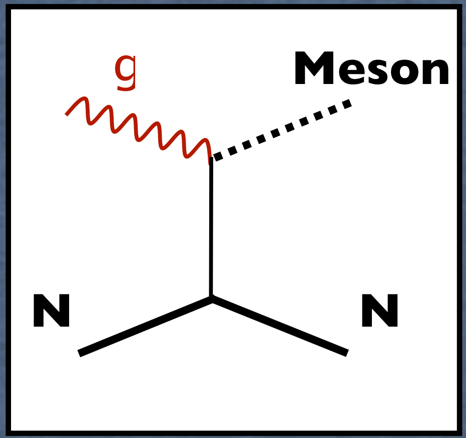
CLAS Collaboration Meeting
Feb 24 2016

Forward tagger status

M.Battaglieri
INFN-GE
on behalf of the MesonEx Collaboration
(and the whole technical team that contributed to make it happen!)

Beyond the quark model: hybrids and exotics

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



★ $q\bar{q}$ system easier to study
★ information on inter-quark potential
★ access to strong interaction dynamics
★ access to gluonic degrees of freedom
★ towards a quantitative understanding of quark and gluon confinement

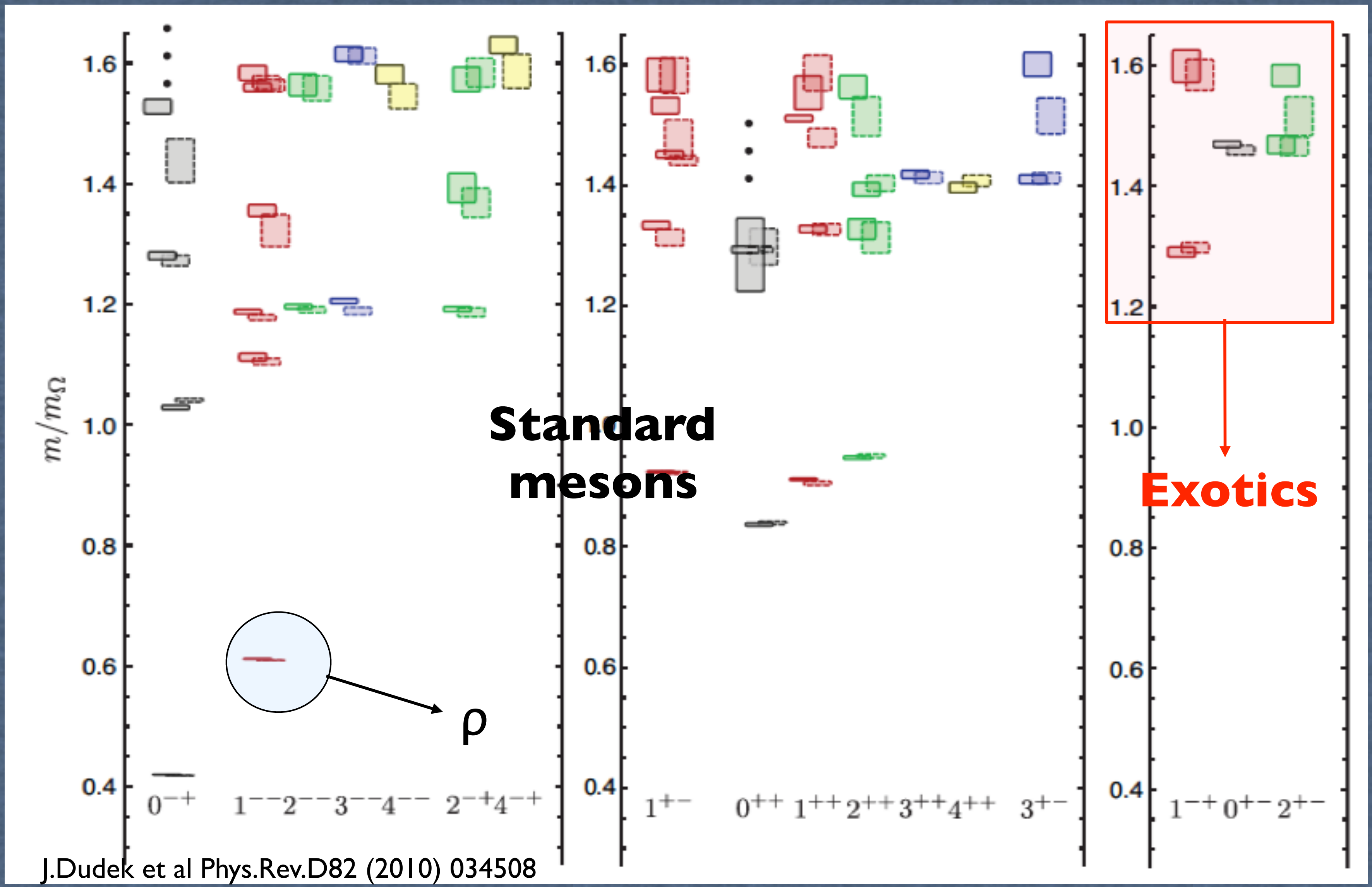
Detailed study of the meson spectrum and search for *exotic* configurations

Why photoproduction?

★ Complementary to hadro-production
★ Hybrid mesons with exotic quantum numbers are more likely produced by S=1 probe
★ Linear polarization acts like a filter to disentangle the production mechanisms and suppress backgrounds

Requires high intensity tagged photon beam and large acceptance detector

QCD Lattice calculations



Lattice-QCD predictions for the lowest hybrid states

0^{+-} 1.9 GeV
1^{-+} 1.6 GeV

Hybrid mesons and glueballs mass range:

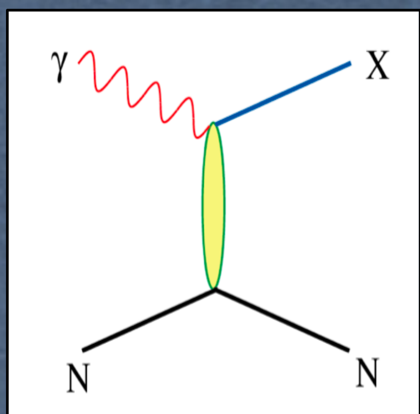
1.4 GeV - 3.0 GeV

This mass range is accessible in photoproduction experiments with a beam energy in the range 5 GeV < E_g <12 GeV

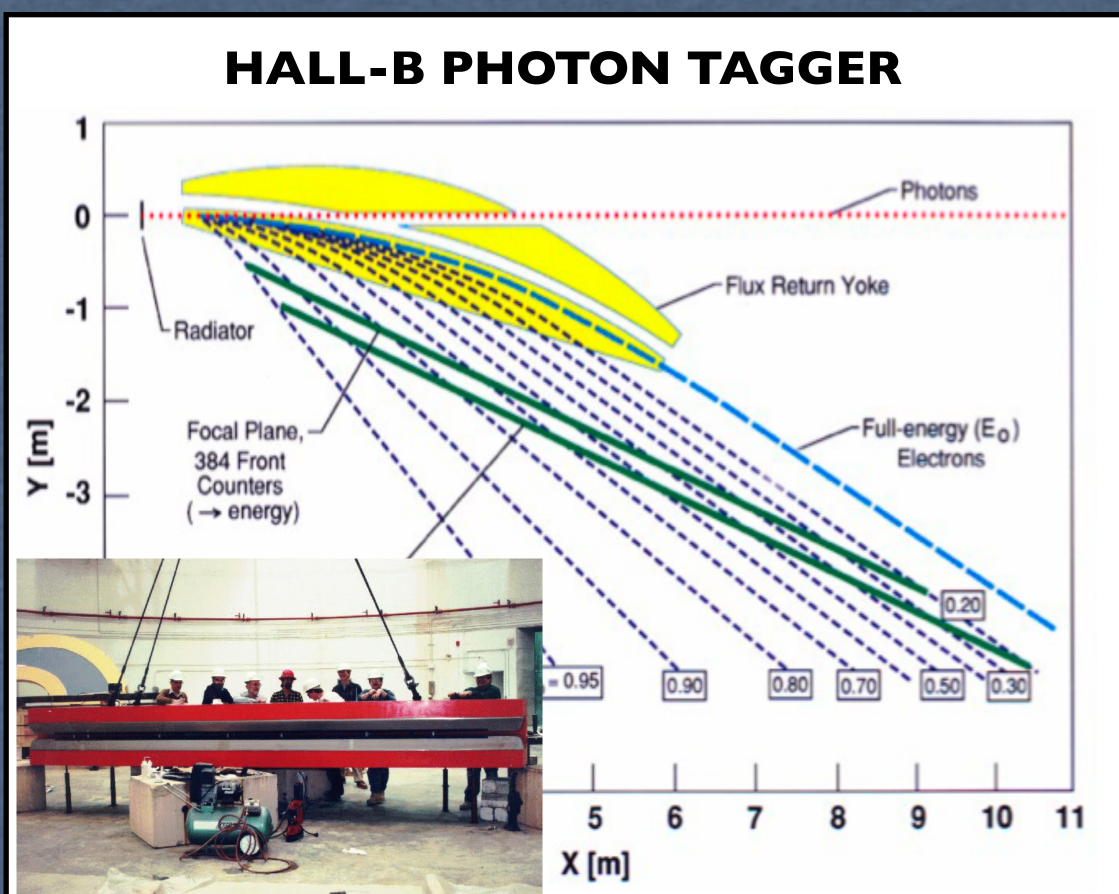
Perfectly matched to JLab12 energy!

Meson spectroscopy with photons at JLab-12 GeV

The photon beam requirements

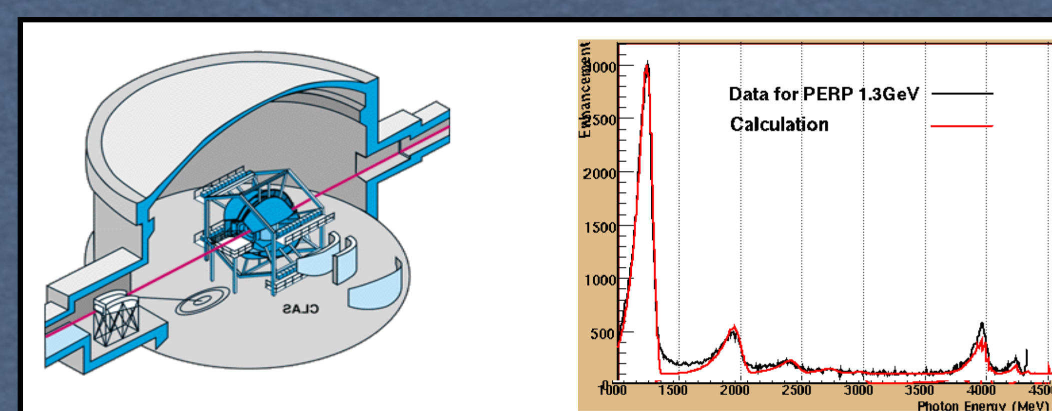


- ★ High luminosity
- ★ Tagger (initial photon energy) is required to add 'production' information to decay
- ★ Linear polarization is useful to simplify the PWA and essential to isolate the nature of the t-channel exchange



The existing dipole magnet is unable to deflect the 11 GeV primary beam on the existing beam-dump

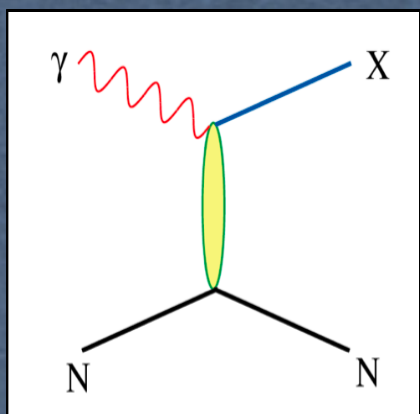
The existing PHOTON TAGGER will be available for energies up to E_g~6.1 GeV



Coherent tagged Bremsstrahlung (Hall-D) not an option for Hall-B@ 12 GeV

Meson spectroscopy with photons at JLab-12 GeV

The photon beam requirements



★ High luminosity

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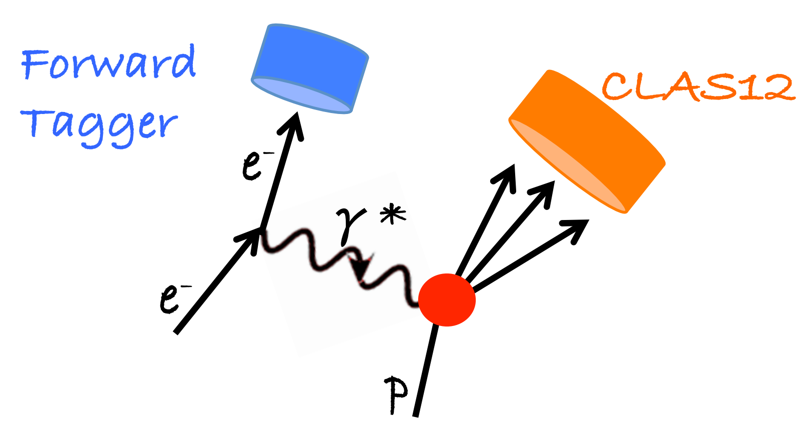


$E_{scattered}$	0.5 - 4.5 GeV
θ	2.5^o - 4.5^o
ϕ	0^o - 360^o
ν	6.5 - 10.5 GeV
Q^2	0.01 - 0.3 GeV^2 ($< Q^2 >$ 0.1 GeV^2)
W	3.6 - 4.5 GeV

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

★ Electron scattering at "0" degrees (2.5^{O} - 4.5^{O})
low Q^2 virtual photon ⇔ real photon

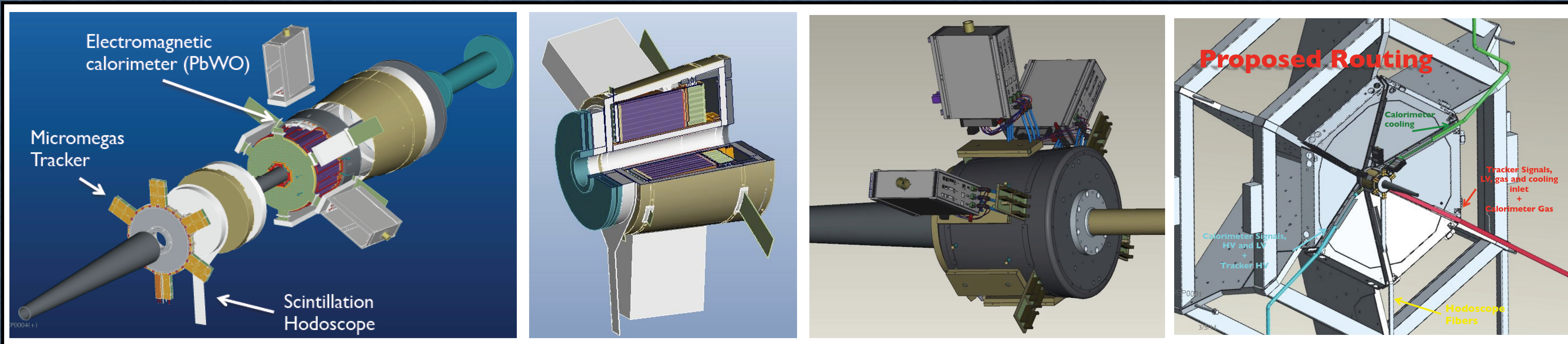
★ Photon tagged by detecting the scattered electron at low angles
High energy photons 6.5 < E_g < 10.5 GeV

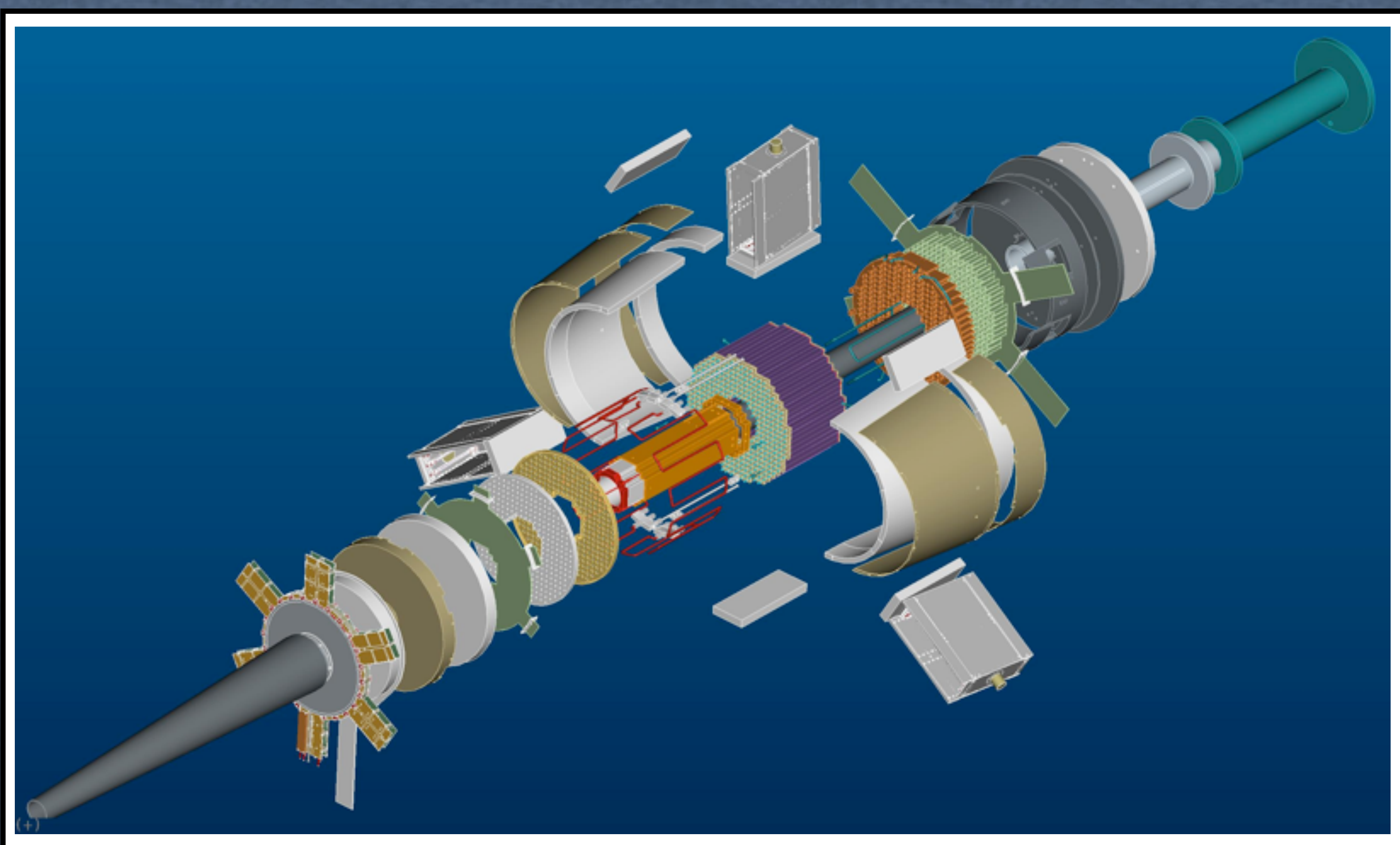
★ Quasi-real photons are linearly polarized
Polarization ~ 70% - 10% (measured event-by-event)

★ High Luminosity (unique opportunity to run thin gas target!)
Equivalent photon flux N_γ ~ 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)

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

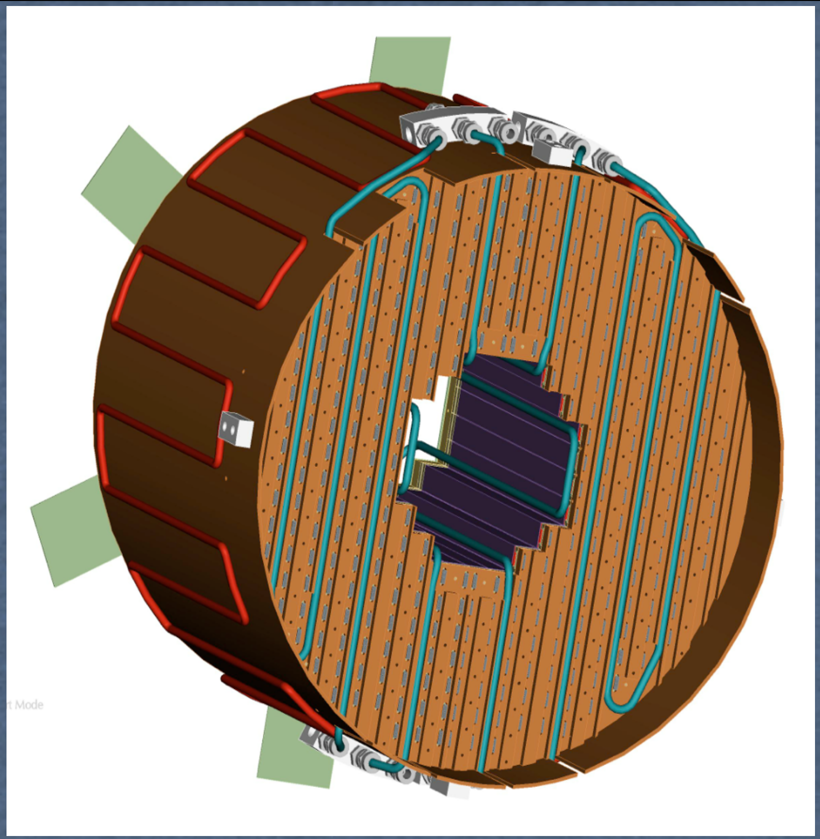
Calorimeter + hodoscope + tracker

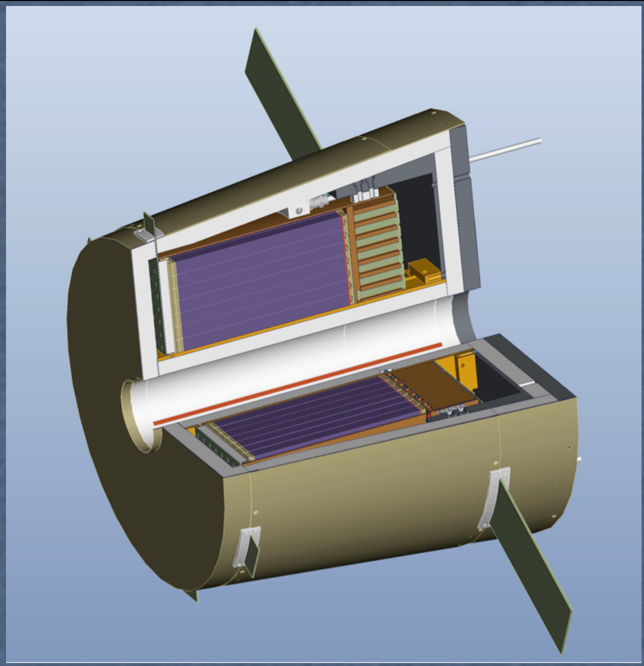
Electron energy/momentum

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

Photon energy ($\nu = E-E'$)

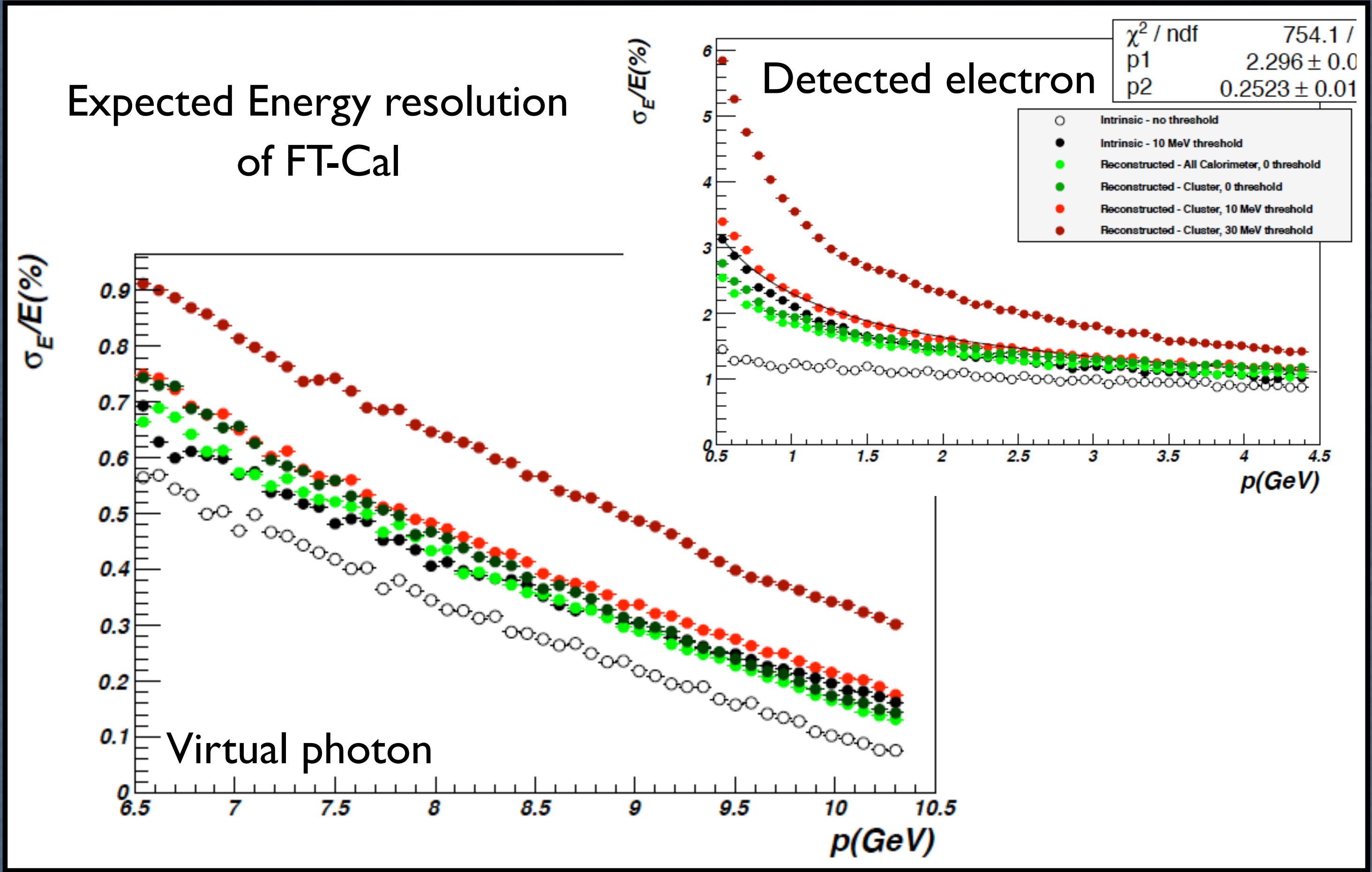
Polarization $\varepsilon^{-1} \sim 1 + \nu^2/2EE'$





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%/√E(GeV) ⊕ 0.5%

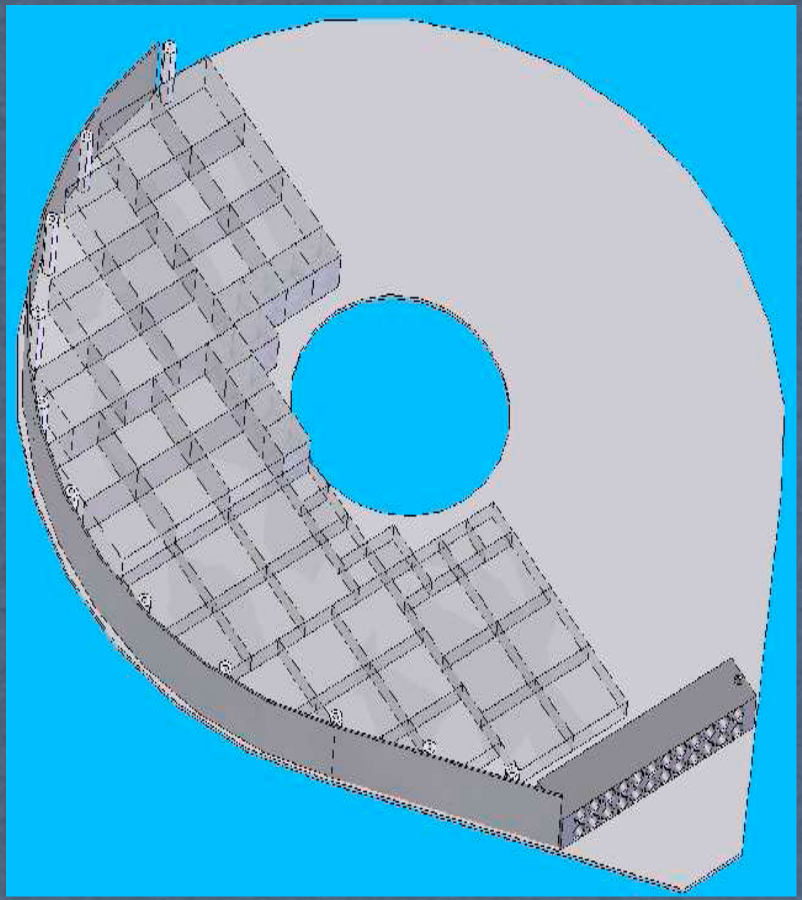


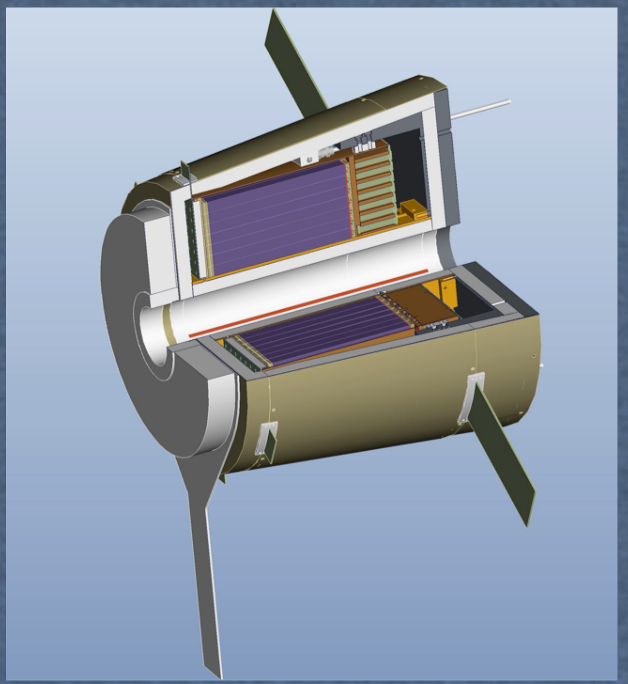
FT-Hodo

Calorimeter + **hodoscope** + tracker

veto for photons

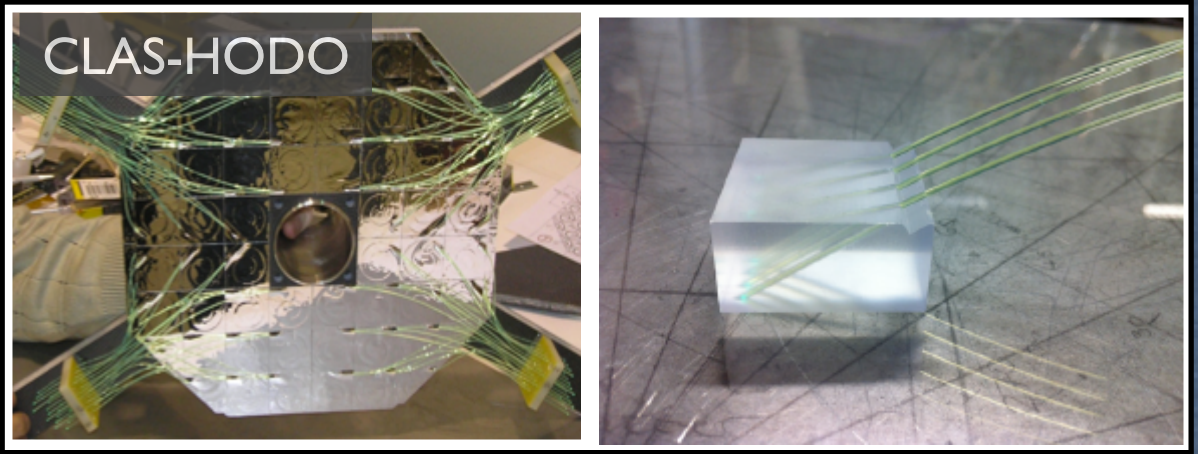
Plastic scintillators tiles with WLS fibres coupled to SiPM

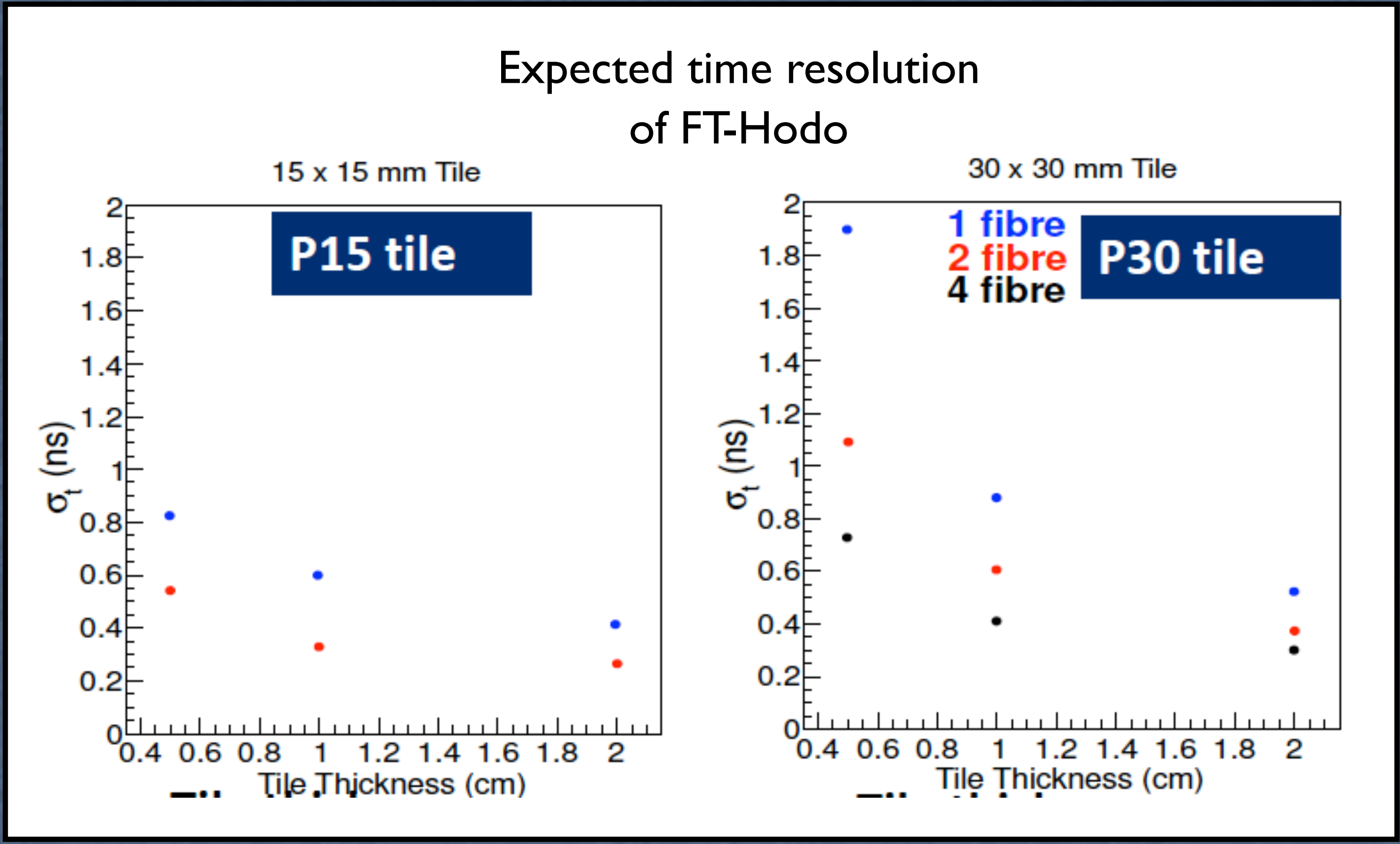




Requirements

- ✳ 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 ElJen 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**

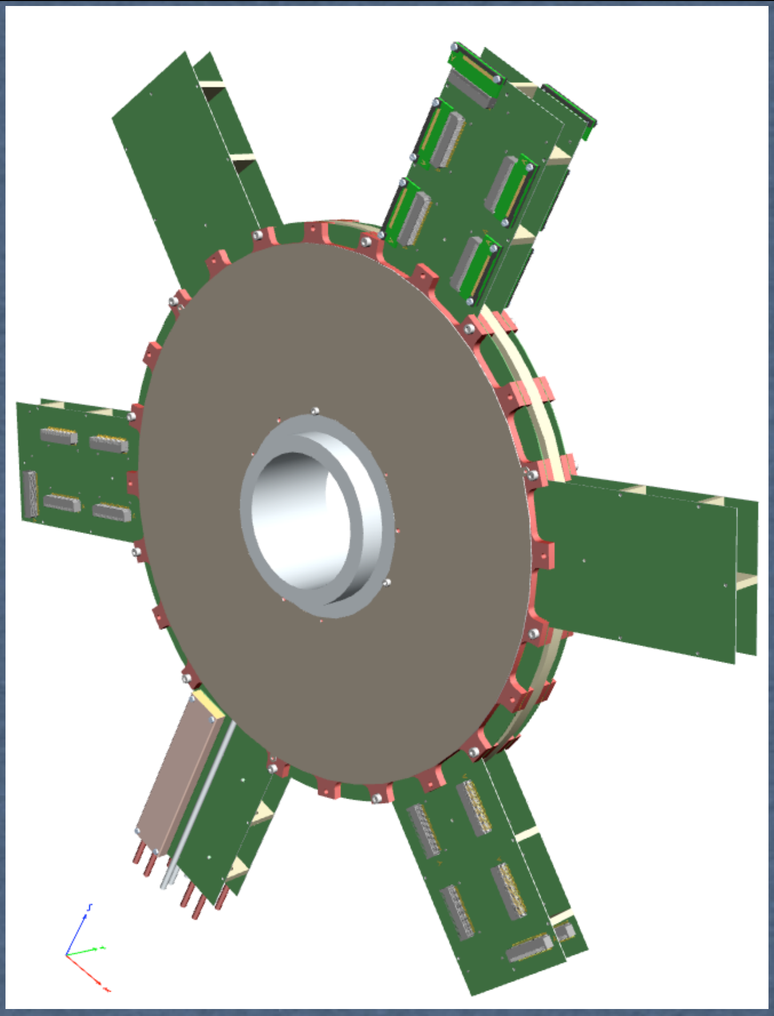
$Q^2 = 4\,E\,E'\,\sin^2 \vartheta/2$

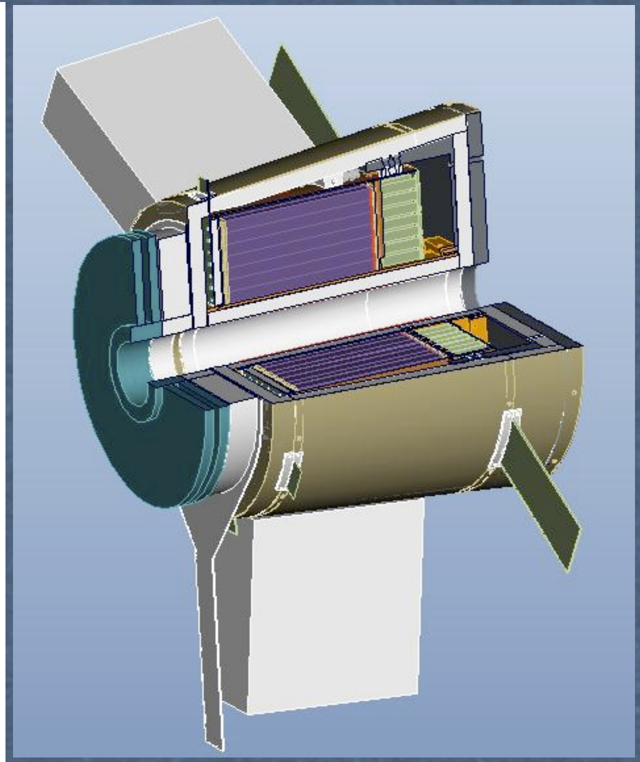
Scattering plane

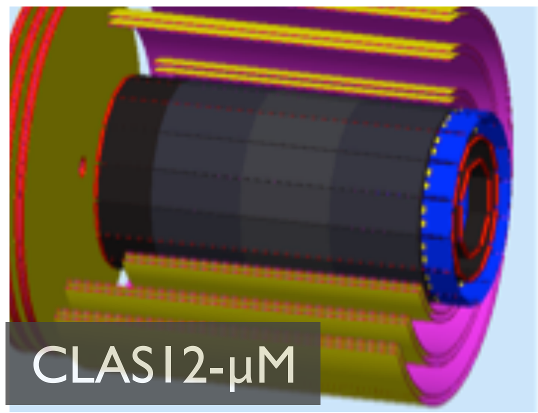
Requirements

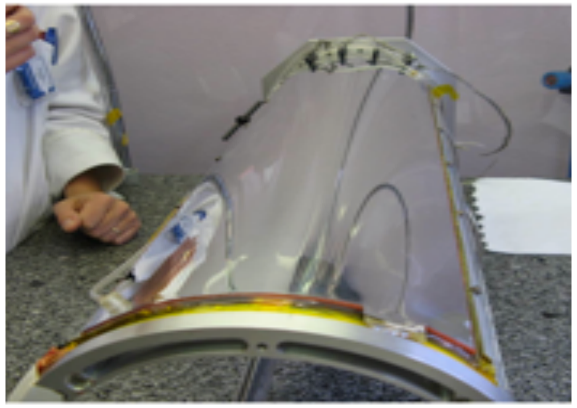
✳ High pixel density (FW)
✳ 100-300 μm resolution
✳ Integrated in the CLAS12 base equipment

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







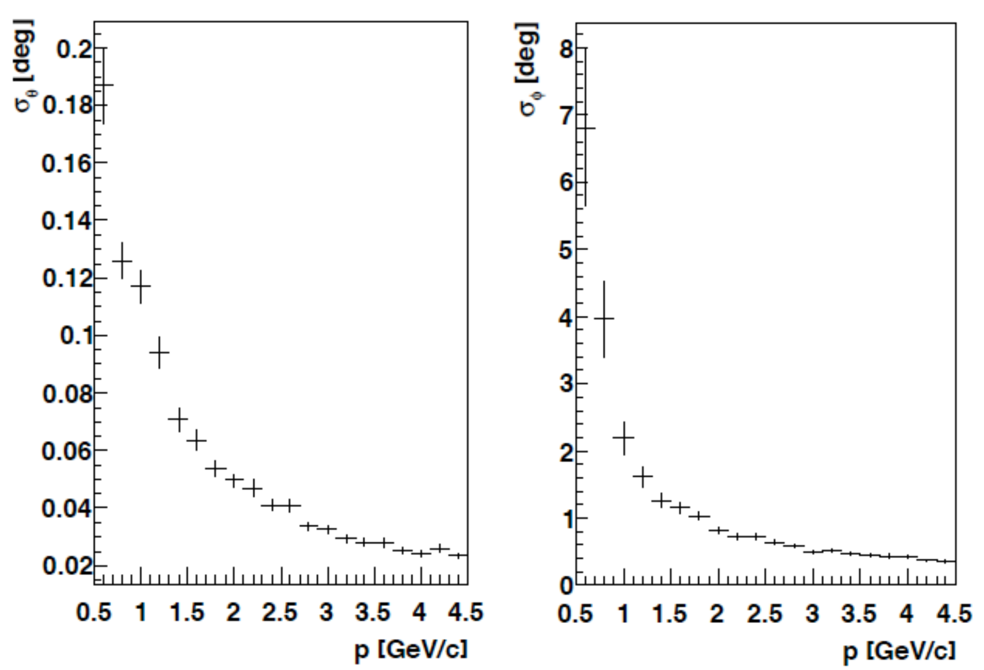


FT-Trck Specs

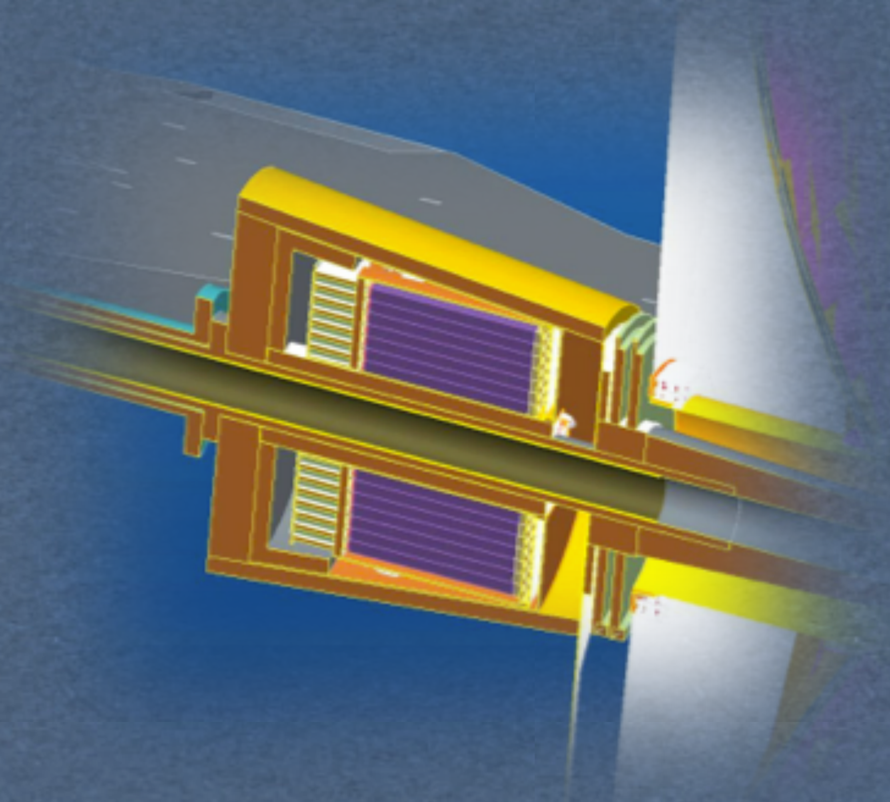
✳ Two double layers of bi-face bulk Micromegas
✳ Pitch: 500 μm
✳ FE electronics: 3392 channels, same FE used for MCT
✳ Services and slow controls shared with MCT
✳ Spatial resolution: < 150 μm

Expected angular resolution of FT-Trck

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



FT components



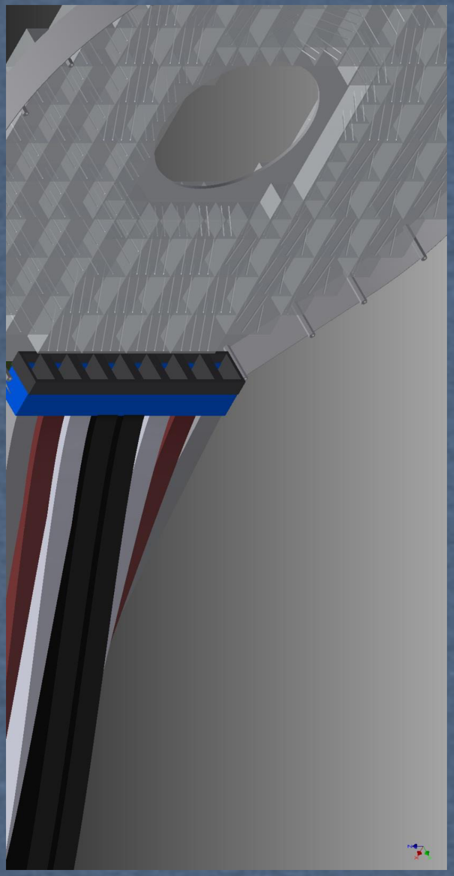
Crystals

Light sensors

Front-end electronics

Cooling

LED Monitoring



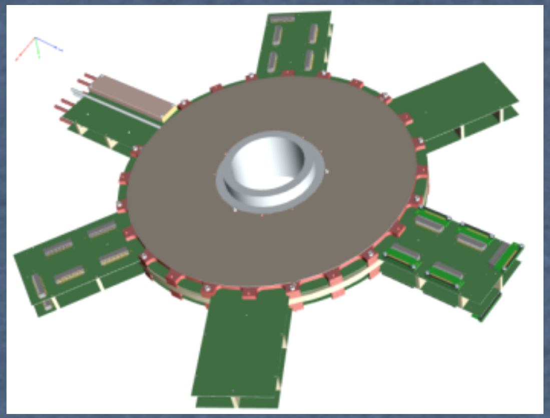
Tiles

WLS + clear fibers

SiPM

Front-end electronics

Monitoring



PCB

Gas system

Front-end electronics

FT Mechanics

Read-out electronics

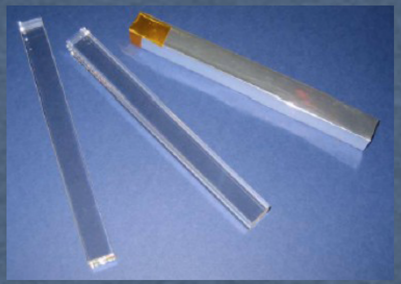
Slow-controls

PbWO crystals for the FT-Cal

Calorimeter requirements

- ✳ Radiation hard
- ✳ Good light yield
- ✳ Energy resolution
- ✳ Time resolution
- ✳ Compact Light read-out

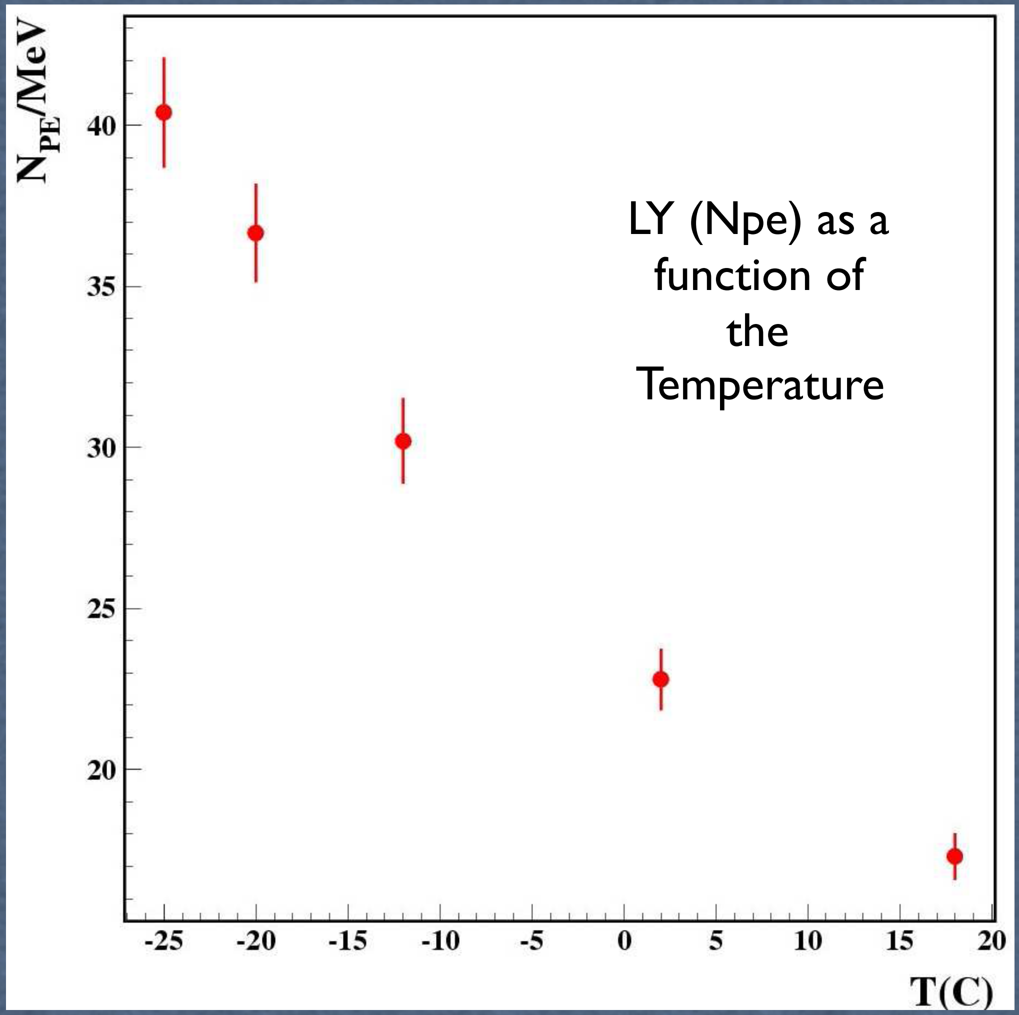
Homogeneous, fast, dense, inorganic-crystals: PbWO4 Type-II

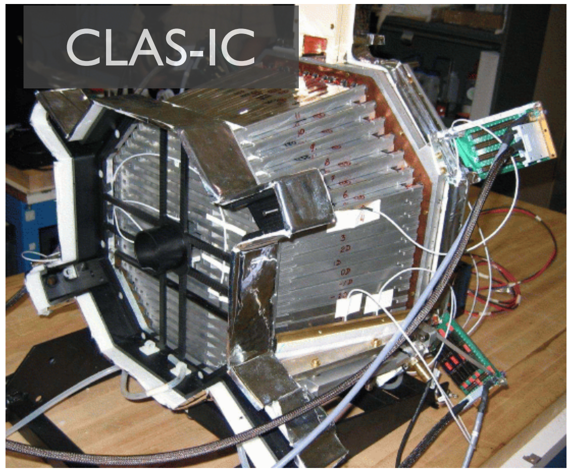


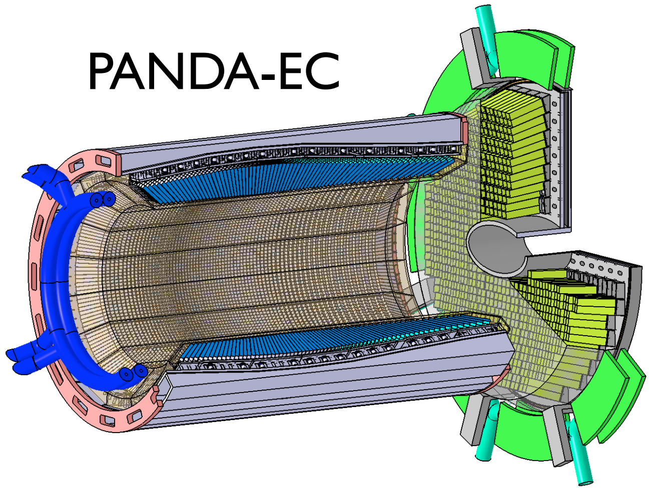
PbWO4

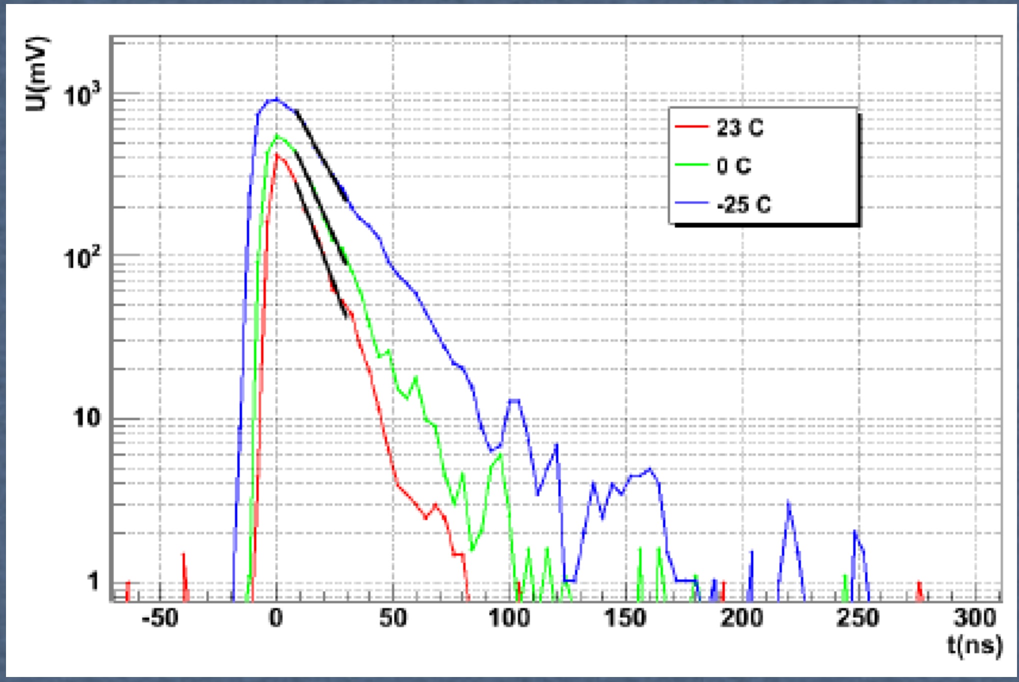
τ_{Decay} ~ 6.5 ns
R_M ~ 2.1 cm
ρ ~ 8.3 g/cm3
X_0 ~ 0.9 cm
light yield 0.3% (LY NaI(Tl))
L.Y. Increased by cooling

- CMS(LHC) ECAL
- ALICE (LHC) PHOS
- CLAS (JLab) IC
- PANDA (GSI) EMC





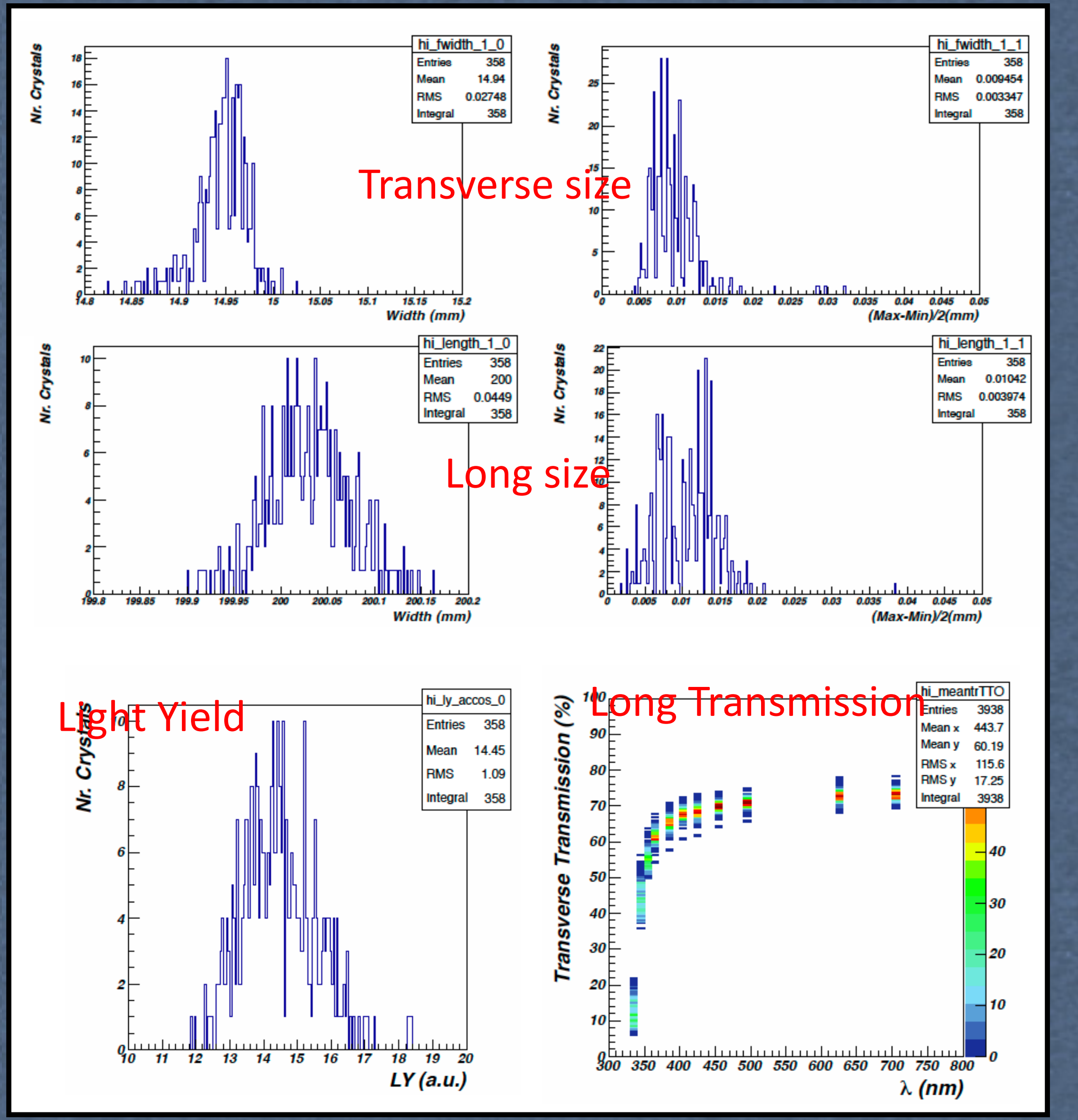


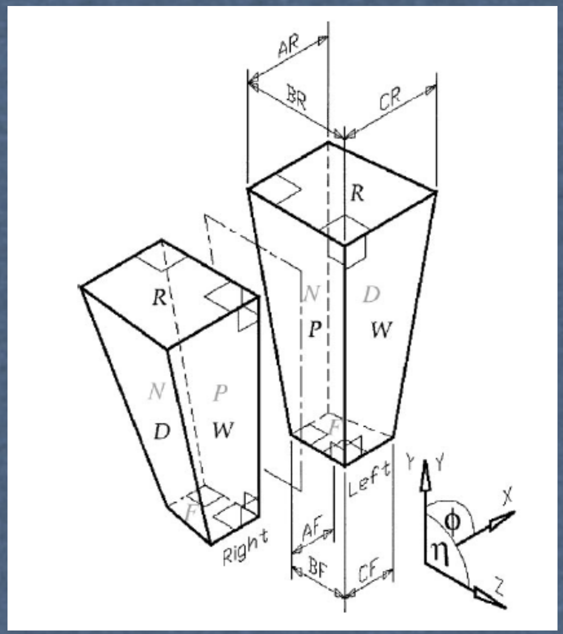


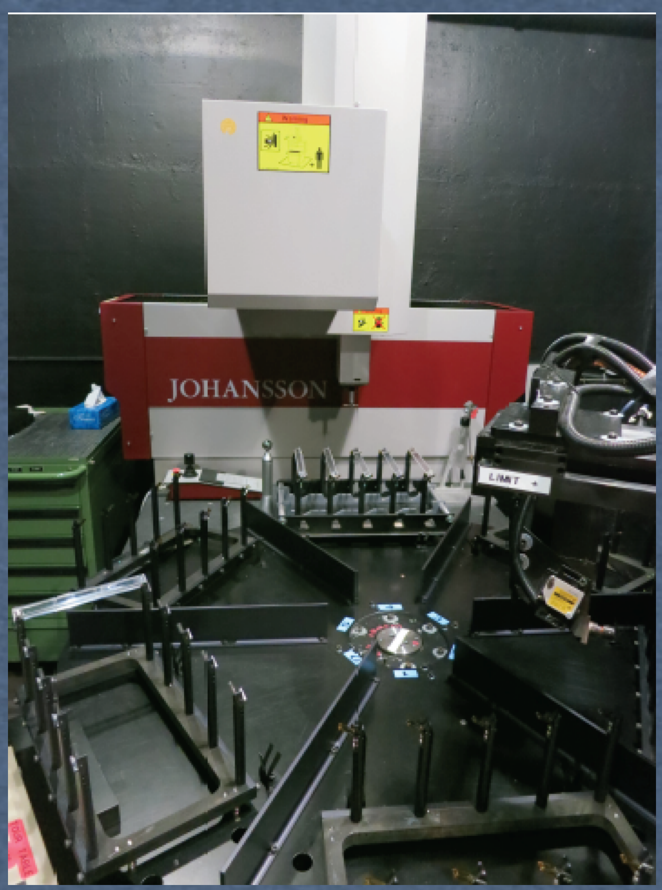
PbWO crystals for the FT-Cal

★ Negotiating for ~ 1year PANDA left-over available at BTCP after bankrupt and with RINC to get crystals (multiple
★ 370 crystals (332 + 38 spares) purchased from SICCAS (Shanghai Institutes of Ceramics Chinese Academy of Science)

★ 20% received damaged
★Extensive tests about specs at ACCOS (CERN) (25% out of specs)
★~1 year to get all crystals in house



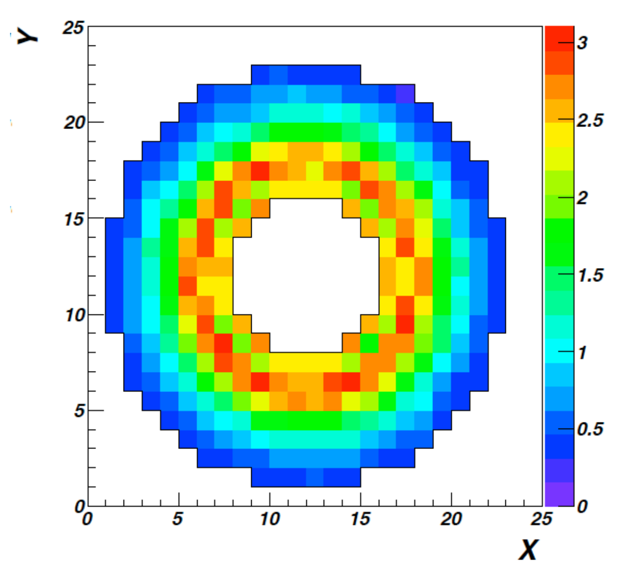




PbWO crystals for the FT-Cal

★ Radiation hardness is a critical parameter for the FT-Cal

Full luminosity: $L_e \sim 10^{35}$ cm^{-2} s^{-1}



FT-Cal (Rad/h)

★ Irradiation orginally planned for a sample of crystals at CERN

★ Due to the inconsistent results from the sample and the SICCAS numbers, we decided to characterises ALL crystals

★ Irradiation performed at the Sthralumcenter of the GIESSEN University (Germany)

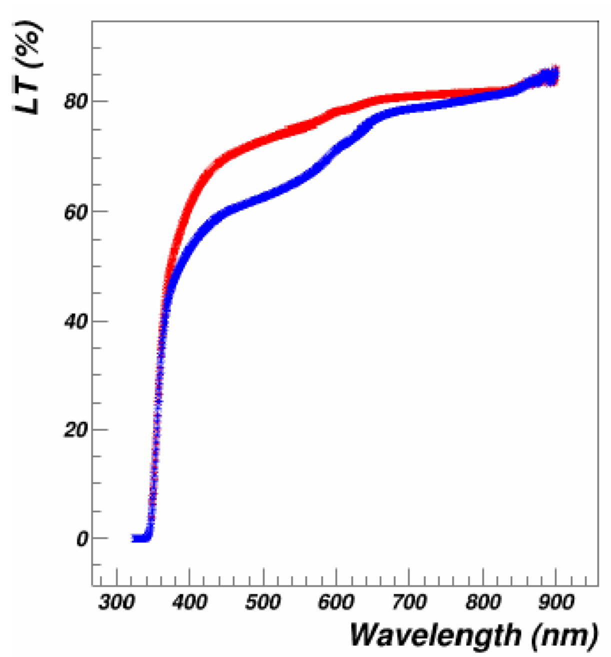
★Co-60 30 Gray (3000 Rad in 20mn) gamma source

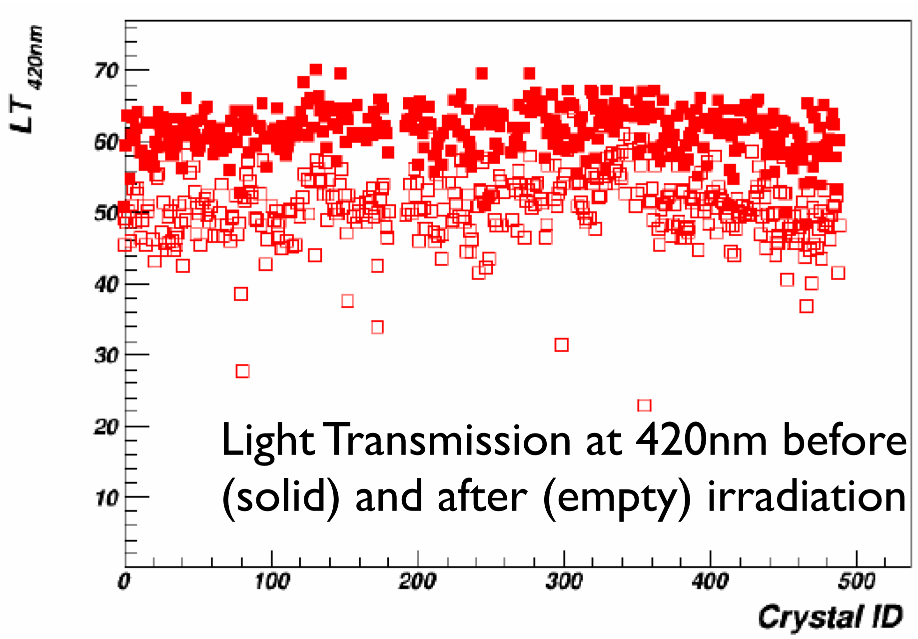
★ Radiation hardness characterised by the quantity dk

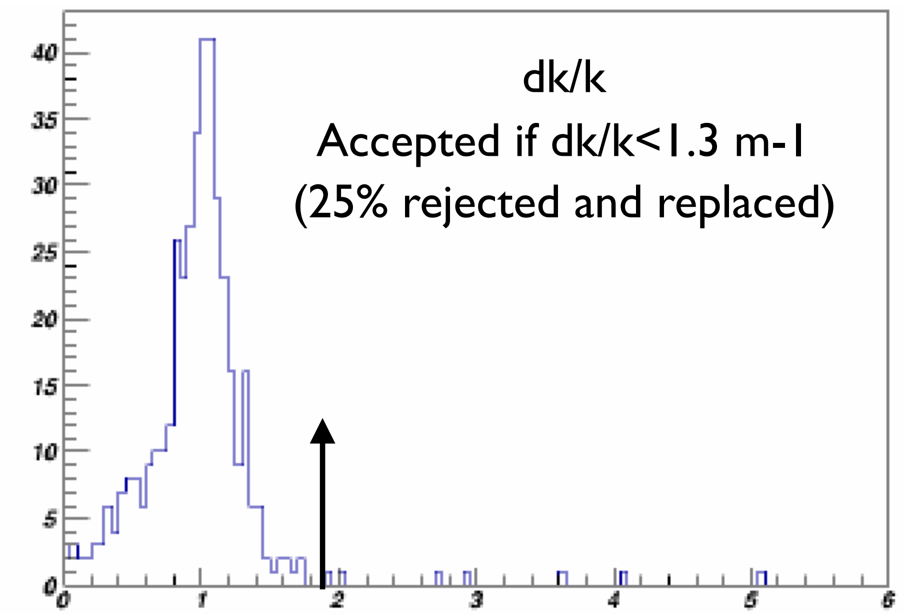
dk = 1/ length ln(Tbef /Tafter)

★Thermal annealing (200C) recovers the original tlight transmission

★ LED monitoring system can be used for crystal recovery







PbWO crystals for the FT-Cal

★ Radiation hardness is a critical parameter for the FT-Cal

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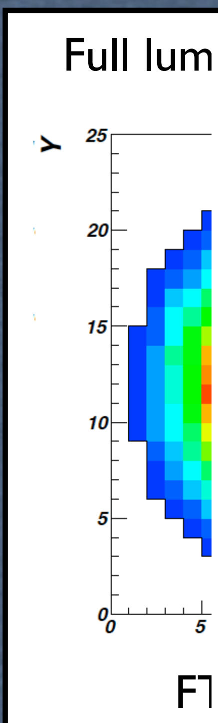

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Assessing the performance under ionising radiation of lead tungstate scintillators for EM calorimetry in the CLAS12 Forward Tagger

S. Fegan [a,*], E. Auffray [b], M. Battaglieri [a], E. Buchanan [c], B. Caiffi [a], A. Celentano [a], L. Colaneri [d], A. D'Angelo [d], R. De Vita [a], V. Dormenev [e], E. Fanchini [a], L. Lanza [d], R.W. Novotny [e], F. Parodi [a], A. Rizzo [d], D. Sokhan [c], I. Tarasov [f], I. Zonta [d]

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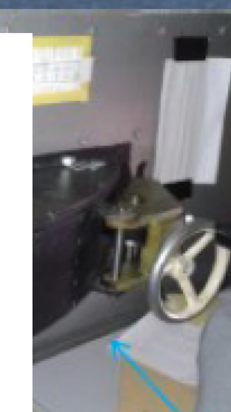
[b] CERN, European Organisation for Nuclear Research, Geneva, Switzerland
[c] University of Glasgow, Glasgow G12 8QQ, United Kingdom
[d] Istituto Nazionale di Fisica Nucleare, Sezione Roma2 Tor Vergata and Università degli studi di Roma Tor Vergata, Via Scientifica 1, 00133 Roma, Italy
[e] II. Physikalisches Institut, Universität Gießen, 35392 Gießen, Germany
[f] GSI Helmholtzzentrum fur Schwerionenforschung GmbH, Germany



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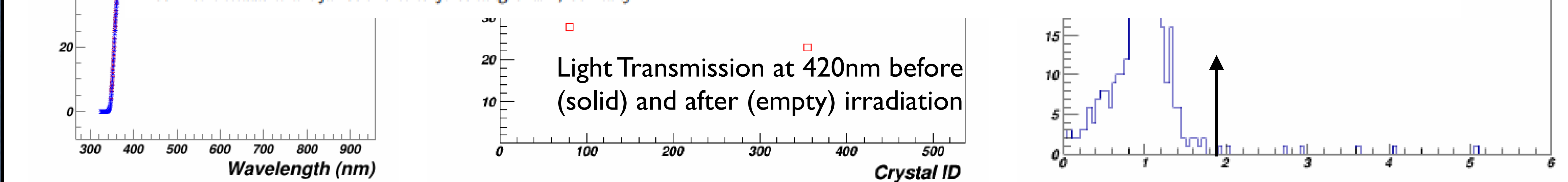
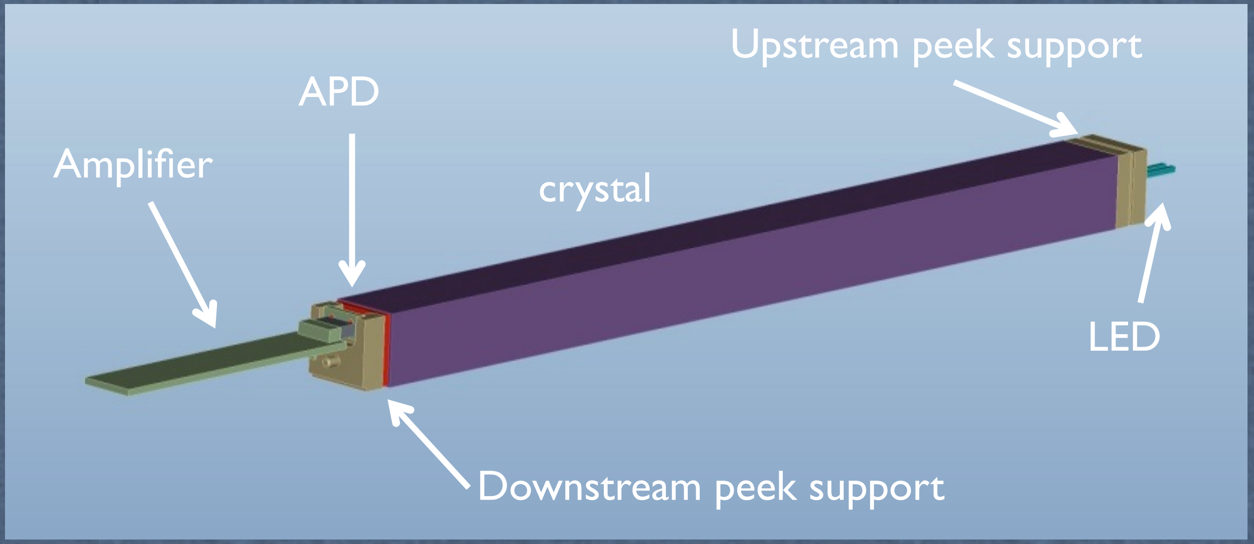
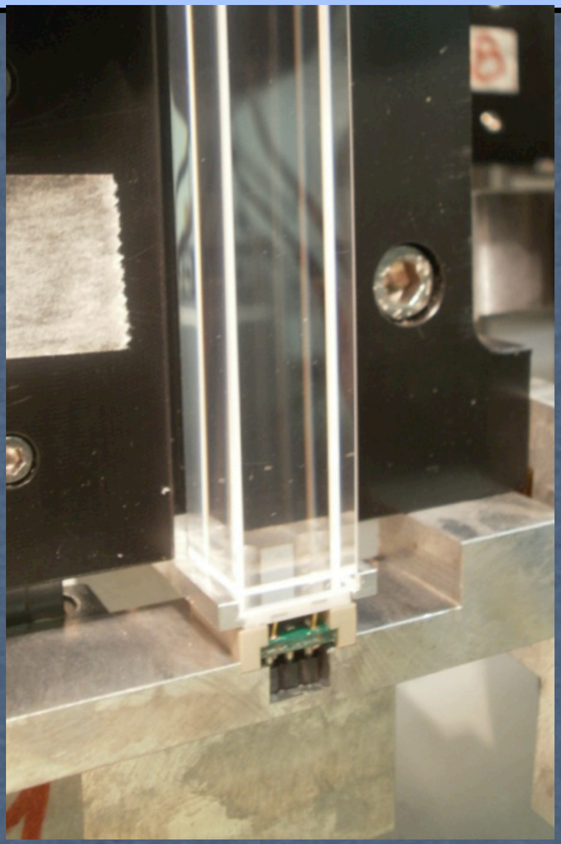
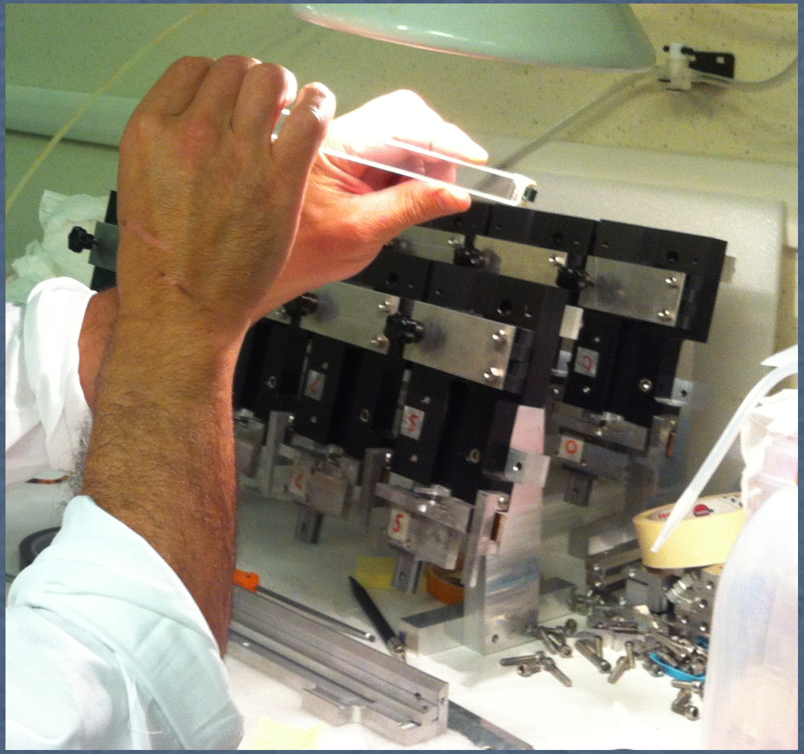


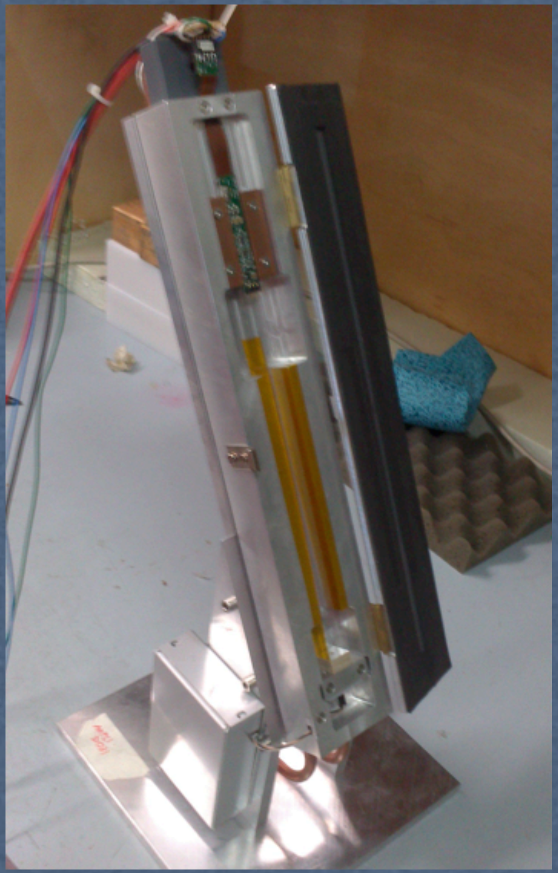
Light Transmission at 420nm before (solid) and after (empty) irradiation

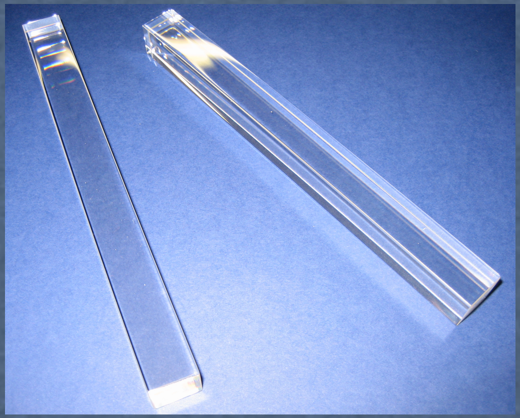
PbWO crystals for the FT-Cal

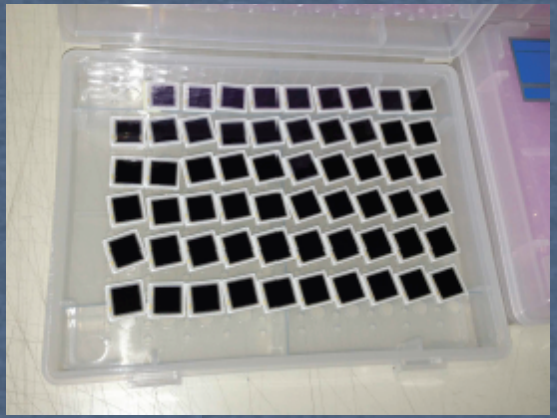




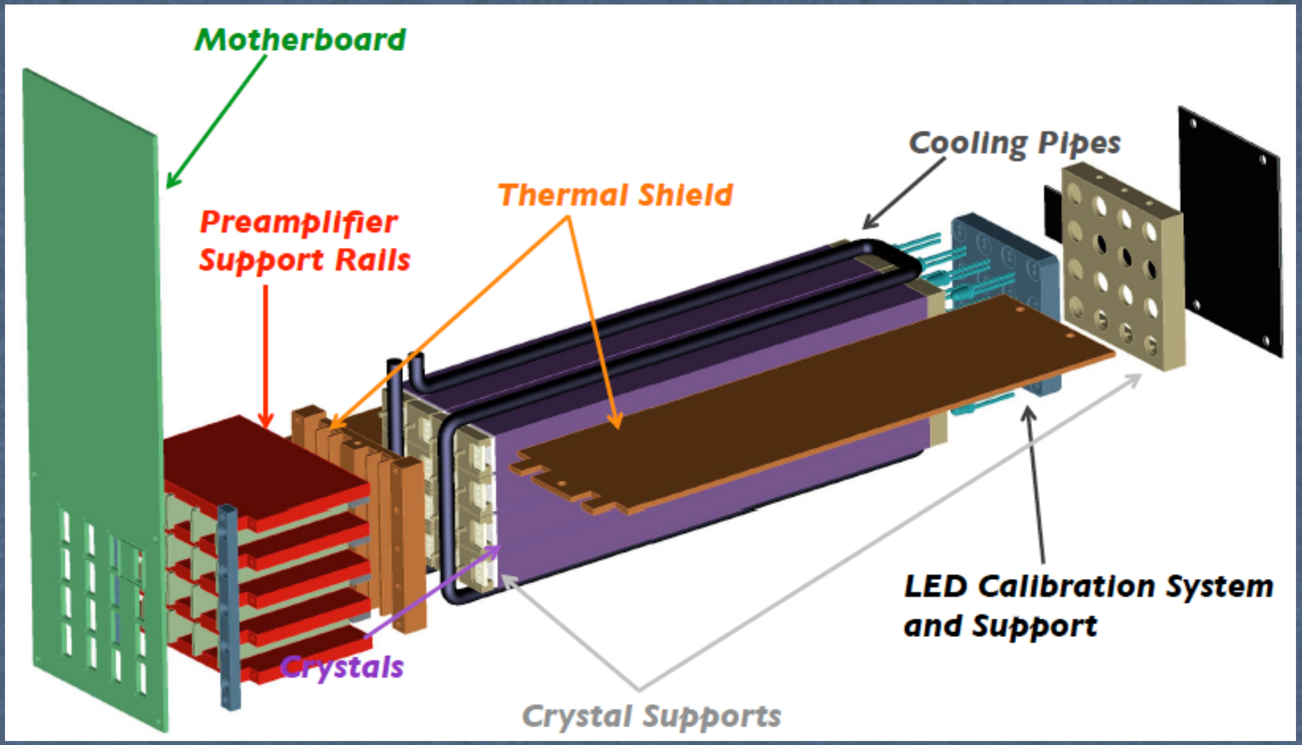






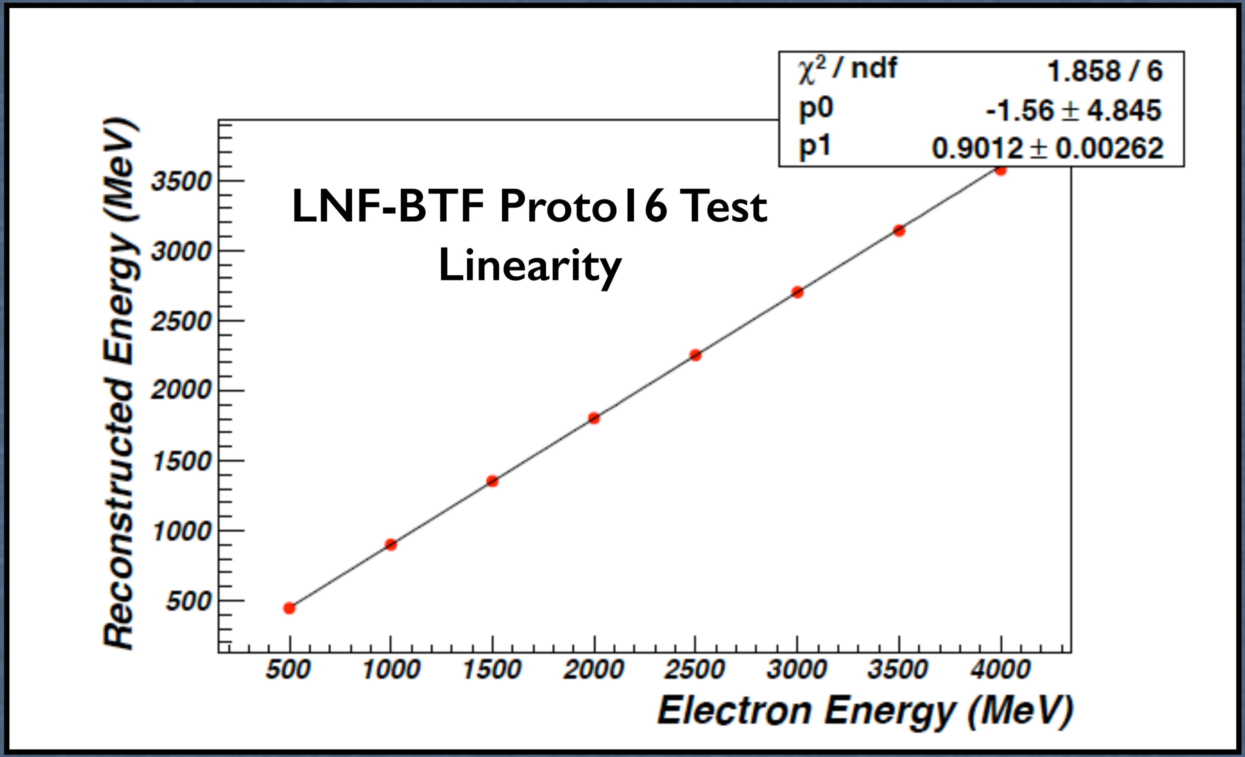


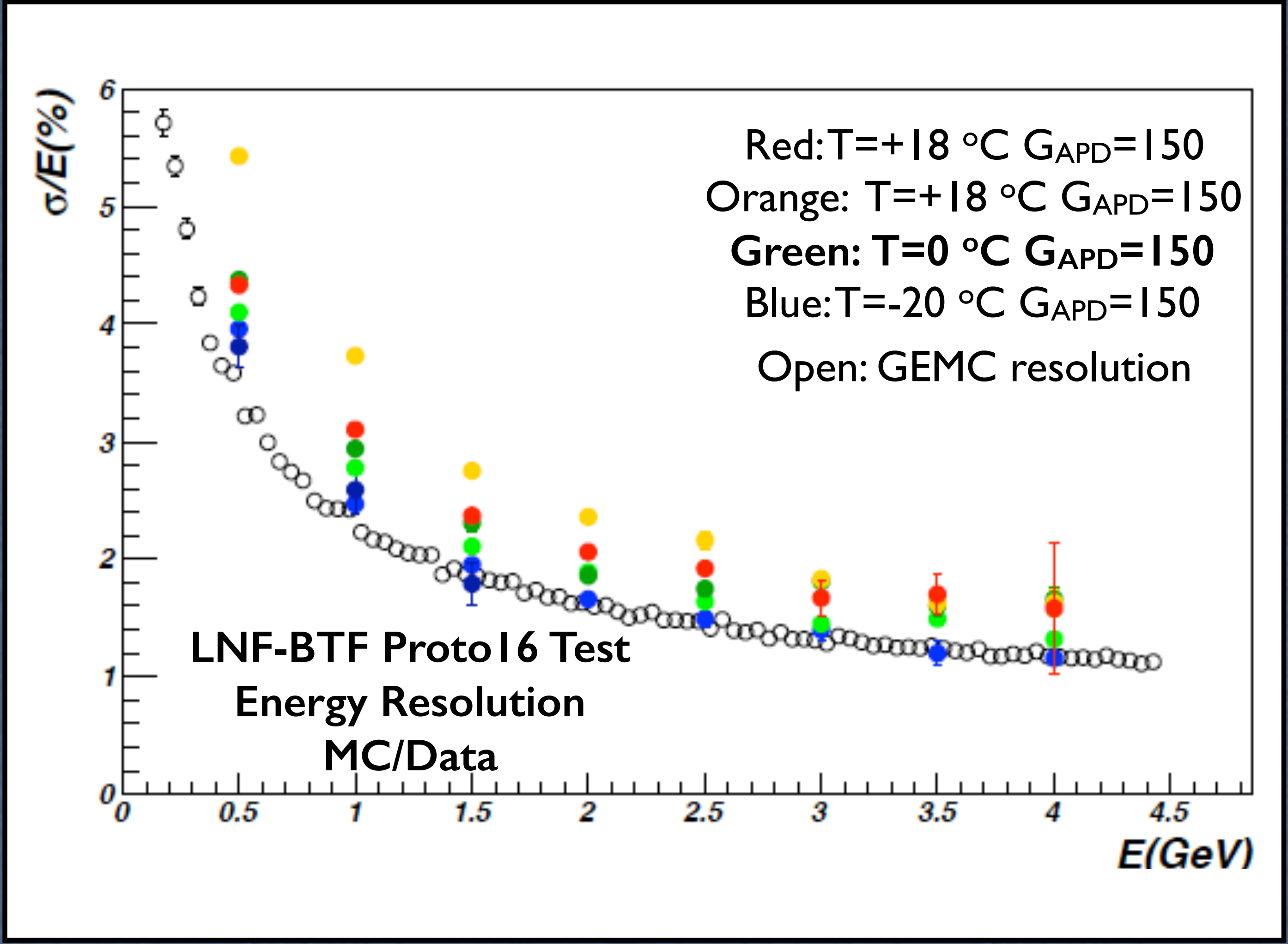
FT prototyping and on-beam tests



FT prototypes

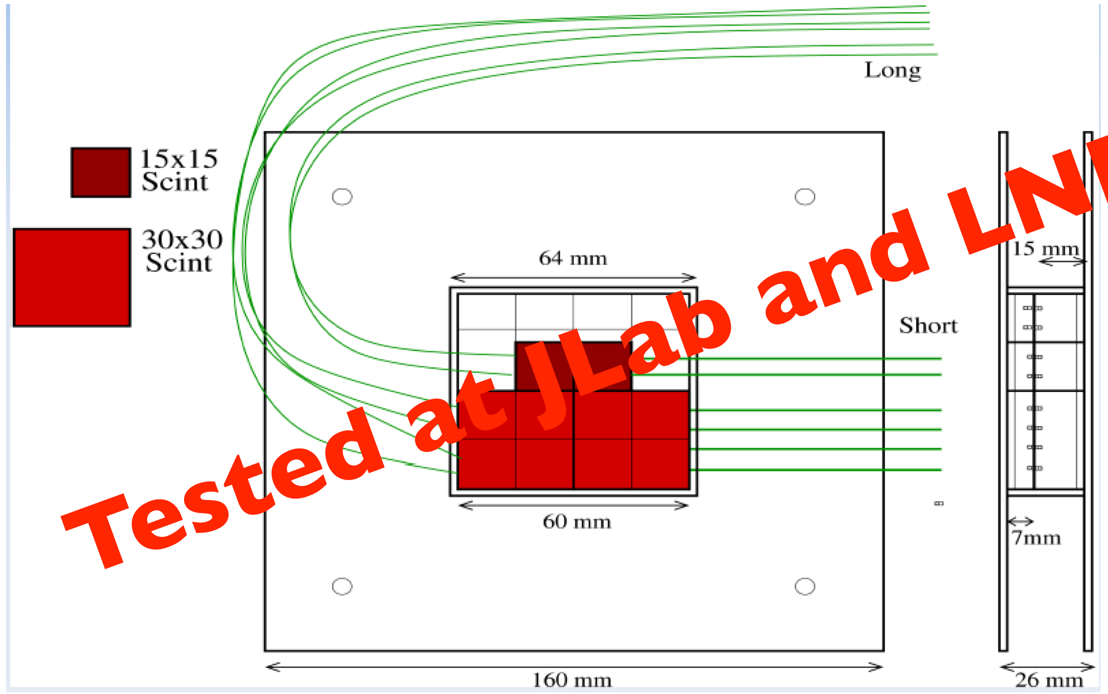
- ✳FT-Cal+FT-Hodo
- ✳Proto9 (3x3 matrix) tested at Jlab
- ✳Proto16 (4x4 matrix) at LNF-BTF
- ✳ Mechanical improvement since preliminary design
- ✳Expected energy resolution and linearity
- ✳MC validation

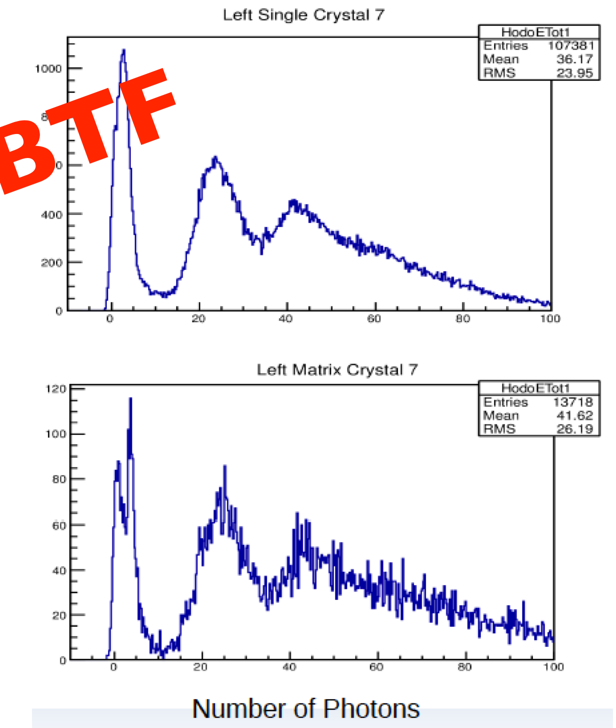




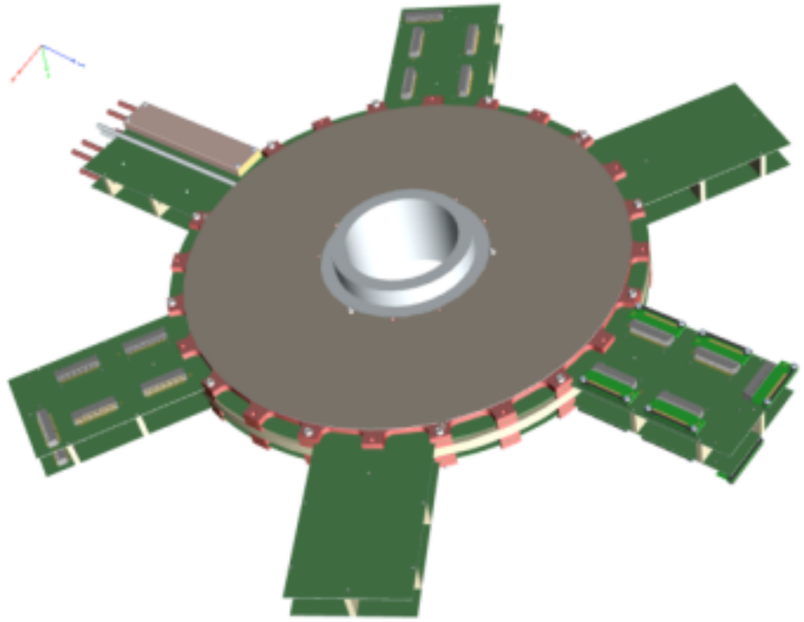
FT prototyping and on-beam tests

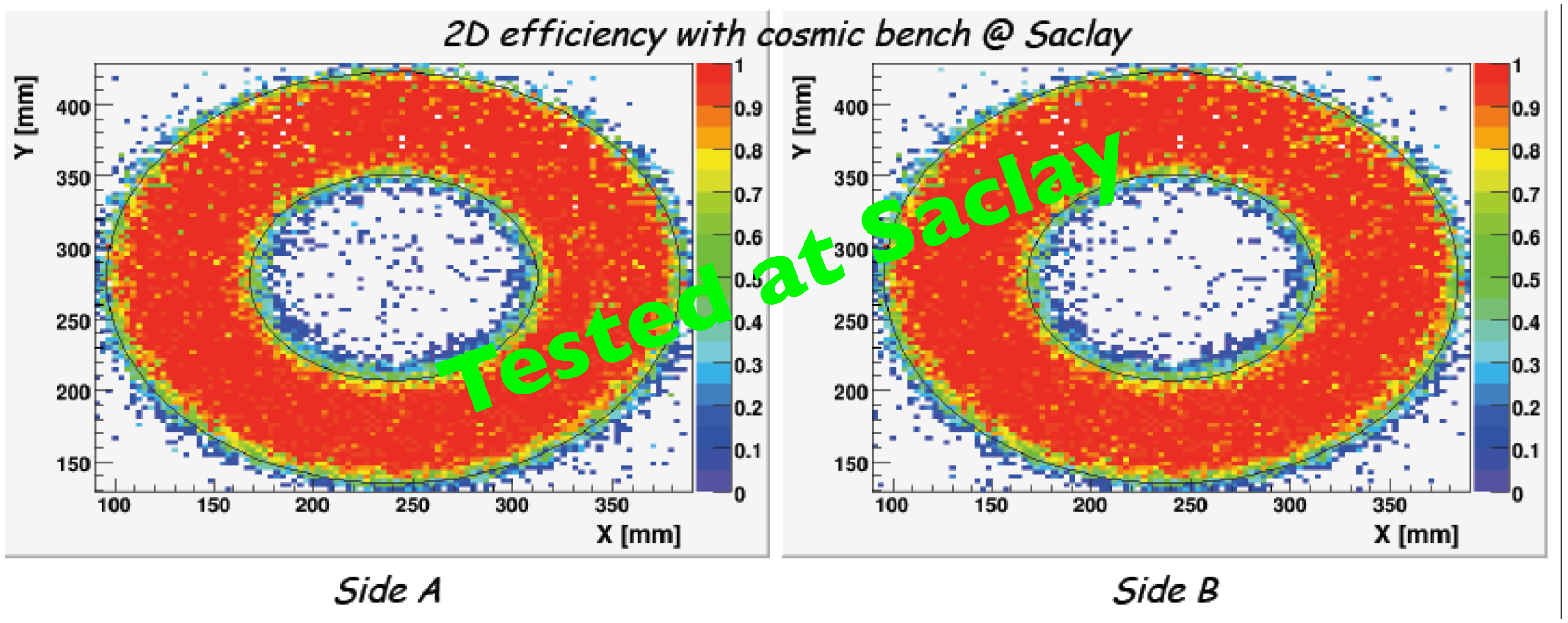
FT-Hodo prototype





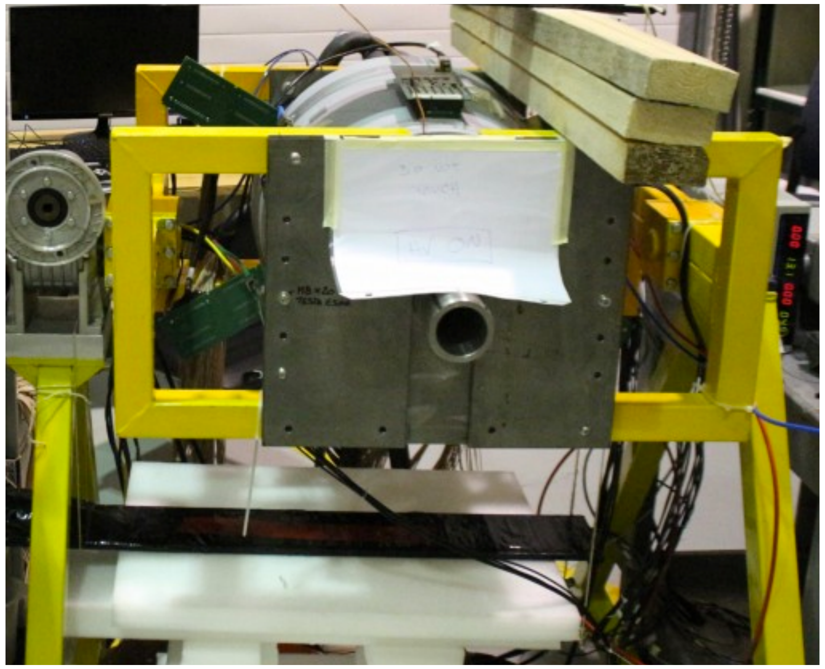
FT-Trck prototype



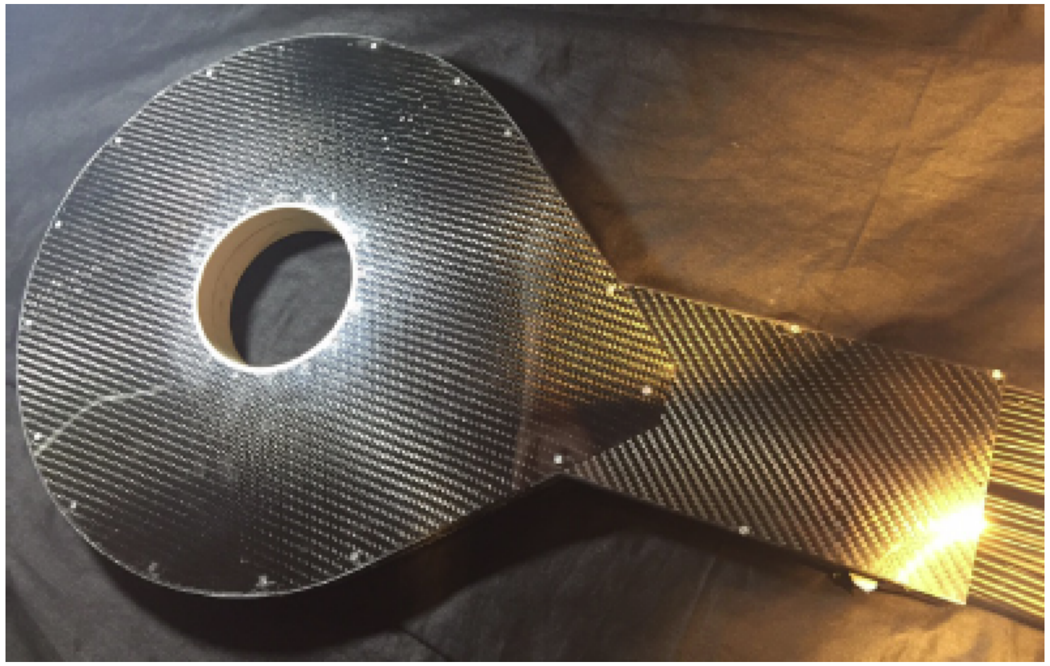


FT hardware: status and plans (I)

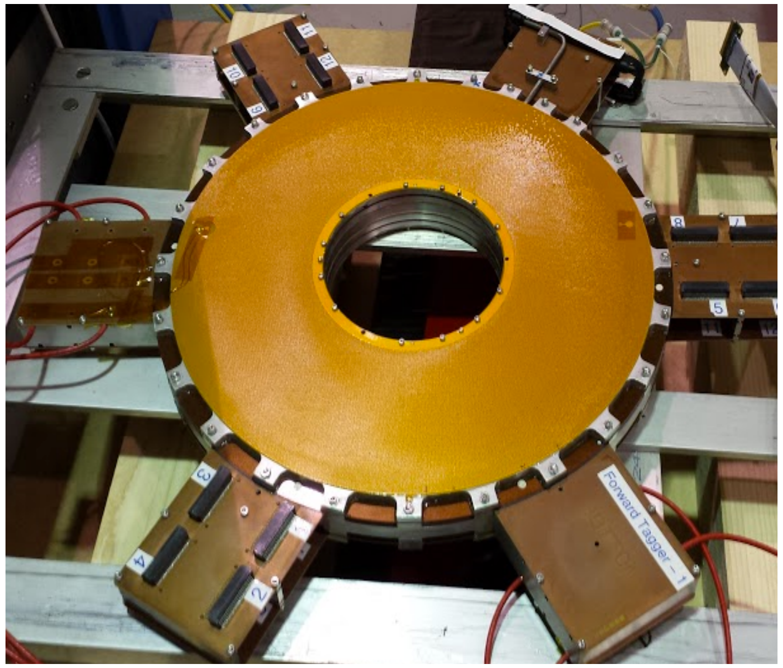
FT-Cal



FT-Hodo



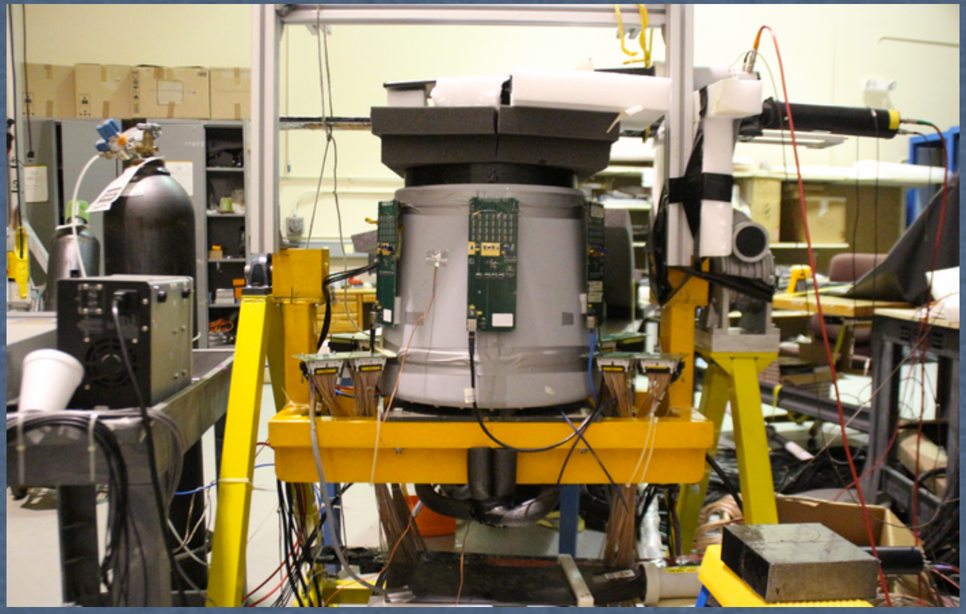
FT-Trck



JLab
EEL building

- FT-Cal: assembled at JLab, cabled and connected to DAQ, tacking cosmic data
- FT-Hodo: assembled at JLab, cabled and connected to DAQ, tacking cosmic data
- FT-Trck: being assembled at Saclay, DAQ ready, cosmic tests expected for March

- FT-Cal + FT-Hodo implemented in the same DAQ configuration and tacking cosmic data in vertical position



FT DAQ and Slow Controls

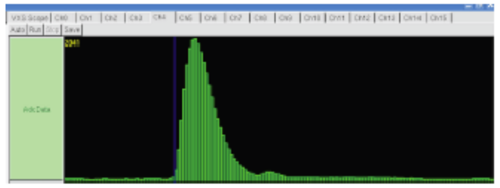
HV/LV/T Chiller GUI

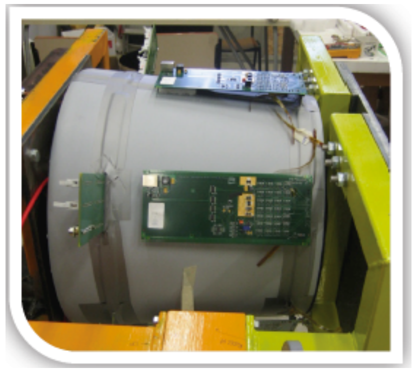
- HV/LV controls using the final cables
- Chiller interfaced to Epics
- Temperature control (not yet connected)
- FT-Hodo HV/LV control in progress

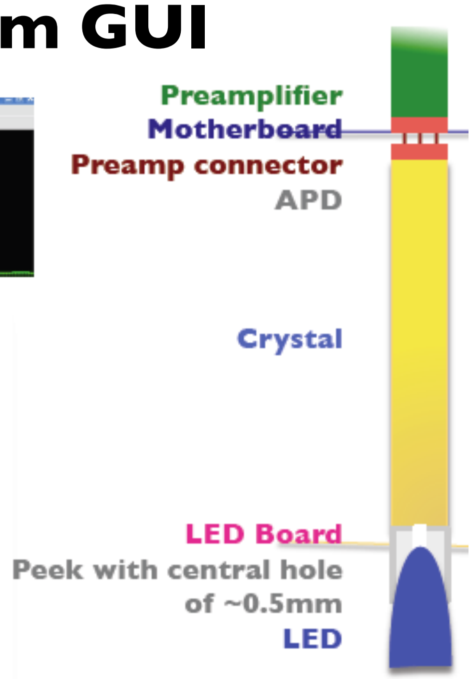
★ **FT-Cal and FT-Hodo connected to fADC and implemented in CODA**

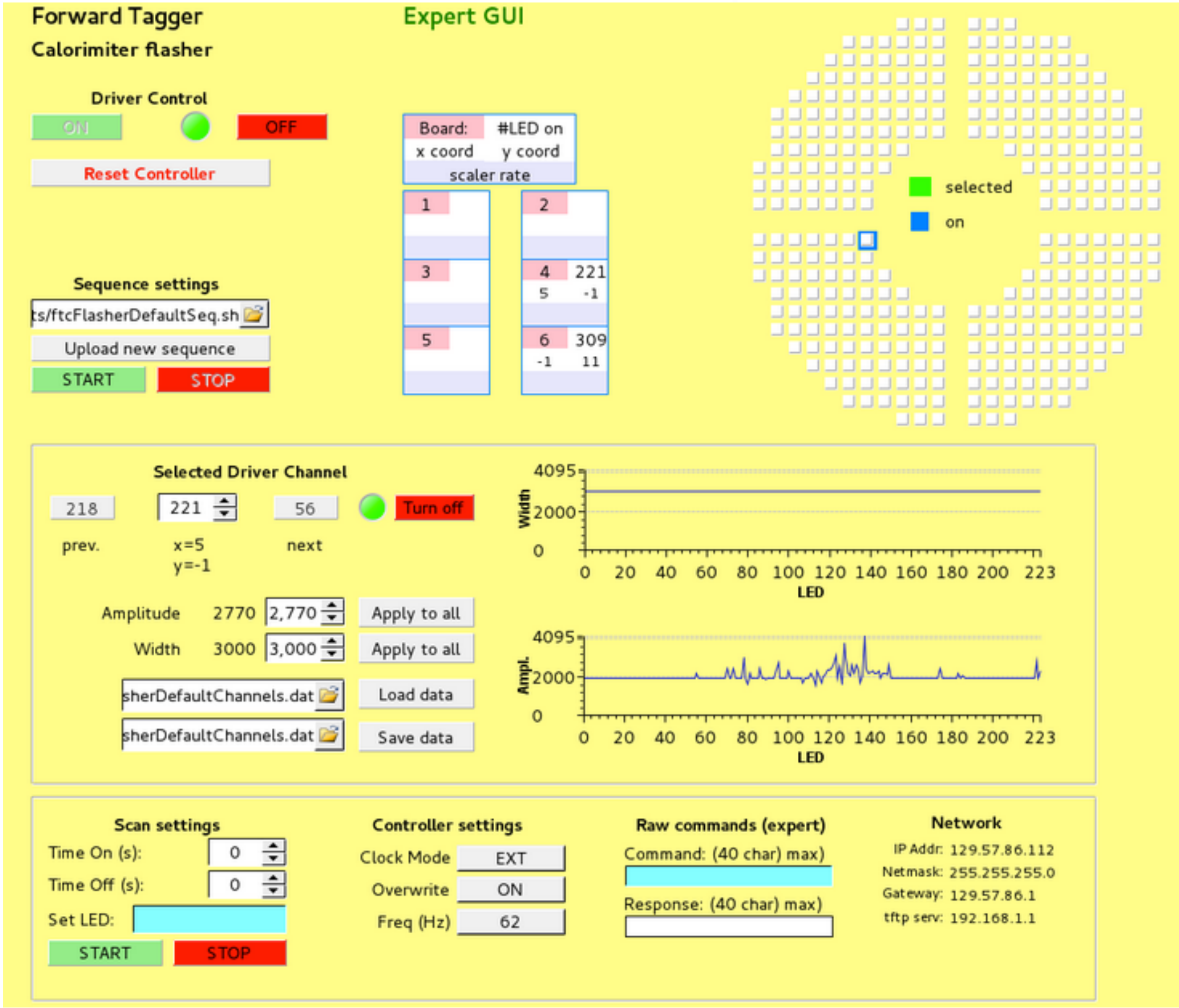
LED Monitoring System GUI

- Fast and easy to check crystal + DAQ
- Planned regular runs to check stability



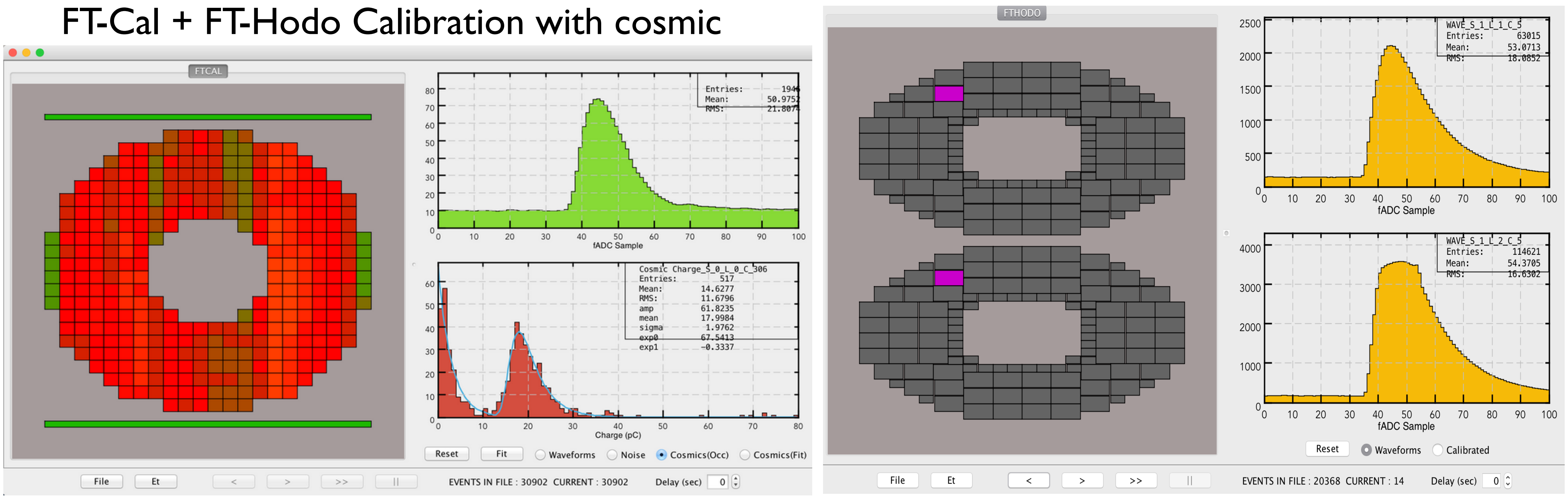






FT hardware: status and plans (II)

FT-Cal + FT-Hodo Calibration with cosmic



- Implement .OR. trigger from FT-Cal fADCs
- Implement .AND. trigger from FT-Cal.and.FT-Hodo fADCs
- FT-Cal preamps replacements and inner W pipe removal
- Include the FT-Trck in the FT mechanical assembly
- Include the FT-Trck in the RO list
- Take cosmic data with the whole FT

JLab EEL building

March

April/May

June

summer

- Move the electronics to the Hall
- Move the FT to the Hall and integrate in CLAS12
- Take cosmic data to check the final configuration

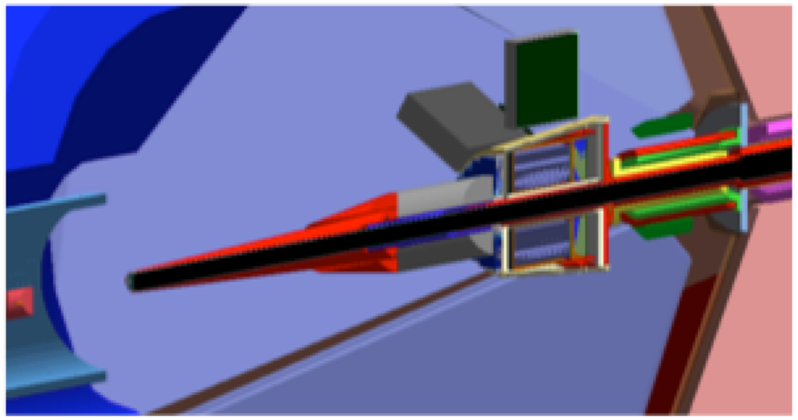
JLab Hall-B

after summer?

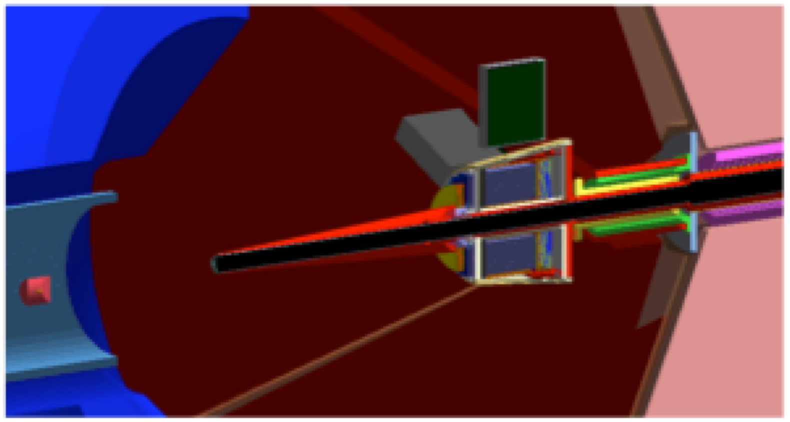
FT in CLAS12

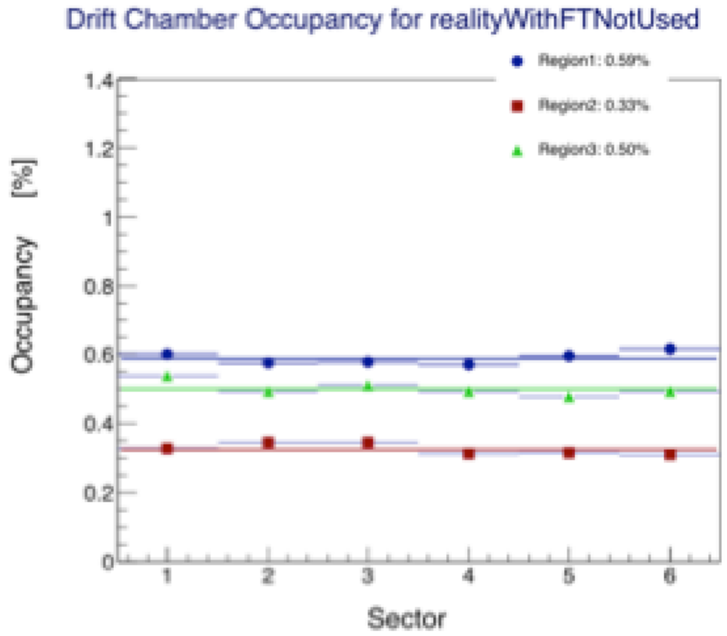
Summary: two configurations

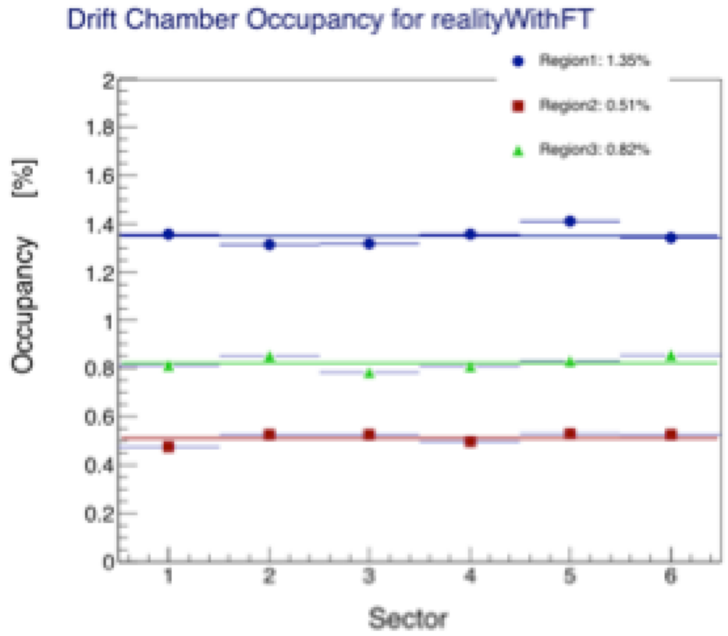
I) FT in place and shielded



II) FT in place and operational



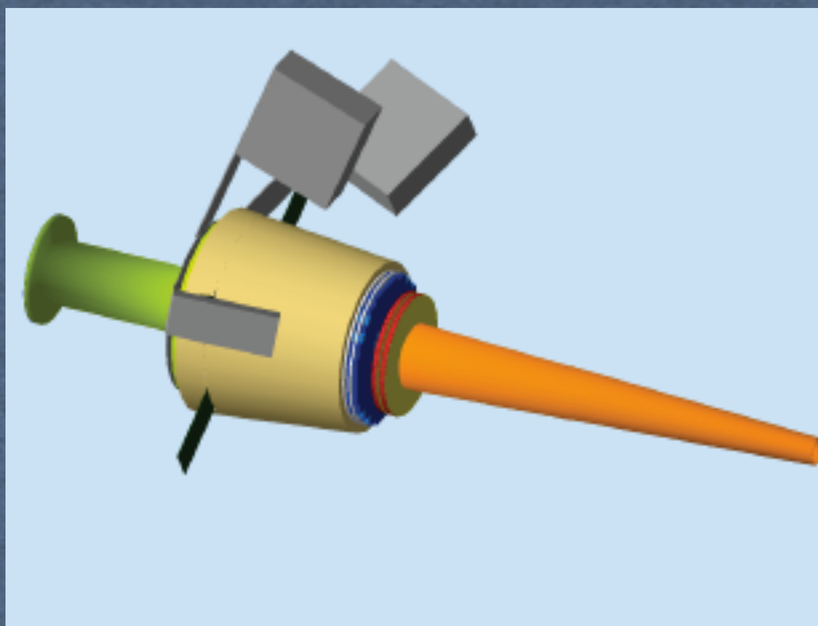




Same FT shield can be used when FT is not in used.
Removal of FT tracker has minimal schedule impact

M.Ungaro
R. De Vita
First CLAS12 Experiment Workshop
JLab - Feb 24 2016

FT software: status and plans

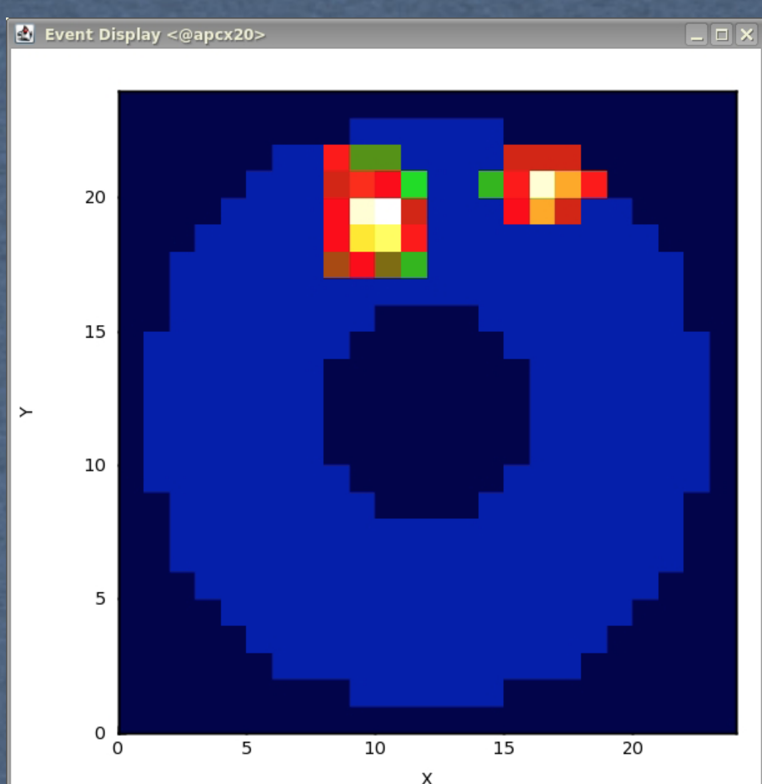


MC

- Full implementation on GEMC 2.X (geometry, digitisation, output)
- To be done: EVIO hybrid banks, geometry from DB …

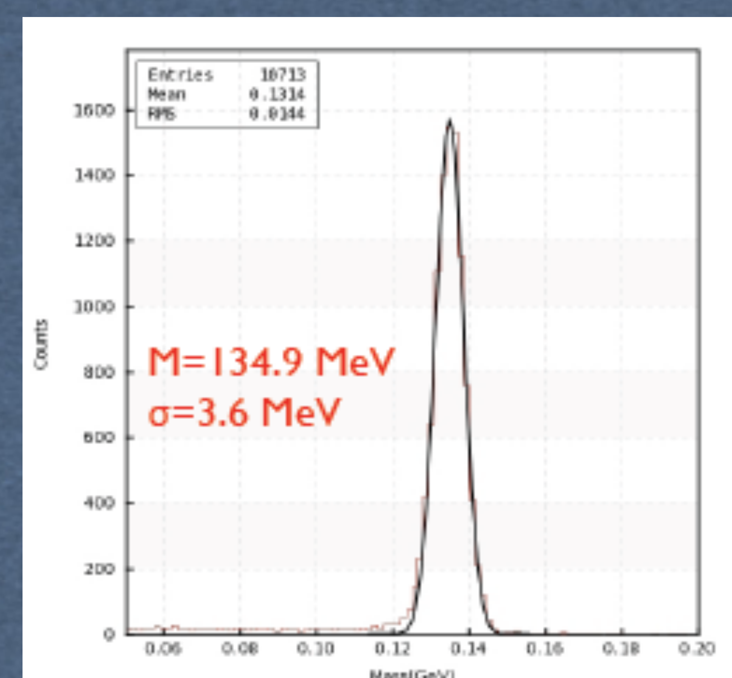
REC

- FT-Cal: data reading, hit processing, cluster reconstruction
- FT-Hodo: data reading, hit processing, layers matching
- FT-Trck: algorithm developed, implementation just started …
- FT matching and final banks output: in progress



An example: pi0 reconstruction

- FT reconstruction packaged tested on simulated events with full CLAS12 geometry
- Generated events: e p → e p π0
- Analysis of reconstructed events focused on low angle pi0 with either one or both gammas in the FT



- Momentum and angles are correctly reconstructed

Preparing the MesonEx physics data analysis

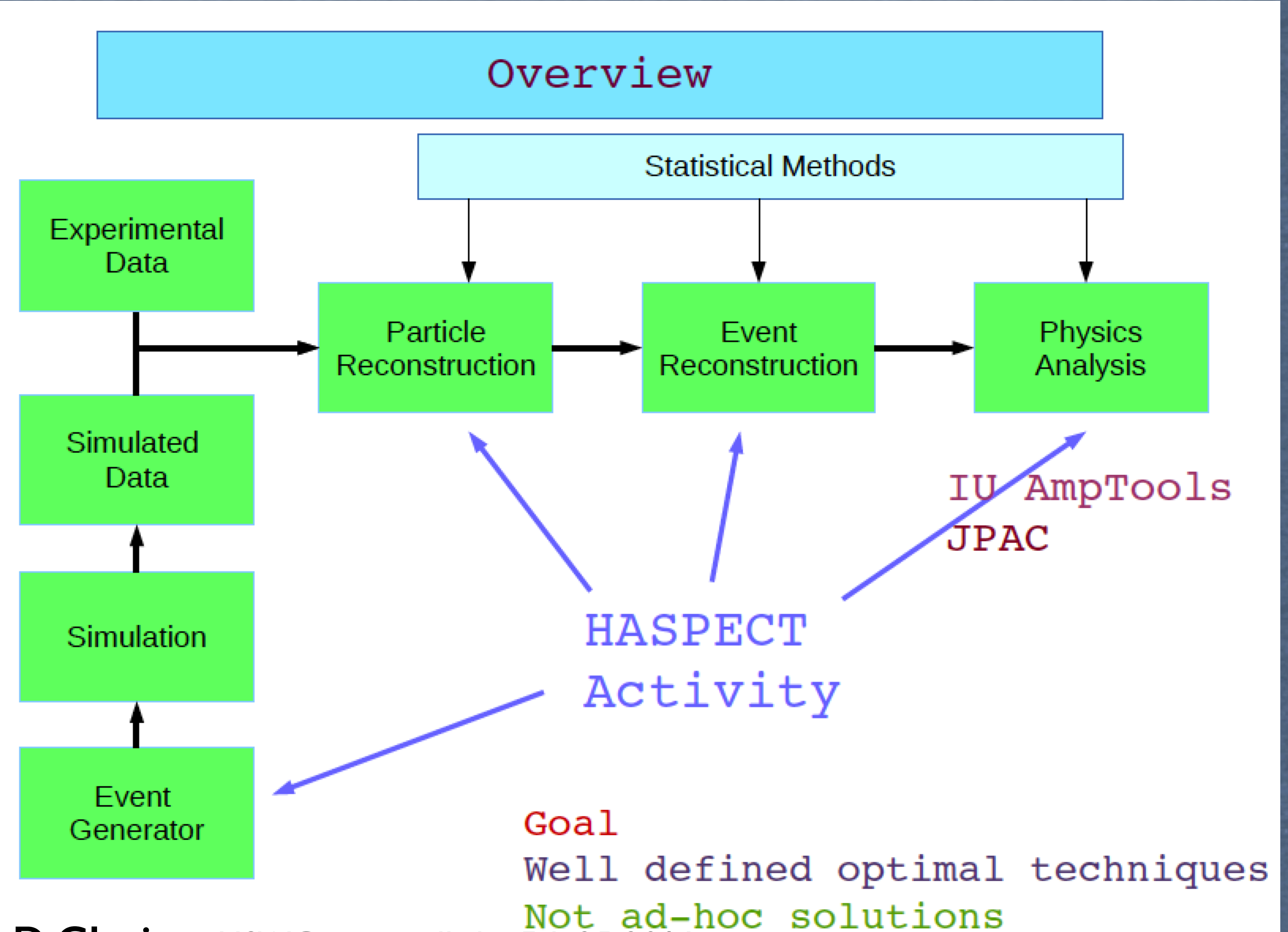
I) Setting up MesonEx analysis framework (now)

★ Systematic approach
★ Common analysis framework
★ JPAC involvement
★ Simple MC incorporationg physics
★ GEMC and CLAS12 reco sw
★ CLAS6 data to understand bg
★ Trigger studies

$\gamma p \to n\, \pi^+$
$\gamma p \to p\, \pi^0$
$\gamma p \to p\, \pi^+ (X)$

$\gamma p \to N\, \pi\, (\pi)$
$\gamma p \to N\, \omega, \eta, ..$
$\gamma p \to N\, \pi\, \pi\, (\pi)$
$\gamma p \to p\, \varphi$
$\gamma p \to N\, M$

$\gamma p \to N\, K\, K$
$\gamma p \to N\, K\, \pi$
$\gamma p \to N\, K\, \pi\pi$

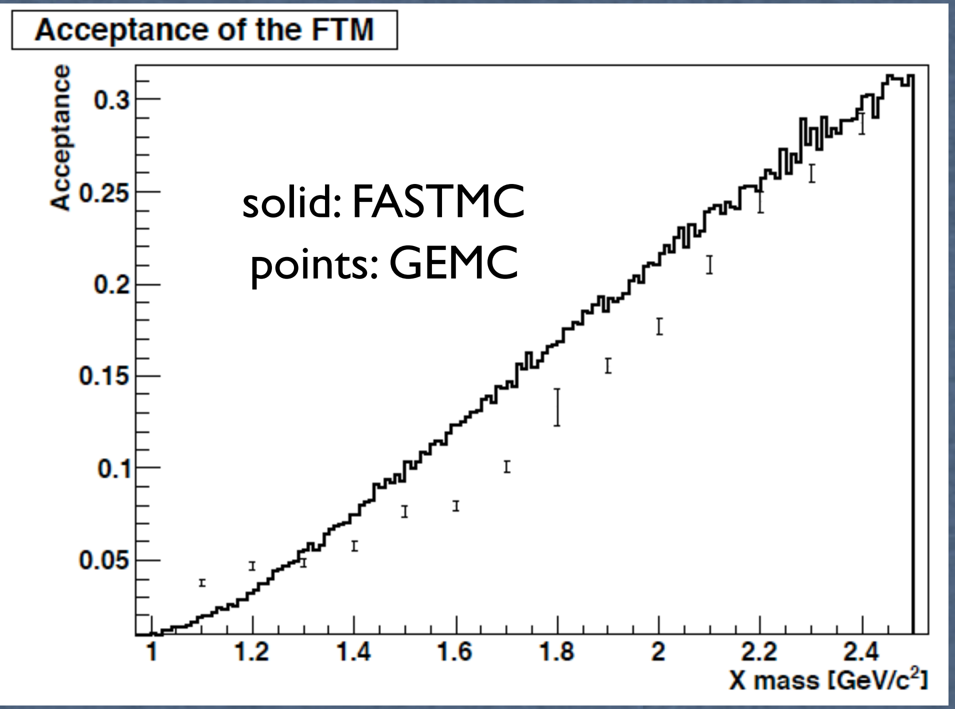


D.Glazier *HSWG meeting JLab - Feb 25 2016*

FT Reconstruction and Partial Wave Analysis (PWA)

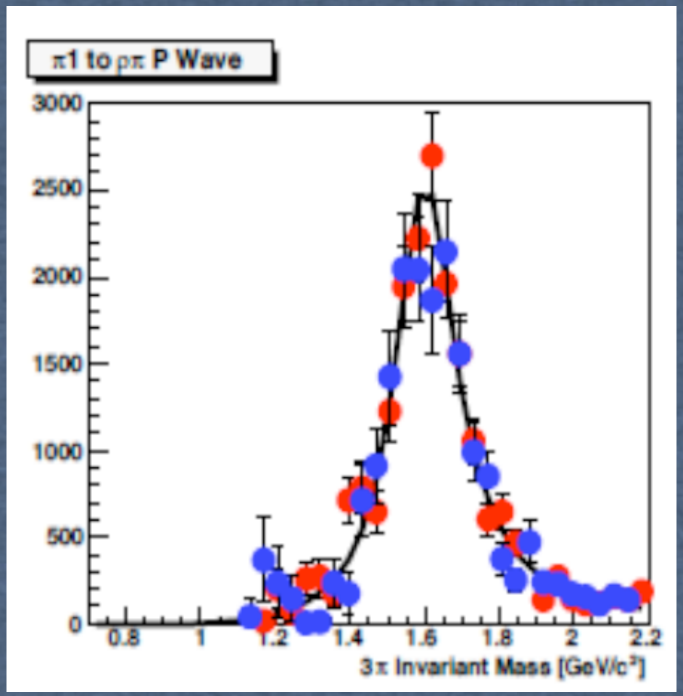
Reference reaction
$\gamma\, p \rightarrow (n)\, \pi^+ \pi^+ \pi^-$

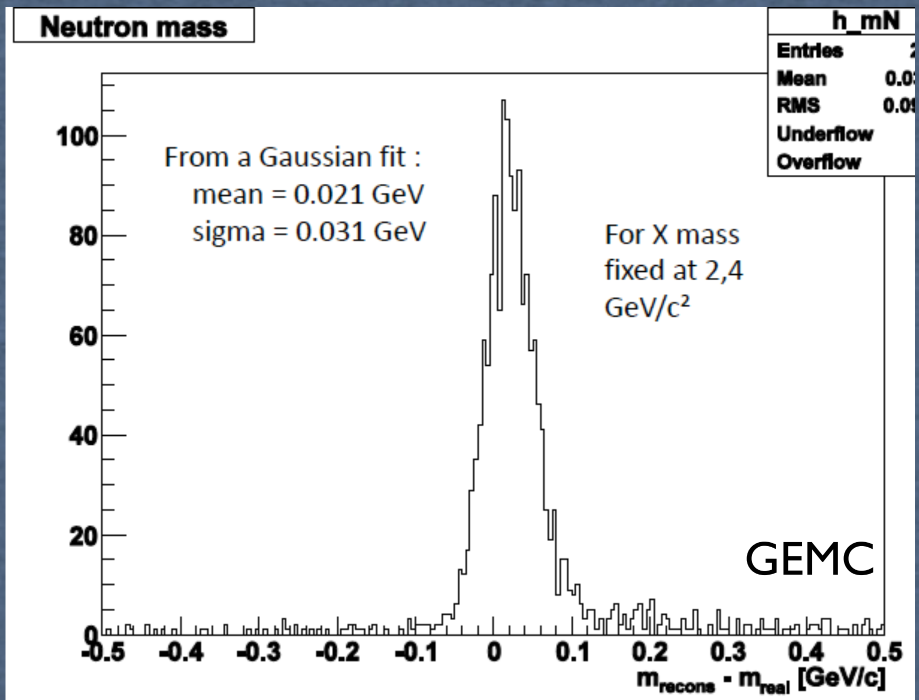
- Exotic wave $X \rightarrow \rho\, \pi^+ \rightarrow \pi^+ \pi^+ \pi^-$ ($J^{PC} = 1^{-+}$) 2.5 % of the total
- Events projected onto CLAS12 (GEMC) and fitted with the recon software (PWA)
- Statistics correspond to few days of running



Reconstruction

- Full reconstruction tested on pseudo-data (FT-Cal+FT-Hodo +FT-Trk) using both FASTMC and GEMC
- Rates, efficiencies and resolutions with the full CLAS12 gen/rec chain





Data analysis work-plan

II) Data analysis commissioning

- ★ Use known reactions for calibration and data quality assurance
- ★ Compare results from CLAS6 in the overlapping kinematics
- ★ First measurement polarised vector meson photoprodution
- ★ Demonstrate quasi-real photoproduction is well understood
- ★ Demonstrate effect of linear polarisation on production mechanisms
- ★ Compare to GlueEx or existing data

III) Data analysis

- ★ Extract ‘easy’ observables: SDME, Xsec, Dalitz plots, Moments and, eventually, Partial Wave Analysis

Physics output

- ★ Simple Moments analysis - extended kinematics
- ★ Exploiting linear polarization (asymmetries)
- ★ Spin Density Matrix Elements (SDME)
- ★ longitudinal plots
- ★ Testing Dalitz with new amplitudes (Veneziano)
- ★ [Xsection in the extended kinematics (Eg=6-11 GeV) ?]
- ★ Mesons never observed in photoproduction (narrow peaks)

D.Glazier talk tomorrow at the HSWG Meeting!

Summary

✳ The FT will extend the CLAS12 electron and gamma acceptance at low angles

✳ Low-Q2 (quasi-real) photons will be available in Hall-B for MesonEx, Very Strange and other proposals

✳ The three detectors composing the FT, calorimeter, hodoscope and tracker were designed based on reliable technologies (PbWO, plastic scintillator, micrometega)

✳ Despite the relative size of the detectors, they are quite sophisticated and a thorough R&D on components has been necessary

✳ Technical solutions have been tested on detector prototypes off- and on-beam providing good agreement with simulations

✳ FT-Cal and FT-Hodo now deployed in EEL building at JLab, FT-Track will be soon testing all ancillary controls and sub-systems with cosmic rays

✳ Current effort on calibration and monitoring tools

✳ Setting up the analysis framework to start physics analysis from day-1

✳ Our goal is to have the FT ready to be installed in CLAS12 at early convenience