Central Neutron Detector
Calibration and Performance

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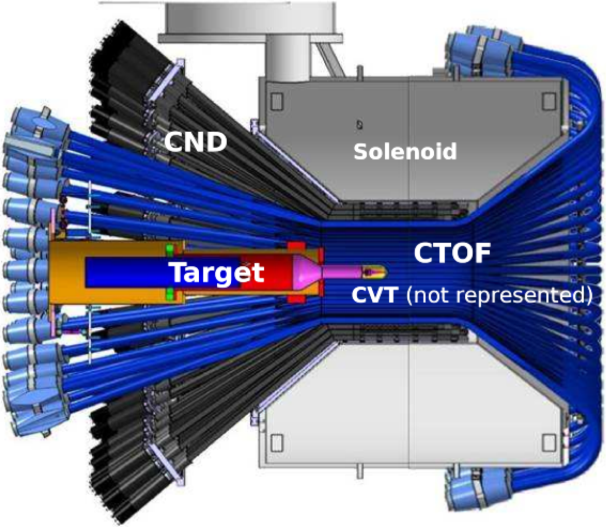
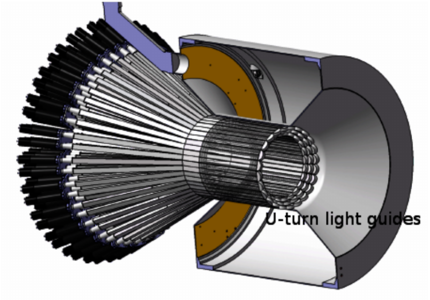
Overview

1. The Central Neutron Detector
   - Design
   - Motivation
2. Calibration
   - Time and Position
   - Attenuation & Energy
3. Preliminary Performance in RG-B
   - Calibration Quality
   - Do we see Neutrons?

The Central Neutron Detector

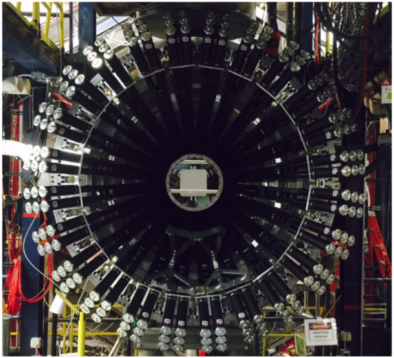


The CND



- 144 scintillator paddles
- 24 sectors, 3 layers
- Two neighbouring paddles (Left/Right) paired in each sector: connected via u-turn light guide at the downstream end
- Connected to light guides and PMTs on other side

The CND



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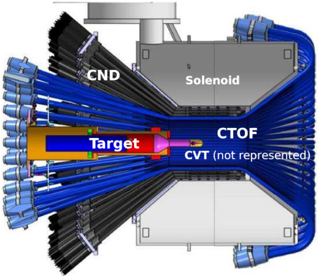
Why the CND?

GPD flavour decomposition

$$H^p = \frac{4}{9}H^u + \frac{1}{9}H^d \qquad H^n = \frac{1}{9}H^u + \frac{4}{9}H^d$$

- Neutron **G**eneralised **P**arton **D**istribution extractions
- CTOF's neutron detection efficiency too low for useful stats
- CND designed for DVCS of neutrons with deuteron target
- DVCS neutrons tend to recoil at large angles (approx. $>40^\circ$)
- π^0 DVMP has similar kinematics



Calibration - Time and Position

Calibration is done by taking only negatively charged particles, which due to kinematic constraints will essentially all be π^- — MIPs .

TDC to time: $t_{L/R} = TDC_{L/R} \cdot TDC\_to\_time$

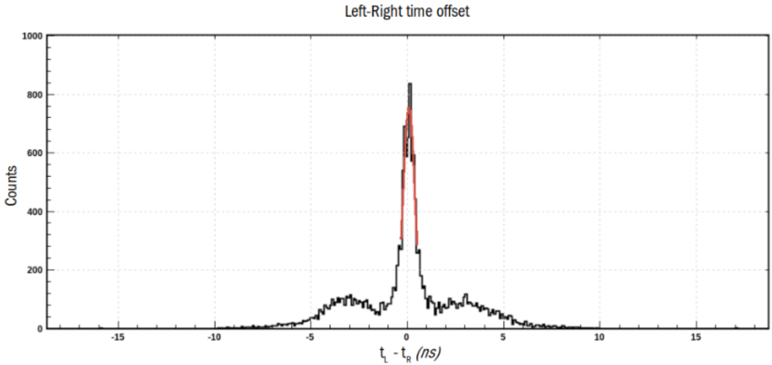
Time of hit in the Left paddle can be decomposed as:

$$t_L = t_{tof} + \frac{z_{CND}}{v_{eff_L}} + t_{off} + t_{off_L} + S_{tt} + TDC_{jitter}$$

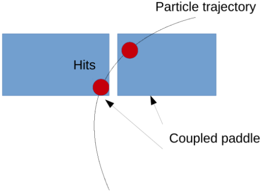
$$t_R = t_{tof} + \frac{L - z_{CND}}{v_{eff_L}} + \frac{L}{v_{eff_R}} + t_{off} + u_{loss} + t_{off_R} + S_{tt} + TDC_{jitter}$$

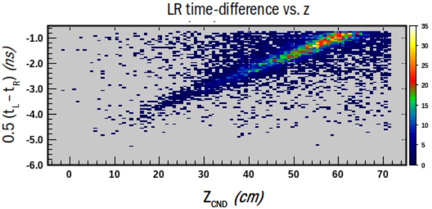
What we want; What we calibrate; What we get from other CLAS12 sub-systems

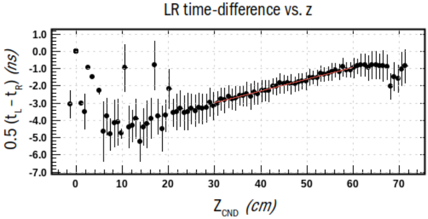
Left-Right time offset



- $LR_{off} = t_L - t_R$ is calculated and plotted.
- Magnetic field from the solenoid curves tracks, causing double hits in paired paddles which gives a peak.
- Peak fitted with Gaussian.







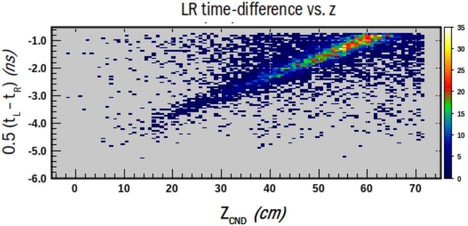
- Equations for t_L and t_R can be combined to show that:

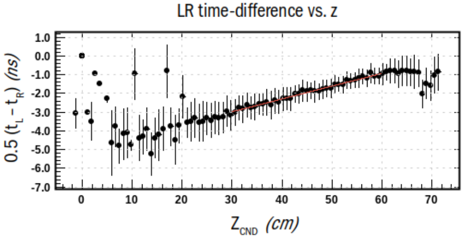
$$\frac{LR_{off}}{2} = \frac{t_L - t_R}{2} = \frac{1}{v_{eff_L}} \cdot z_{CND} + C_L$$

- z_{CND} is extrapolated from CVT track.
- Inverse of fitted gradient gives effective velocity of light in paddle.

Adjusted LR-offset and U-turn time loss

$$C_L = -\frac{1}{2}\left(L \cdot \left(\frac{1}{v_{eff_L}} + \frac{1}{v_{eff_R}}\right) + u_{loss} - LR_{off_{adj}}\right)$$





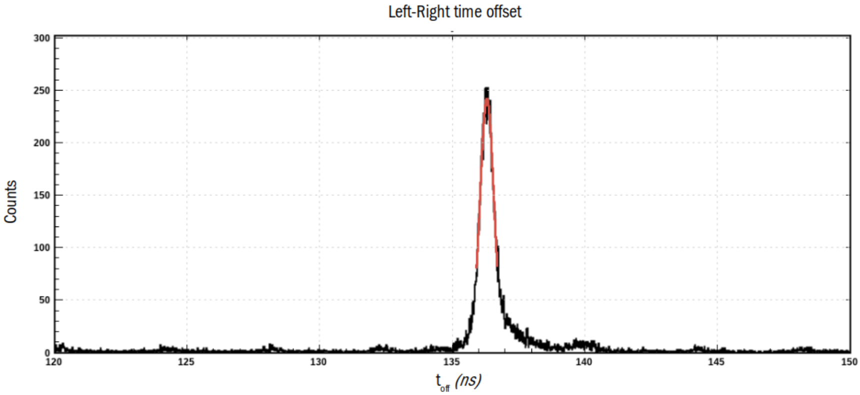
$$LR_{off_{adj}} = t_{off_R} - t_{off_L} = C_L - C_R$$

- Equations for t_L and t_R for a hit in the right paddle gives similar expression for intercept C_R
- Again plot LR_{off} against z_{CND} which is extrapolated from CVT track.
- Intercepts, C_L and C_R give $LR_{off_{adj}}$ which is then used to calculate u_{loss}

Global time offset

Equations for t_L and t_R can also be combined to give:

$$t_{off} = \frac{t_L + t_R}{2} - S_{tt} - t_{tof} - \frac{L}{2} \cdot \left(\frac{1}{v_{eff_R}} + \frac{1}{v_{eff_L}}\right) - \frac{u_{loss}}{2} - \frac{LF_{off_{adj}}}{2}$$



Values (one per paddle-pair) are calculated, histogram is fitted with a Gaussian.

Calibration - Attenuation & Energy

ADC values for a hit the Left paddle can be decomposed as:

$$ADC_L = \frac{E}{E_0} \cdot MIP_D \cdot e^{\frac{-z_{CND}}{A_{tt}}}$$

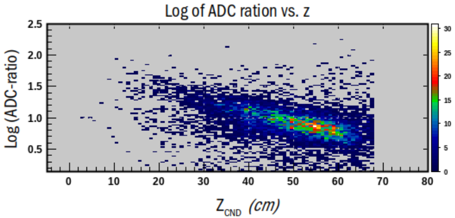
$$ADC_R = \frac{E}{E_0} \cdot MIP_I \cdot e^{\frac{-(L-z_{CND})}{A_{tt}}}$$

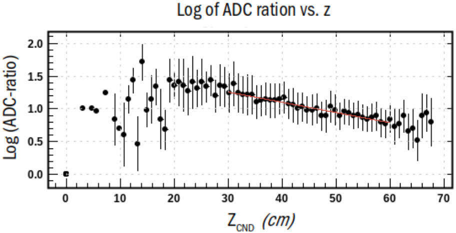
$$E_0 = \frac{h \cdot 0.1956\, MeV\, cm^{-1}}{2} \qquad\qquad E = \frac{path}{h} \cdot E_0$$

What we want; What we calibrate; Known from the geometry

E_0 represents energy deposited in scintillating material by MIPs (π^-).

Attenuation





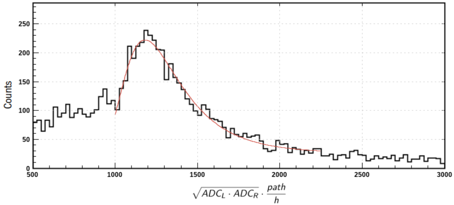
- Dividing equations for ADC_L and ADC_R leads to:

$$\ln\left(\frac{ADC_L}{ADC_R}\right) = -\frac{2}{A_{tt}} \cdot z_{CND} + C_{\mathscr{L}}$$

- Log of ADC ratio plotted against z_{CND} extrapolated from CVT track.
- Gradient of straight line fit gives value for attenuation.

Energy

$$\mathscr{P} = \sqrt{ADC_L \cdot ADC_R} \cdot \frac{path}{h} = \sqrt{MIP_d \cdot MIP_l} \cdot e^{-\frac{L}{2 \cdot A_{tt}}}$$



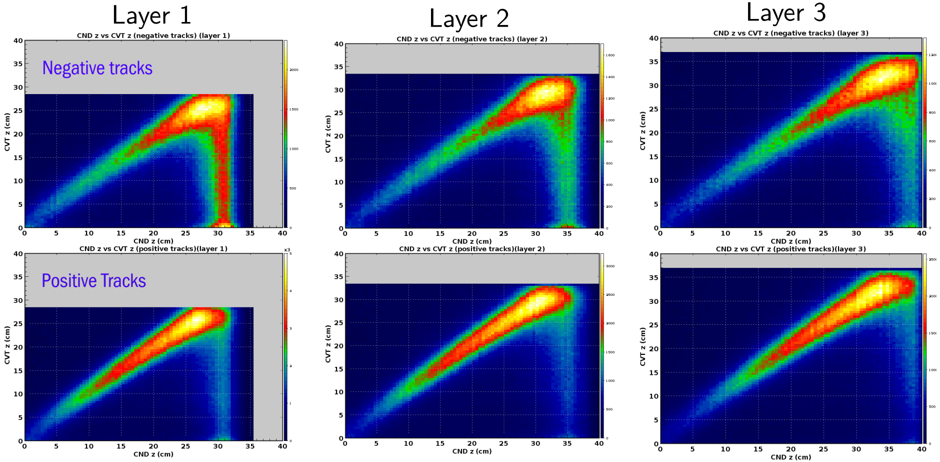
$$C_{\mathscr{L}} = \ln\left(\frac{MIP_D}{MIP_l}\right) + \frac{L}{A_{tt}}$$

$$MIP_D = \sqrt{e^{C_{\mathscr{L}} - \frac{L}{2 \cdot A_{tt}}} \cdot e^{\frac{L}{2 \cdot A_{tt}}} \cdot \mathscr{P}2}$$

$$MIP_D = \sqrt{e^{-(C_{\mathscr{L}} - \frac{L}{2 \cdot A_{tt}})} \cdot e^{\frac{L}{2 \cdot A_{tt}}} \cdot \mathscr{P}2}$$

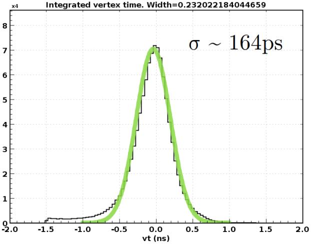
- Log of ADC plotted against z_{CND}
- $C_{\mathscr{L}}$ from attenuation fit.
- $\mathscr{P} = \sqrt{ADC_L \cdot ADC_R} \cdot \frac{path}{h}$ is calculated, plotted and fitted with Landau function

z_{CVT} vs. extrapolated z_{CND}

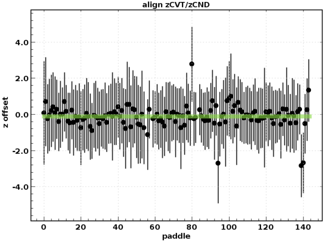


Performance in RG-B: Preliminary

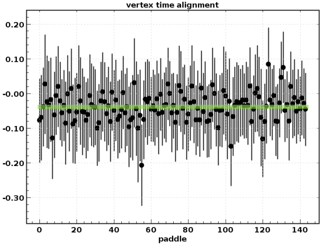
Integrated Vertex Time



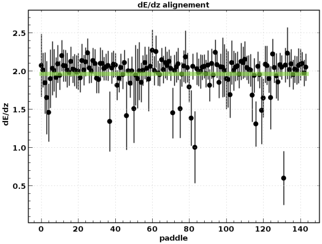
z_{CVT} - z_{CND} allignment



Vertex Time Allignment

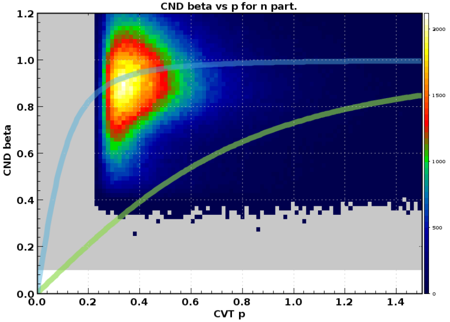


dE/dz allignment

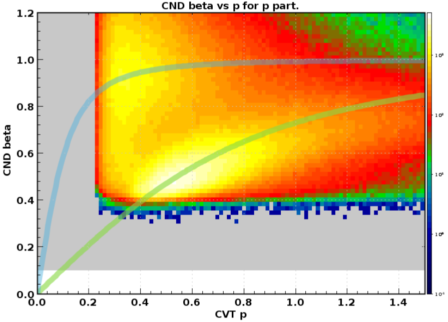


Resolving Charged Particles

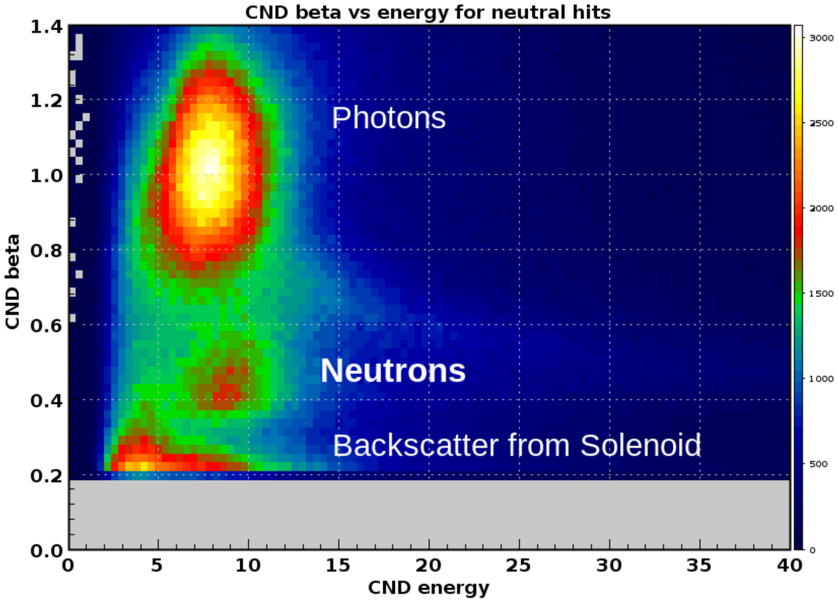
Negative



Positive

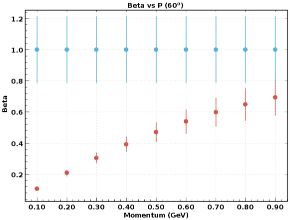


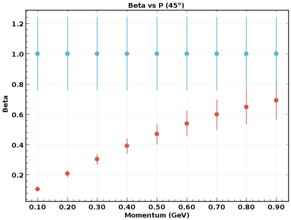
First glance at Neutrons!

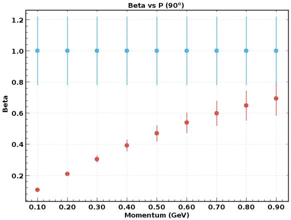


First glance at Neutrons!

Some reinforcement — Neutron : β vs. momentum
(60°, 45 $^\circ$and 90°)







Summary

- CND showing good timing and position resolution.
- Preliminary β vs. p plots shows resolution of charged and neutral particles.
- Seeing neutrons.
- Hope for further improvement from:
  - High-stat calibration.
  - Intelligent cuts to further reduce contamination from neutrals.