The Central Neutron Detector for CLAS12:
Status report

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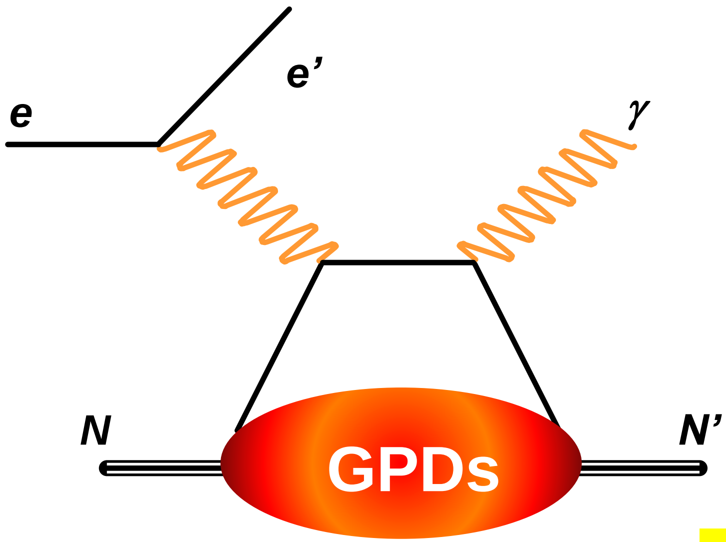
CND: Motivations and requirements



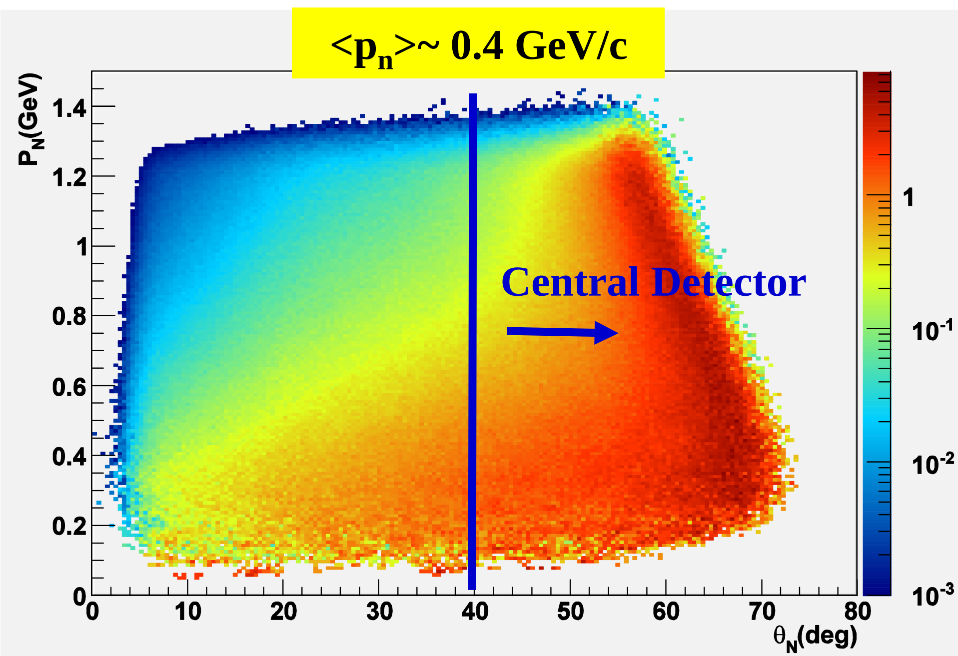
Neutron DVCS with CLAS12:
A combined analysis of **DVCS observables for proton and neutron targets** is necessary for **flavor separation** of GPDs

$$(H,E)_u(\xi,\xi,t) = {}^9\!/_{15}\left[4(H,E)_p(\xi,\xi,t) - (H,E)_n(\xi,\xi,t)\right]$$

$$(H,E)_d(\xi,\xi,t) = {}^9\!/_{15}\left[4(H,E)_n(\xi,\xi,t) - (H,E)_p(\xi,\xi,t)\right]$$

E12-11-003 (BSA for nDVCS): high-impact experiment, for its sensitivity to the GPD E

E12-06-109A (TSA and DSA for polarized nDVCS): PAC44



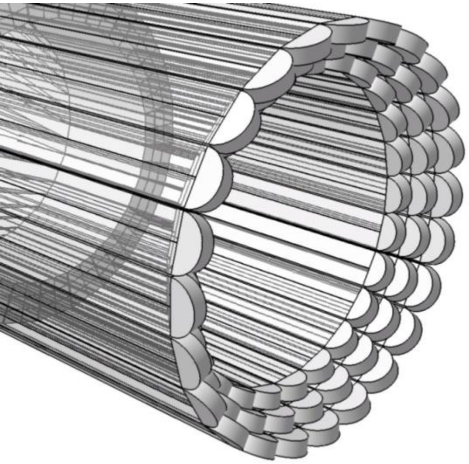
Requirements:

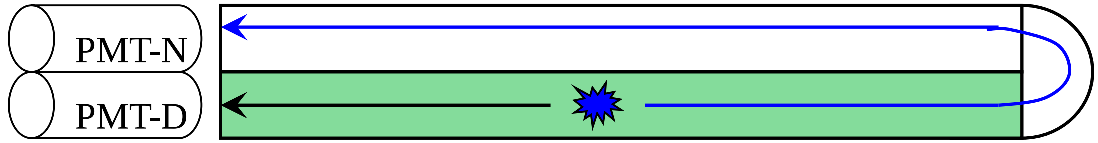
- **good neutron/photon separation** for $0.2 < p_n < 1$ GeV/c → **~150 ps time resolution** (obtained from GEMC simulations)
- momentum resolution **below 10%**

Constraints:

- **limited available space** (~10 cm radially)
→ limited efficiency
→ no space for light guides downstream (CTOF)
- **strong magnetic field** (~5 T) → light readout?

Design and components of the CND





Detector:

- CND design: **scintillator barrel**, 3 radial layers, 48 bars per layer (**144 bars in total**) coupled two-by-two by **"u-turn" lightguides**; it is organized into **24 "2x3 blocks"**
- scintillators have **trapezoidal shape**: length 66 -73 cm, width 4 – 4.7 cm, thickness 3 cm
- **wrapping:** aluminum foil and black scotch tape
- light read upstream by **PMTs** (Hamamatsu R10533), out of the high-field region of the solenoid
- the PMTs are connected to the bars via **~1.5m-long "bent" light guides** (PMMA)
- optical grease for the PMT/guide coupling
- voltage dividers made in IPN Orsay
- the PMTs are placed into **shieldings**: 1mm of µ-metal and 5mm of mild steel

→ **144 scintillators, 72 u-turns, 144 long light guides, 144 PMTs, 144 shieldings**

Read-out electronics (for 144 channels):

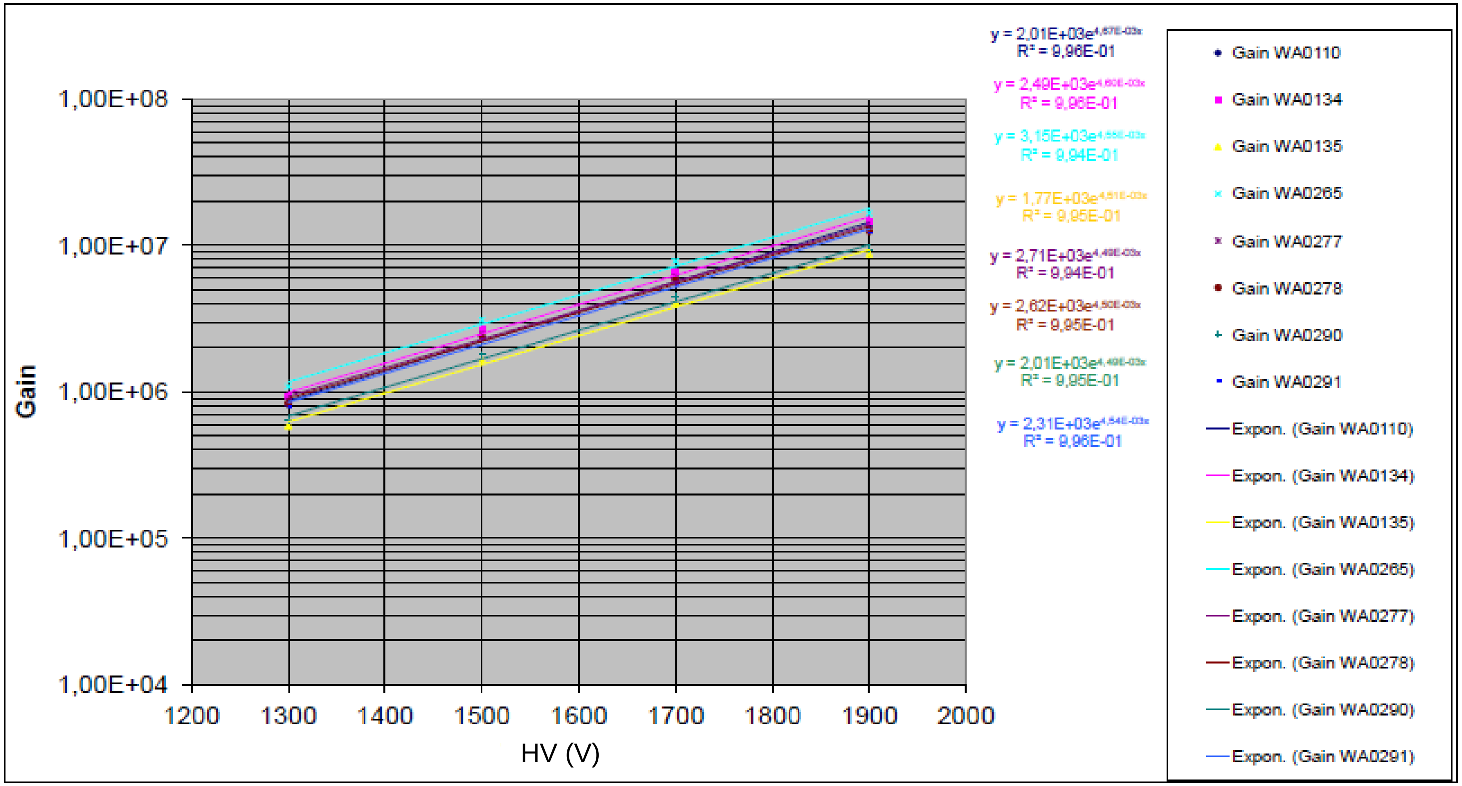
- Active **splitters**: custom-built in IPN Orsay for the Hall-C G0 experiment 64 Ch
- **Constant-fraction discriminators** (CFDs): Gan'Elec, custom made at IPN-GANIL for the TAPS experiment; CAMAC crate (Wiener) + controller (CAEN)
- **TDCs**: CAEN VX1290A 32 Ch, 25 ps/Ch (IPN)
- **Flash-ADCs** 250 VXS 16 Ch (JLab)
- **HV power supplies**: CAEN SYS527, donation of INFN, recovered from the LAC of CLAS
- **RG58** and **RG59** cables for signals and HV

Mechanical support structure:

- 6 aluminum arches
- 6 stainless-steel brackets

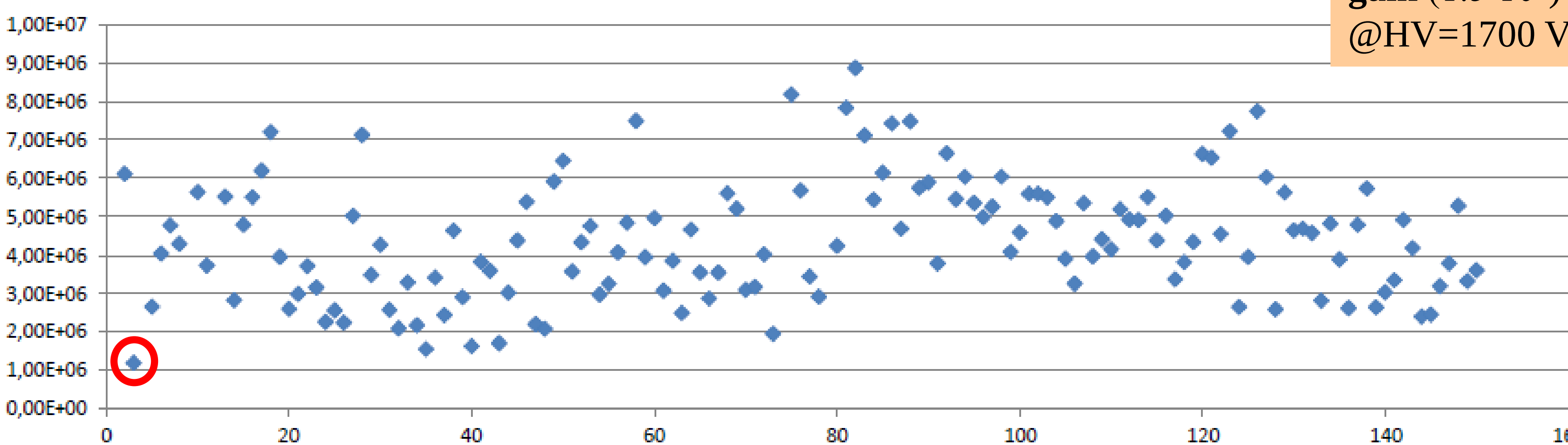
CND construction at IPN Orsay: gluing, wrapping, assembly

Calibration of the PMTs

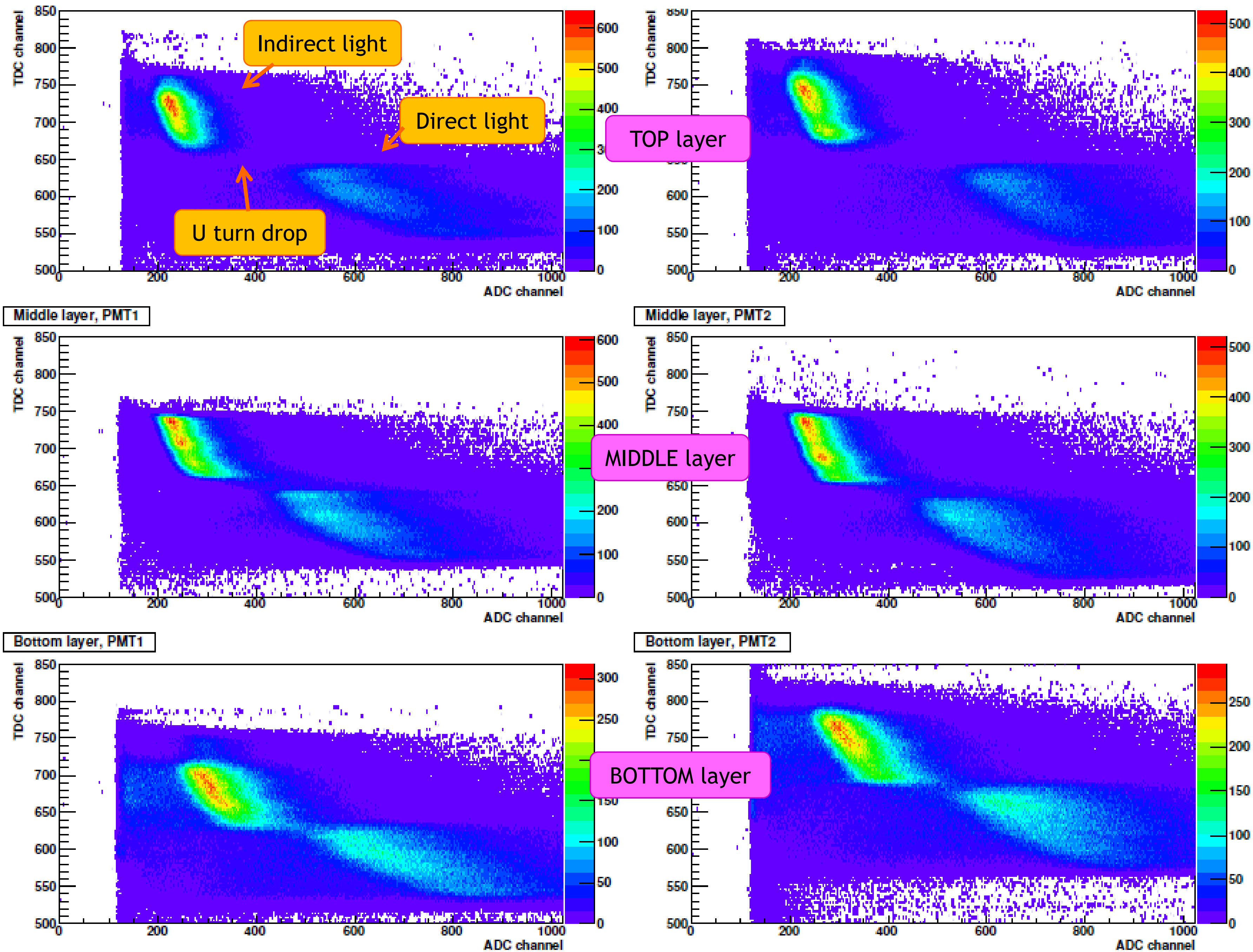


HV chosen to have the **same gain** ($1.5 \cdot 10^6$) for all PMTs

One PMT out of 150 does not reach the **minimum required gain** ($1.5 \cdot 10^6$) @HV=1700 V



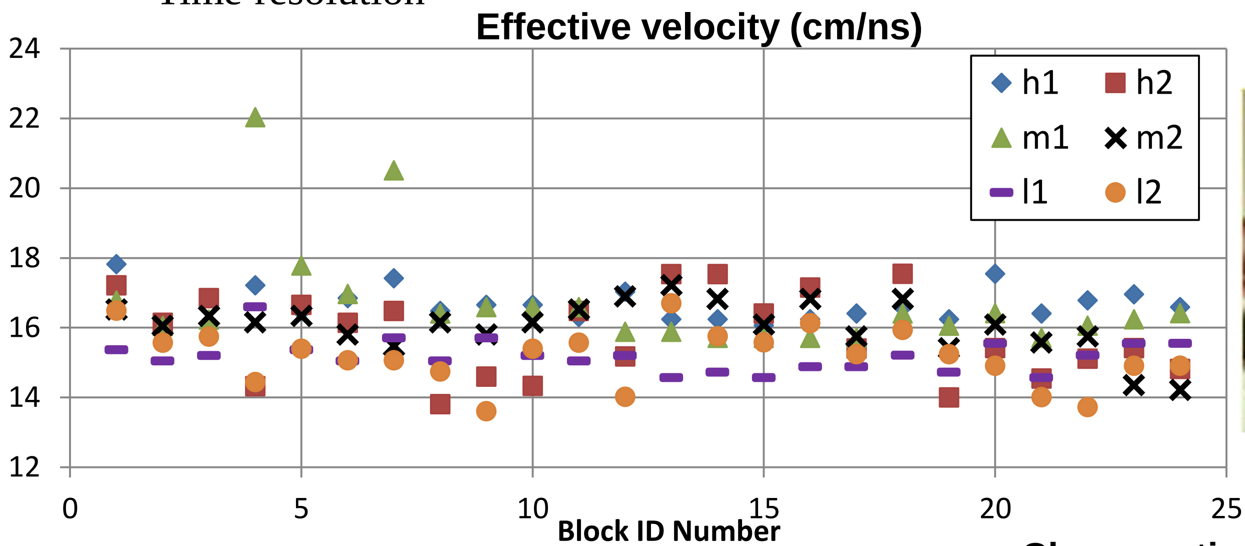
Raw data: TDC vs ADC

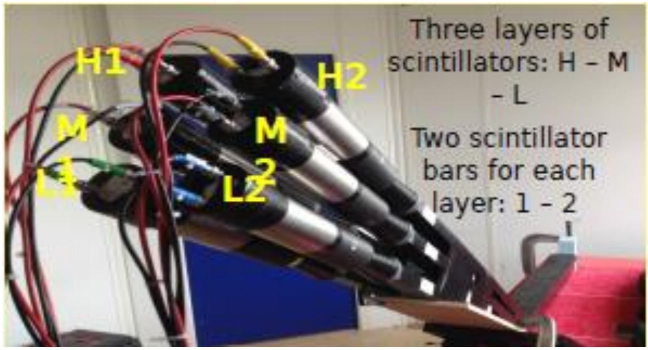


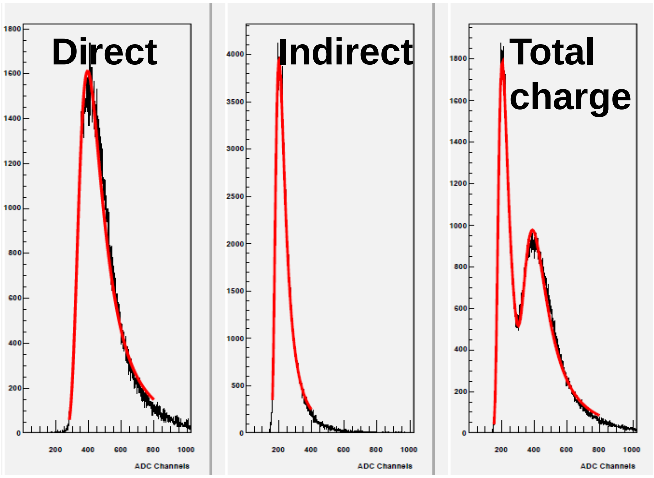
Characterization of the blocks

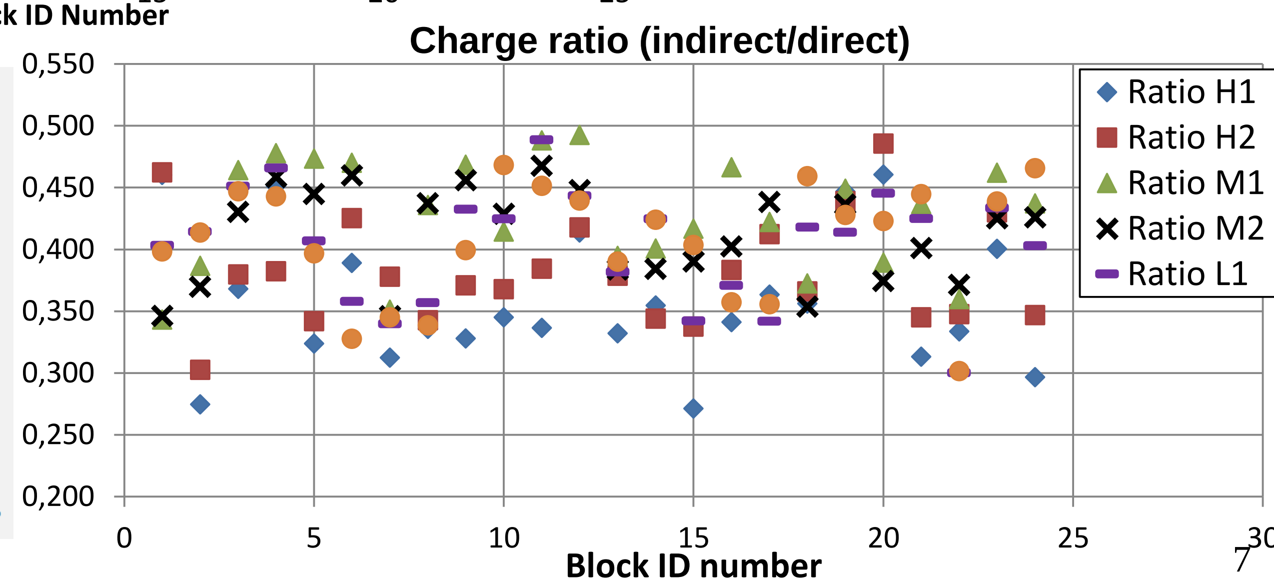
One week of data taking in IPN Orsay to characterize each block, right after assembly (same 6 PMTs used):

- Light collection
- Effective light velocity in scintillator+light guides
- Light attenuation
- Time resolution







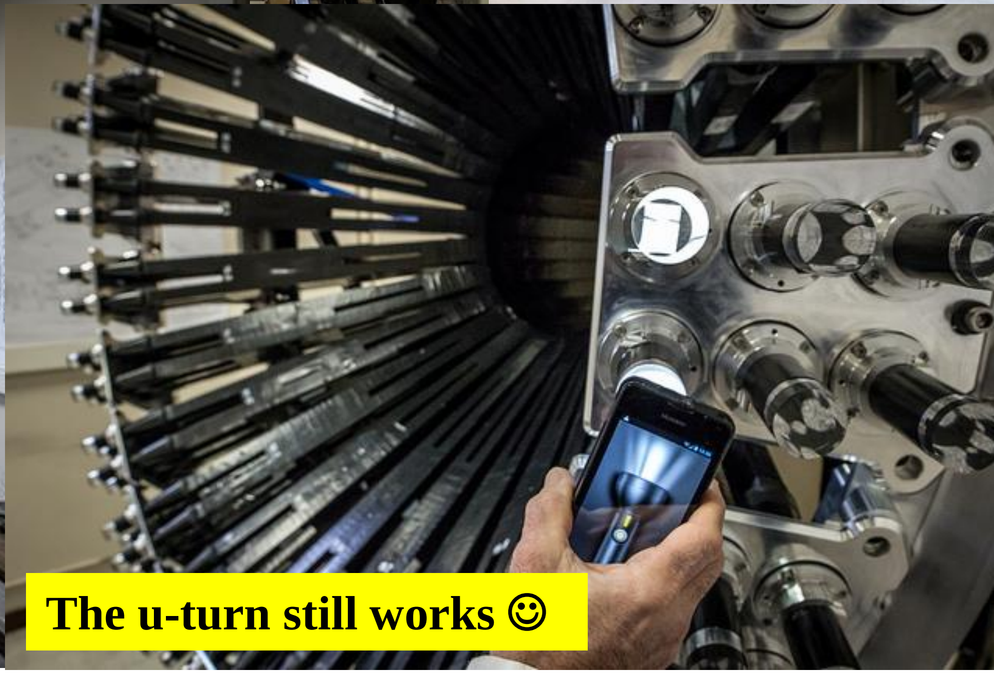


Installation tests in Orsay

Mock-up of the solenoid

Mock-up of the solenoid support ring

CND fully installed at IPN Orsay



The u-turn still works ☺

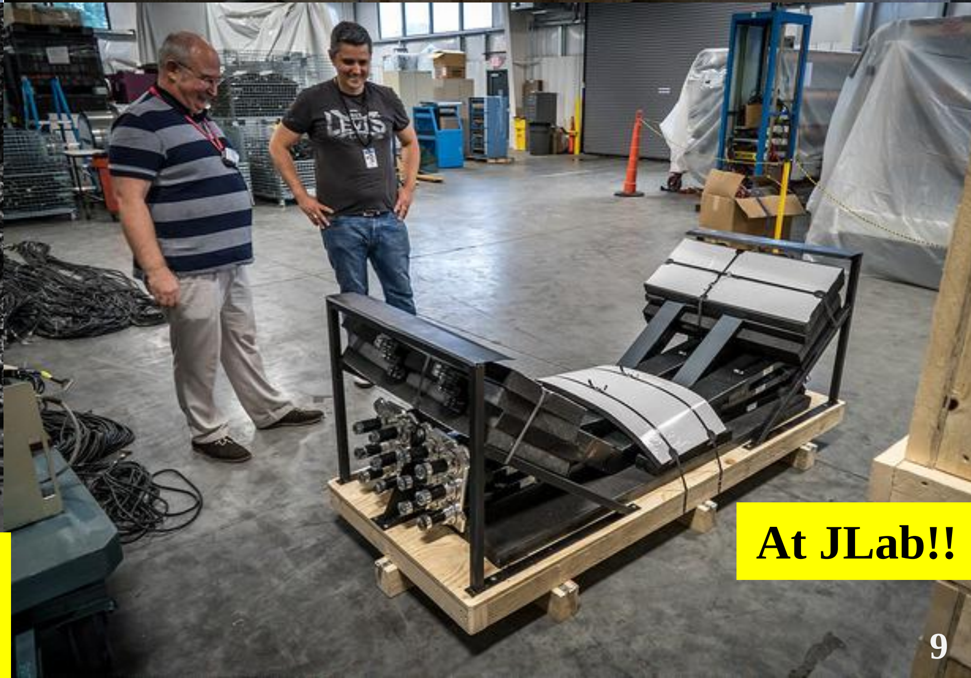
Installation video: https://www.flickr.com/photos/117533494@N07/14452245121/

Shipping to JLab (May/June 2015)

4 blocks per box, safely packed

6 boxes containing the blocks
Equipped with shock and temperature sensors
3 more boxes for structure and electronics

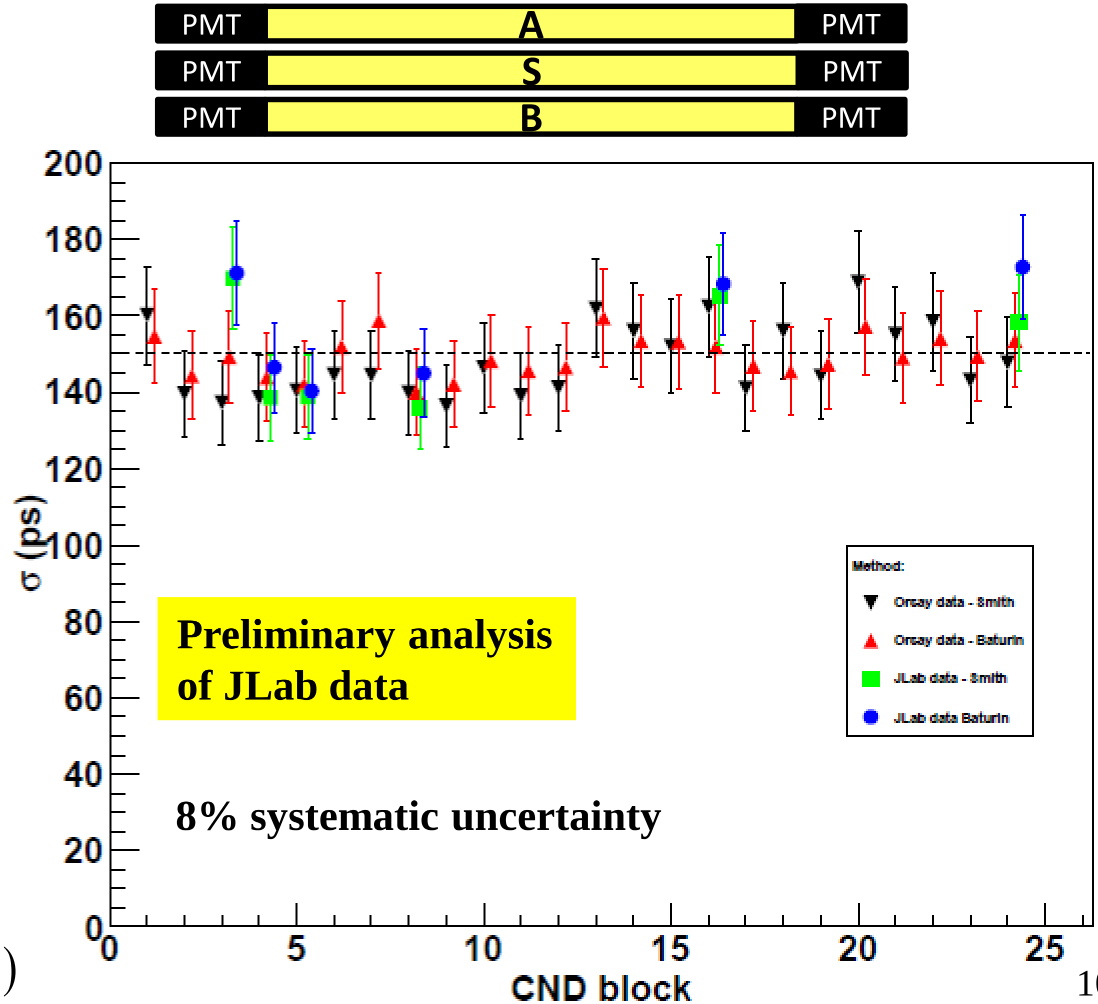
Loading the boxes in the shipping truck in IPN
Then airplane to IAD, and truck again to JLab



At JLab!!

Tests at JLab: February-April 2016

- Test bench set up in the ESB building (thanks to W. Akers)
- **6 blocks** tested out of 24
- **« final » TDCs and flash-ADCs** used (unlike in Orsay)
- used **CLAS12 DAQ** (thanks to S. Boiarinov)
- **cosmic rays** data taking in triple-coincidence mode



$$T_{ref} = (T_{AL}+T_{AR} - T_{BL} - T_{BR})/2$$

$$T_S = (T_{SL}+T_{SR})/2$$

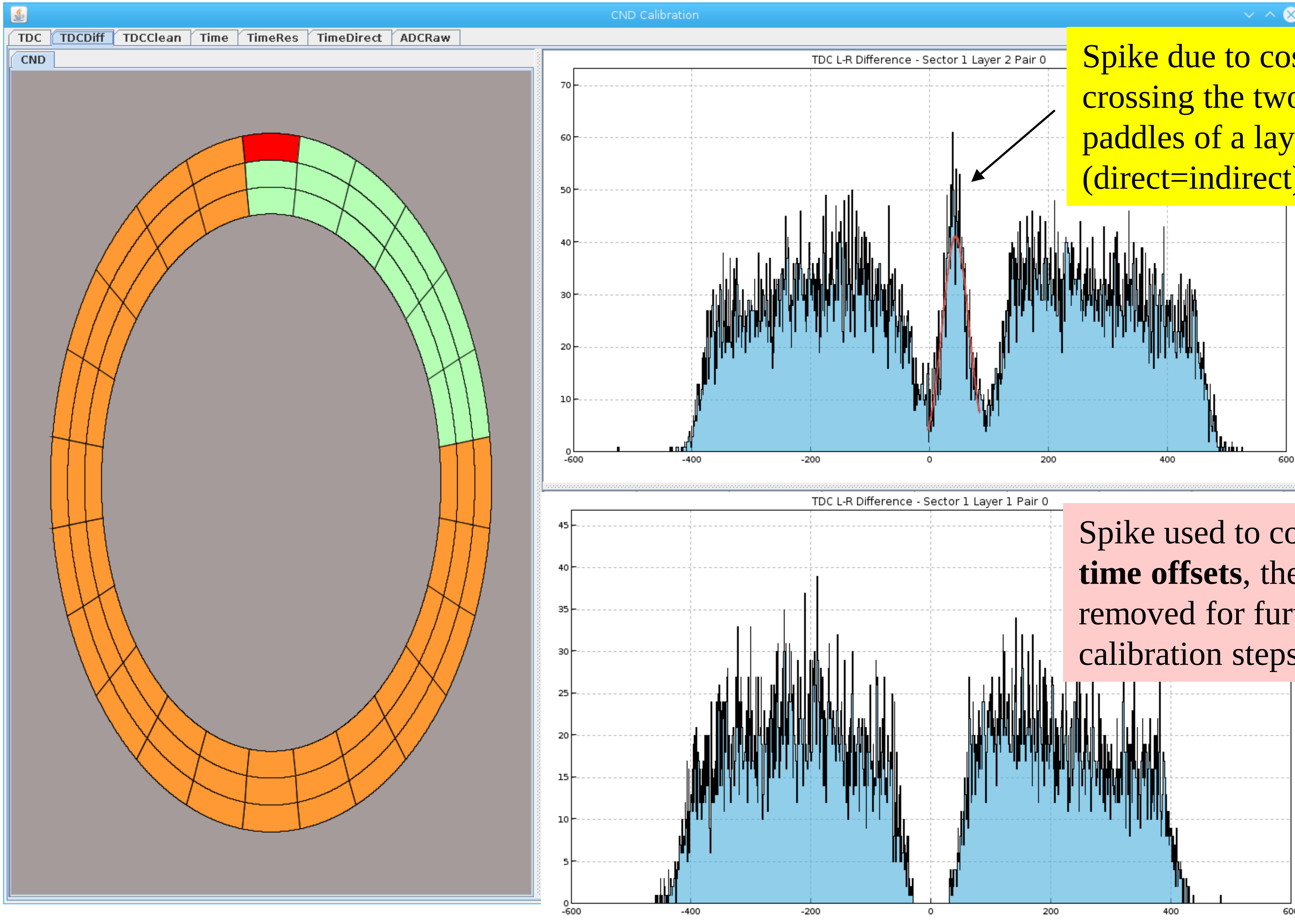
$$T_{cosmic} = (T_{AL}+T_{AR} + T_{BL} + T_{BR})/4 - T_S$$

$$\sigma_S = \sqrt{\sigma^2{}_{cosmic} - (\sigma_{ref}/2)^2}$$

$$\sigma_B = 1/\sqrt{24}\left(T_{AL} + T_{AR} + T_{BL} + T_{BR} - 2T_{SL} - 2T_{SR}\right)$$

JLab data and CND calibration GUI

Work by
G. Murdoch

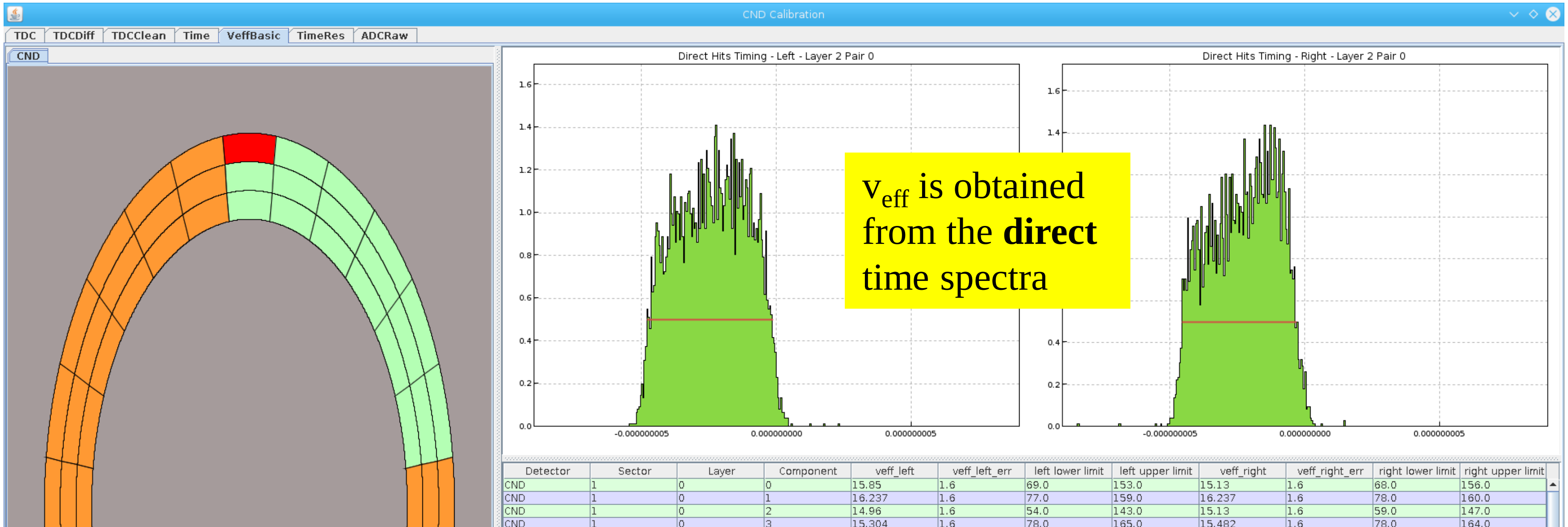


Spike due to cosmics crossing the two paddles of a layer (direct=indirect)

Spike used to correct **time offsets**, then removed for further calibration steps

JLab data and CND calibration GUI

Work by G. Murdoch



v_{eff} is obtained from the **direct** time spectra

10% error bars

Effective velocity calibration for the 6 tested blocks (6 paddles per block)

JLab data and CND calibration GUI

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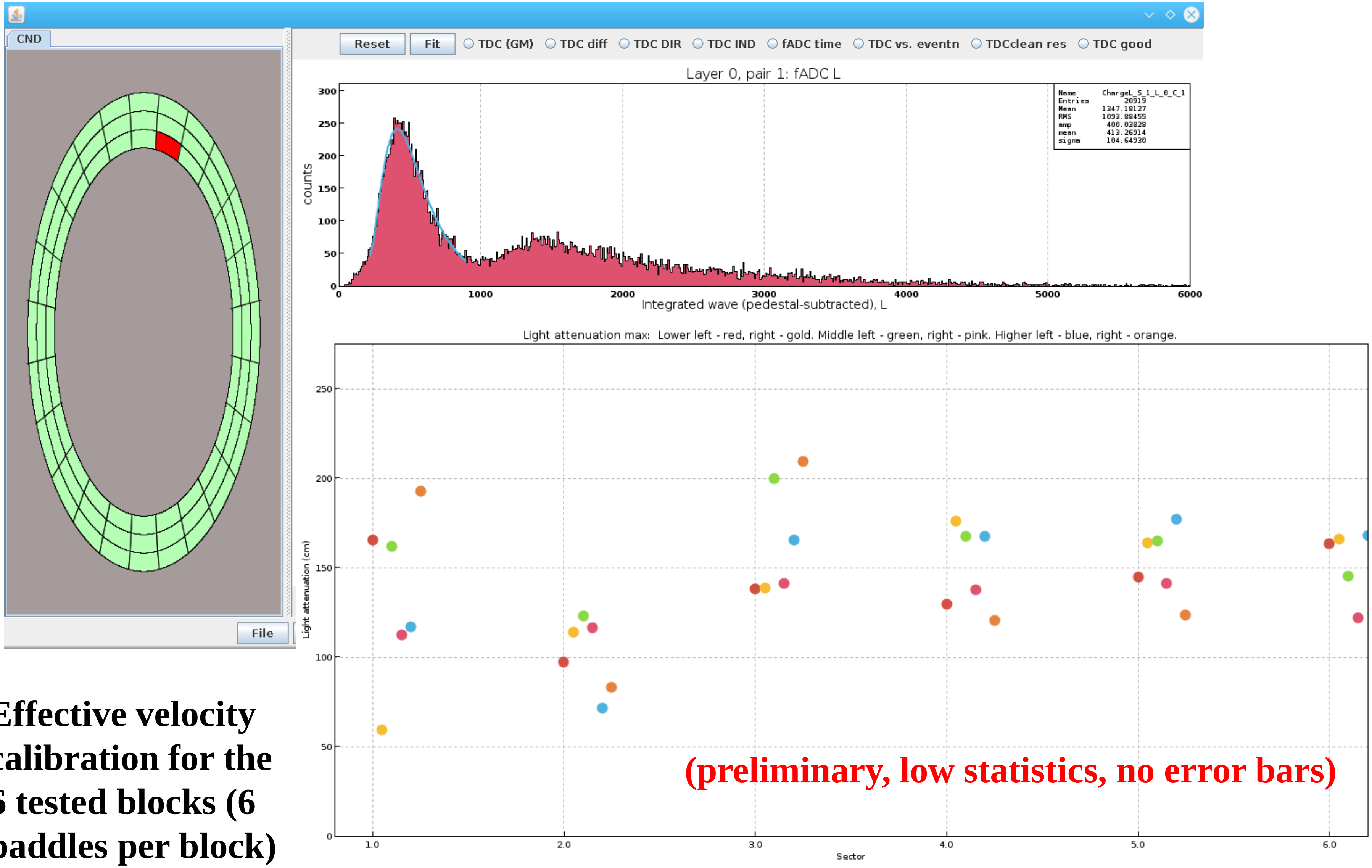


Effective velocity calibration for the 6 tested blocks (6 paddles per block)

CND: calibration challenge (Dec 2016)

Work by
G. Murdoch,
*S. N, **Raffaella***

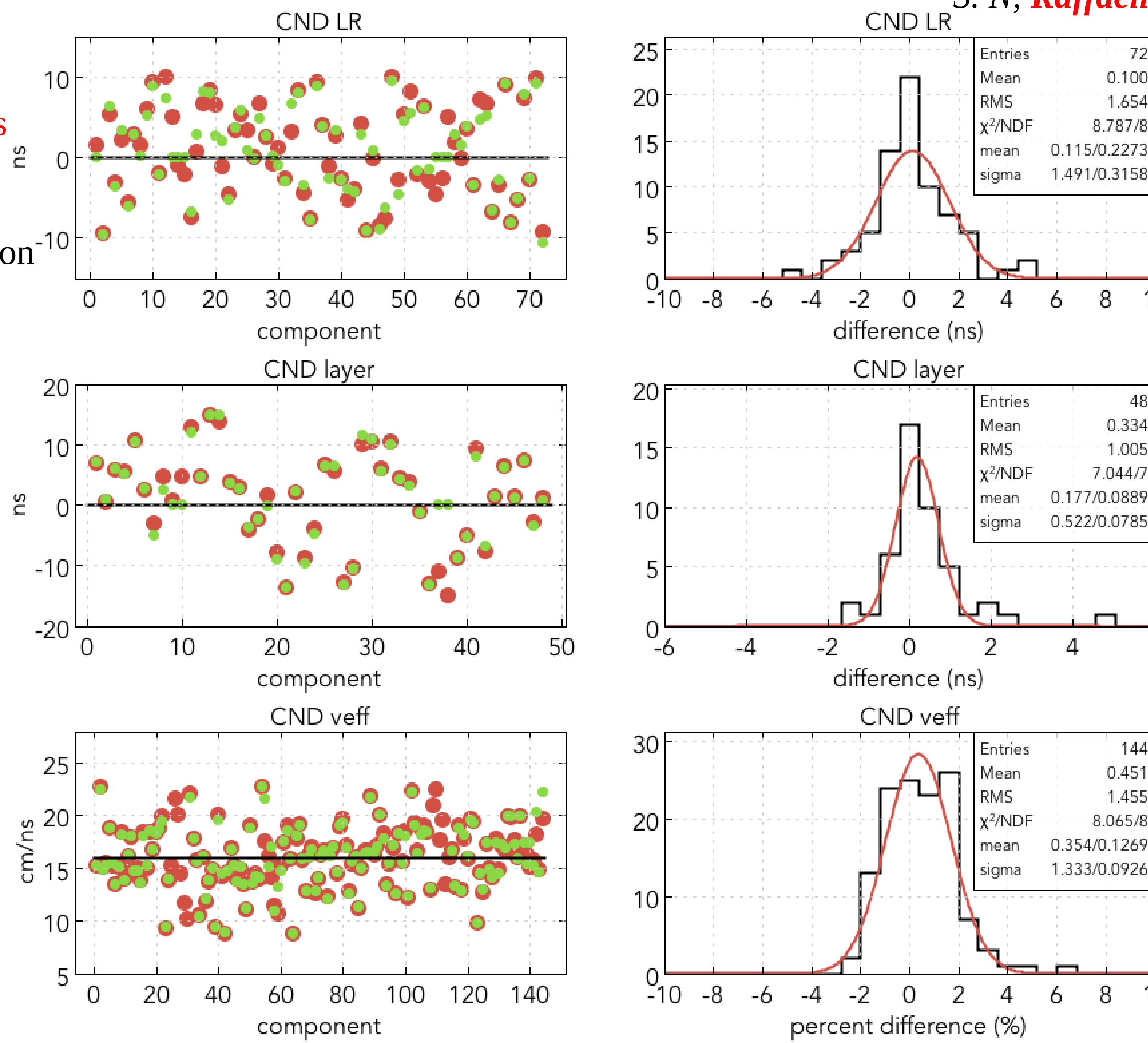
CND calibration constants:

- Left-right time offsets
- Layer-to-layer time offsets
- Effective velocity
- Attenuation length
- ADC-mip energy calibration

GEMC modified to read and use **CCDB constants** in CND digitization

Dead channels correctly identified

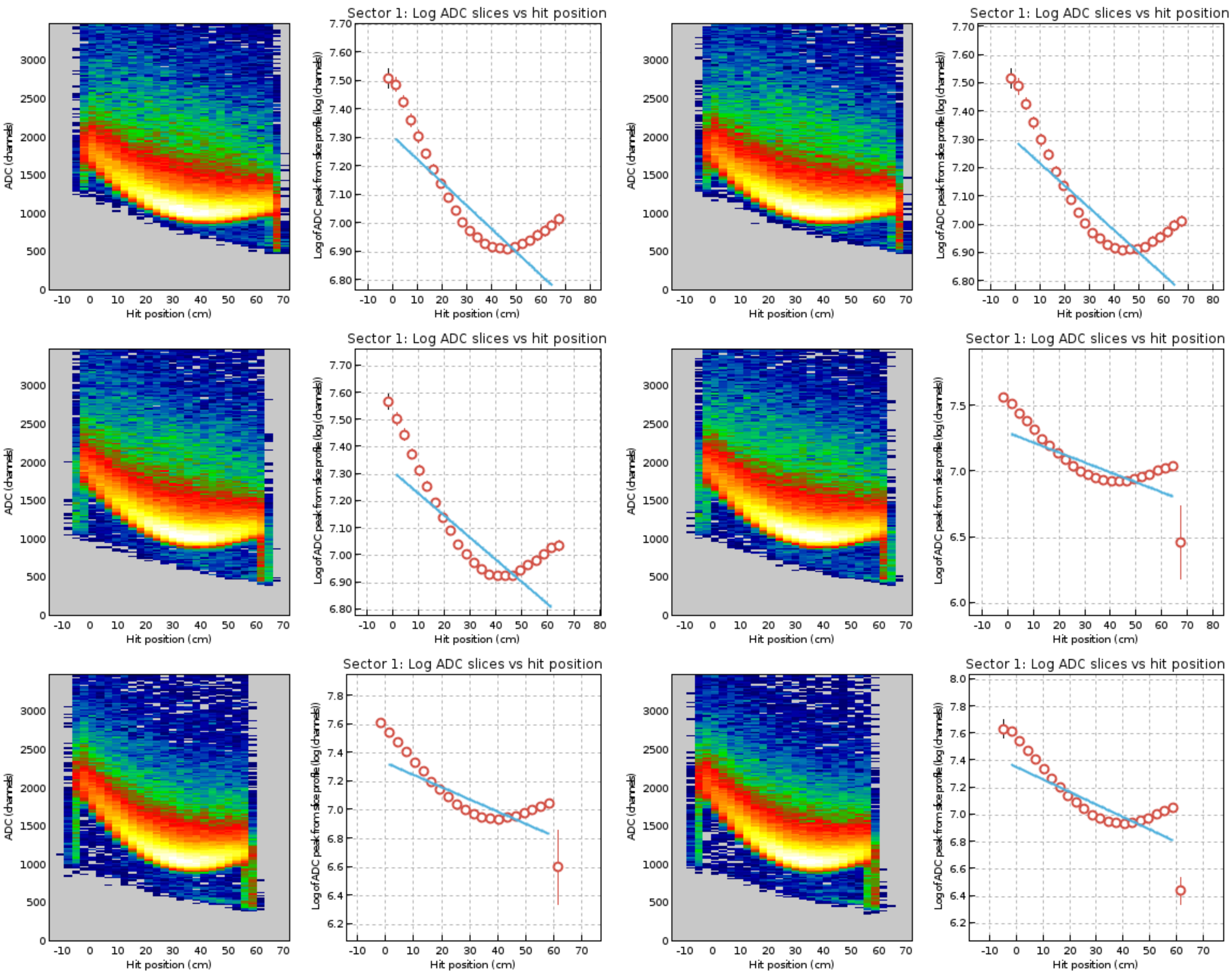
Low statistics may be a problem using real data, especially for $\mathbf{v_{eff}}$ with the present method, due to the low event count rate at backwards angles



CND calibration, latest developments

Work by G. Murdoch, S. N.

ADC vs position, to extract the attenuation length



GEMC simulation, pions emitted from the center of the CLAS12 target, over the full polar-angle coverage of the CND

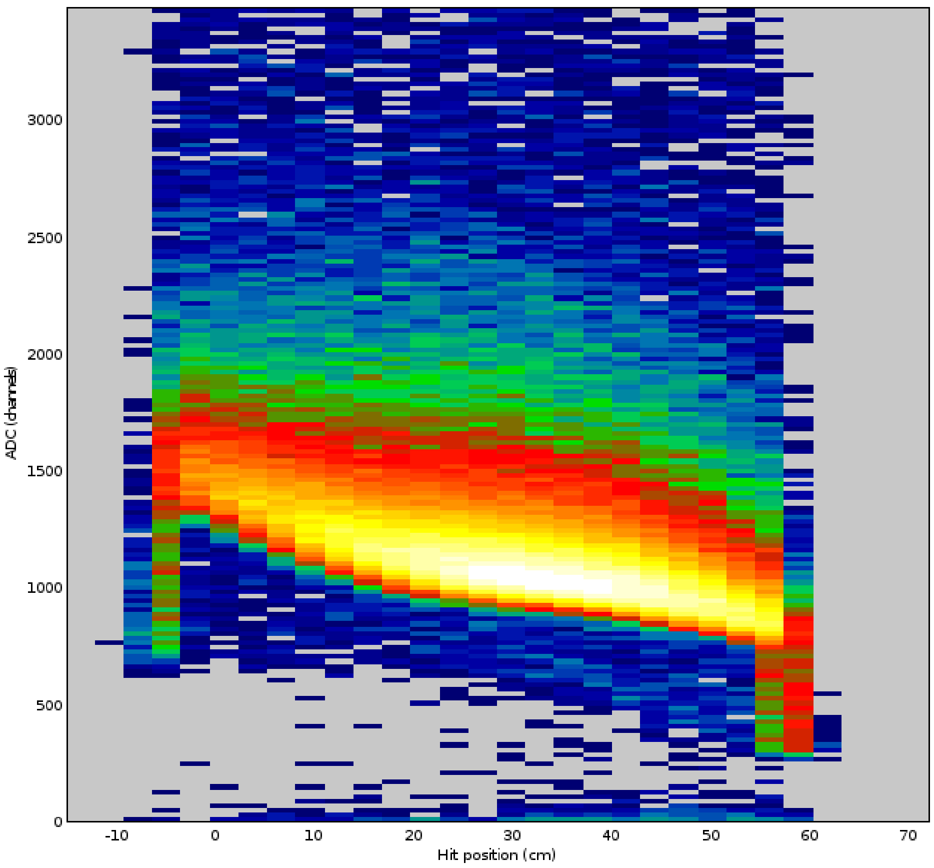
Dip due to lower edep for perpendicular tracks (90°)

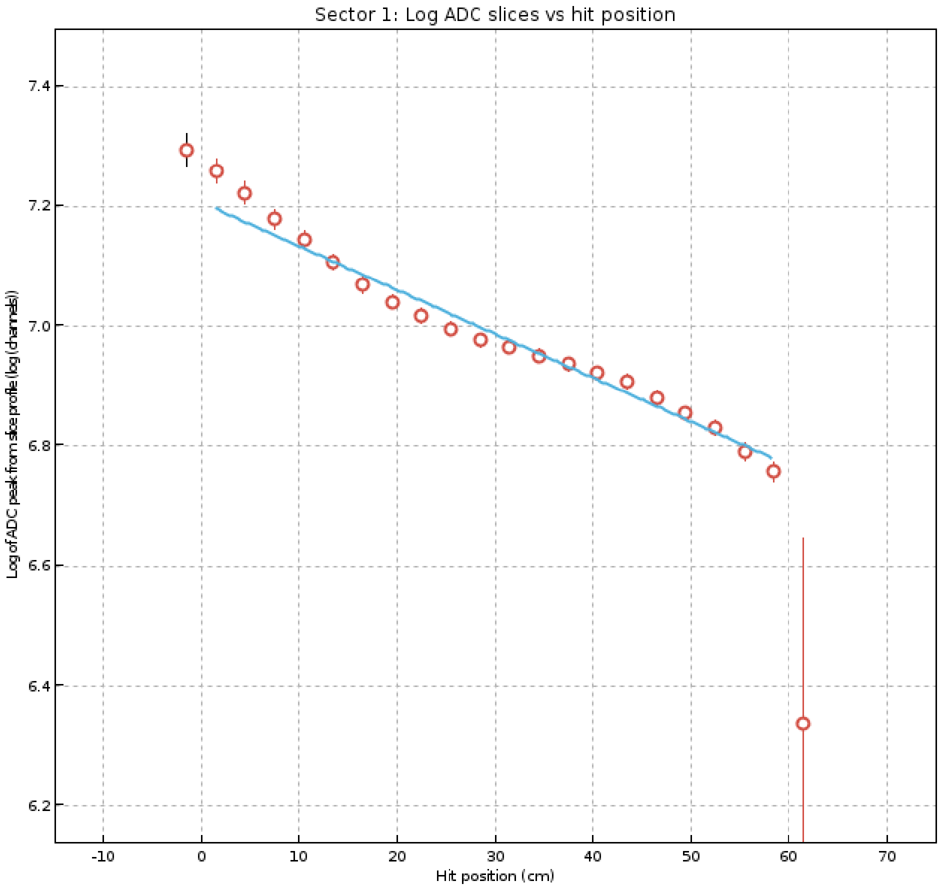
In order to use **real data** to calibrate the **attenuation length**, we need the **path length** (**tracking**)

CND calibration, latest developments

Work by G. Murdoch, S. N.

ADC vs position, to extract the attenuation length





Preliminary test, computing the path length using CND positions only

CND ERR (June 2016)

Comments (CND)

1. We suggest utilizing the programming features of CAMAC based discriminators (CFD). This allows discriminator thresholds to be set remotely and recorded in run database. A CAMAC crate controller with an ethernet connection or VME bridge must be obtained

2. Since CAMAC is a legacy hardware platform, identify a CAMAC crate/power supply as a ready spare. (Hall B should have multiple CAMAC crates from CLAS6)

A new CAMAC crate (Wiener) and a controller (CAEN) were purchased and shipped to Jlab at the end of 2016

3. Online monitoring software and the incorporation into the CLAS software scheme are to be completed
Almost done (Gavin Murdoch)

4. The CND is located in the up-to 5-Tesla magnetic field of the Superconducting Solenoid. Ferromagnetic components and current carrying wires will be subject to large forces. In case of a quench or fast discharge of the magnet, large voltages and/or currents will be induced in metallic surfaces, cables and electronic circuits that may damage the detector system or its associated electronics if appropriate considerations are not taken. It is suggested that the system owners re-check that any measures taken to prevent this from happening are still valid and in place

Recommendations (CND)

1. Develop documentation for shift personnel. This documentation should be concise, accessible to anyone taking shifts, and clearly specify which operations are authorized for shift takers and which are only for experts
2. The Operation Manual for the subsystem must be completed and reviewed as part of the CLAS12 ERR
OPERATION MANUAL and all other documentation written before CLAS12 ERR
3. RG-58 cables should be checked for CL2 or equivalent fire rating before installation **DONE (Chris Cuevas)**
4. The EPICS interface to slow controls for the CND must be completed before routine operation begins
DONE (Nathan Baltzell)

Summary

- The CND was conceived to measure recoil neutrons from nDVCS (two approved CLAS12 experiments)
- The detector was constructed and tested at IPN Orsay, shipped to JLab in June 2015
- Cosmic-rays tests at JLab confirm the 150 ps of time resolution for the 6 tested blocks
- Calibration challenge « passed » for time offsets and effective velocity
- Ancillary ERR in June 2016, no major showstoppers, CND « promoted » to ***baseline detector***

To-do list

- Writing slow controls for the CFD thresholds (new post-doc, and then a PhD student, will soon join IPN Orsay to work on CLAS12)
- Calibrations:
  - Finalize attenuation length
  - Energy calibration (ADC-mip)
  - Determine optimal run conditions and data kinds for each calibration steps (cosmics, raw data, cooked data?)
- Finalize reconstruction software (implementation in latest version of COATJAVA)
- Installation, as soon as the solenoid is ready (September 15th?)