
• Move the FT to the Hall and integrate in CLAS12		
• Take cosmic data to check the final configuration		August/ September

FT detector ready to take data this fall!