**BNL EIC Polarimetry Monthly Meeting**
March 17, 2021 (online)
https://indico.bnl.gov/event/10857/

# *The HJET prompts study using double layer detector prototype*

**A.A. Poblaguev**

*Brookhaven National Laboratory*

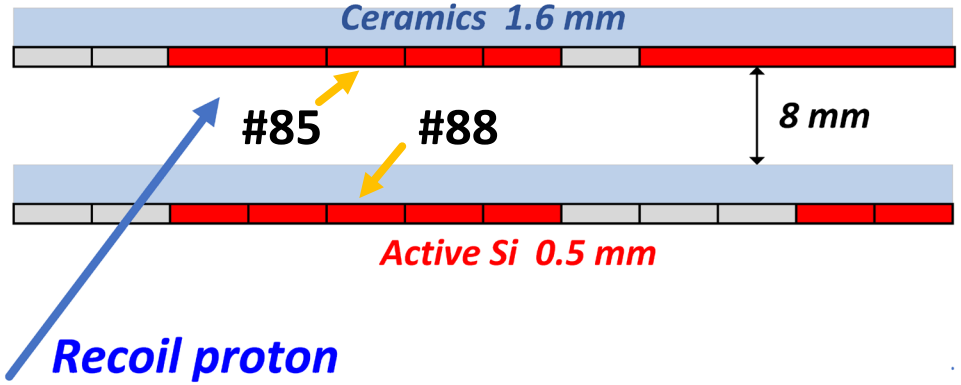
BROOKHAVEN NATIONAL LABORATORY

# *Prototype of a double-layer detector for HJET*

**The prototype was assembled using available components:**

- **1.6 mm of ceramics between layers**
- **~10 mm gap between layers**

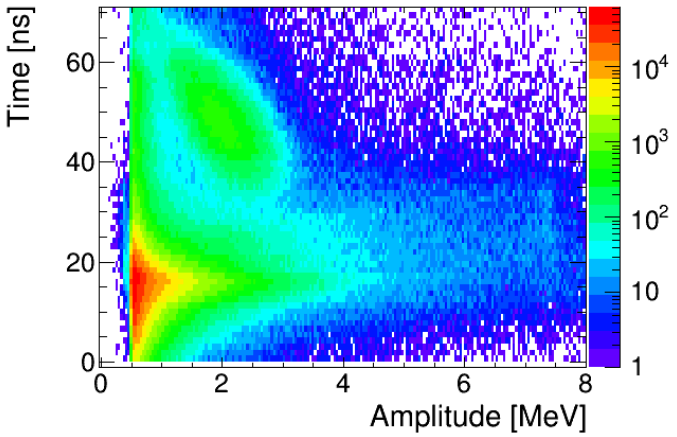
**One of 8 HJET detectors was replaced by the prototype.**

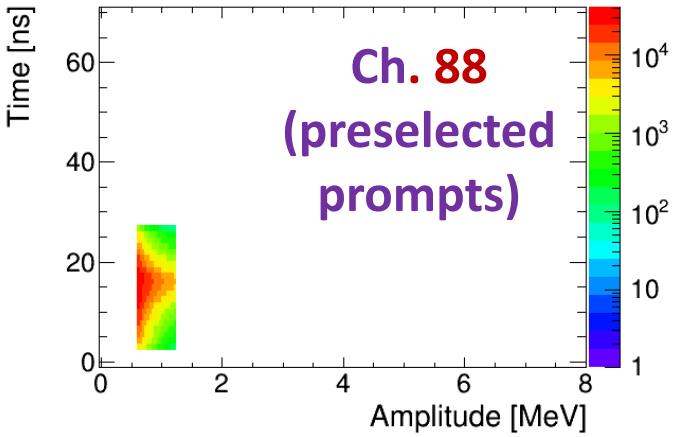



- **The goal was to veto punch-through $\pi, p, d, \alpha, \ldots$ , which are expected to have momentums 100-500 MeV/c. The ceramics between layers must not be the problem for that.**
- **The detector was tested in 5.76 GeV/n Au beam (Run 2020)**
- **The prompts rate in the second layer was 30-40% compared to the first one.**
- **The prompts veto efficiency can be evaluated as $\lesssim$10-20%.**

# Time-amplitude distributions

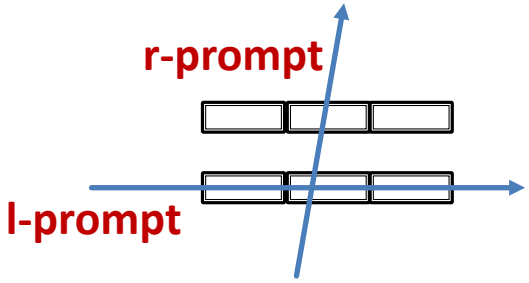
## Ch. 88 (all data)

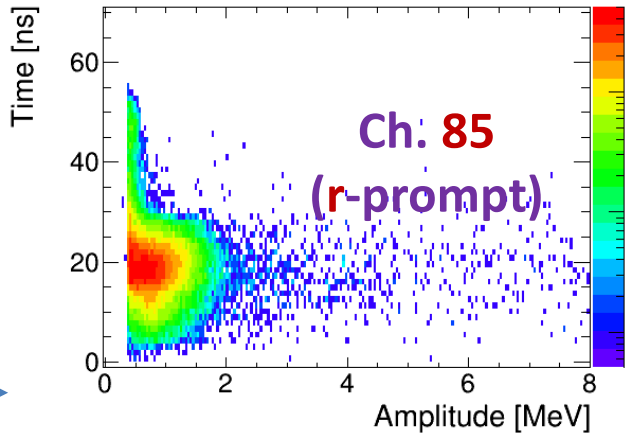


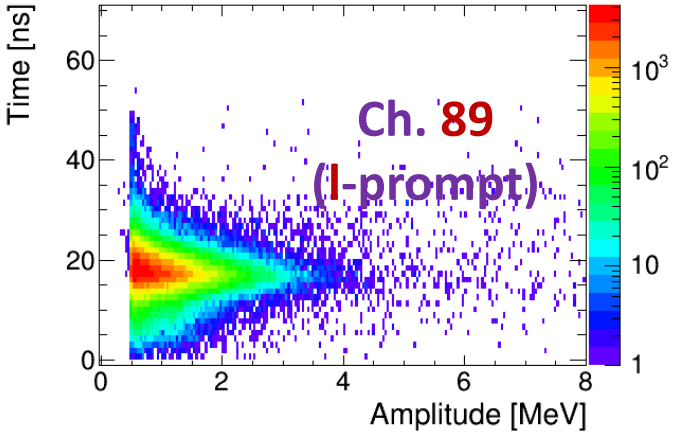




## Coincidences with ch. 88 prompts

**Longitudinal and radial prompts are seen in coincidences**




| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 84 | | 85 | 91 | 92 | | 93 | | |
| | | 86 | 87 | 88 | 89 | 90 | | | 94 | 95 |

# Event Statistics

## Fills 25121-25153:

### All Events (kEvents)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2900 | | 1884 | 1764 | 1859 | | 5030 | | |
| | | 3921 | 5697 | 4161 | 3481 | 4163 | | | 3309 | 11186 |

### Prompts only (kEvents)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 826 | | 603 | 564 | 587 | | 1151 | | |
| | | 1717 | 2641 | 1978 | 1614 | 2006 | | | 1568 | 1690 |

### Correlation with the ch. 88 prompts:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 4.7% | | 3.9% | 3.2% | 2.4% | | 6.9% | | |
| | | 13.4% | 16.6% | 100% | 16.9% | 15.2% | | | 13.8% | 13.4% |

## Fills 25156-25188: (Empty target)

### All data (kEvents)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 902 | | 574 | 542 | 570 | | 1666 | | |
| | | 1266 | 1655 | 1356 | 1207 | 1419 | | | 1237 | 15995 |

### Prompts only (kEvents)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 265 | | 189 | 179 | 186 | | 856 | | |
| | | 680 | 882 | 740 | 651 | 770 | | | 665 | 856 |

### Correlation with the ch. 88 prompts:

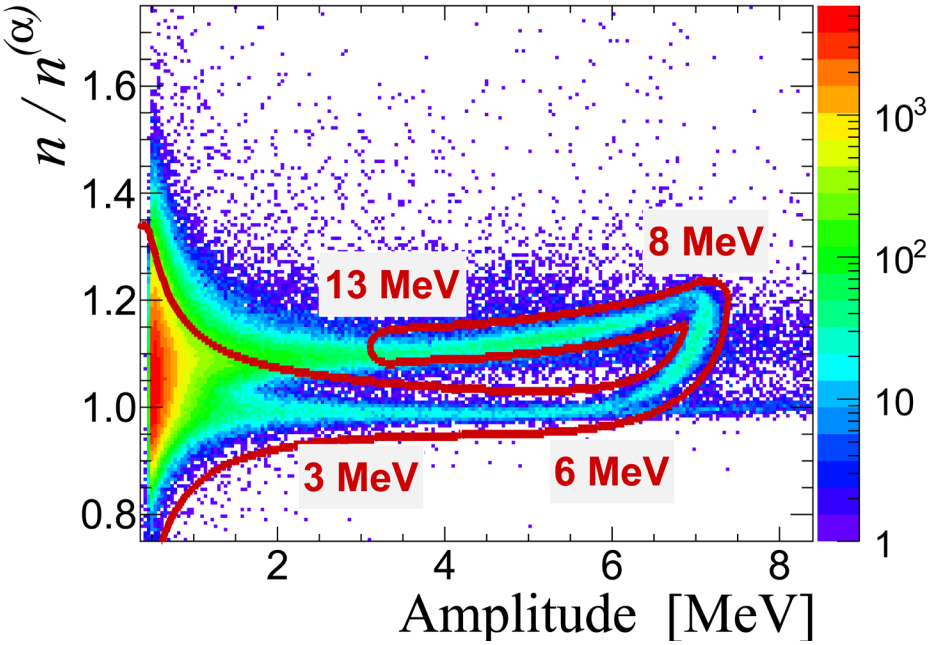
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 6.4% | | 4.8% | 4.3% | 3.6% | | 12.0% | | |
| | | 25.2% | 30.3% | 100% | 28.1% | 28.4% | | | 23.2% | 22.4% |

- The empty target prompt rate is about factor 3 lower than in regular run.
- The second layer prompt rates are about 40% of the first layer one.
- Efficiency of the prompt vetoing by the second layer is 20-30% (30-40% for empty target).
- Large angles ($\gtrsim 45$ deg.) for the punch through correlated signals.
- The l-prompts signals are well identified and can be used for precision alignment of $t_0$'s.

**The observations disagree with the expectations based on assumption that prompts are fast particles originated from the scattering point**

# *Waveform dependence on the particle kinetic energy*

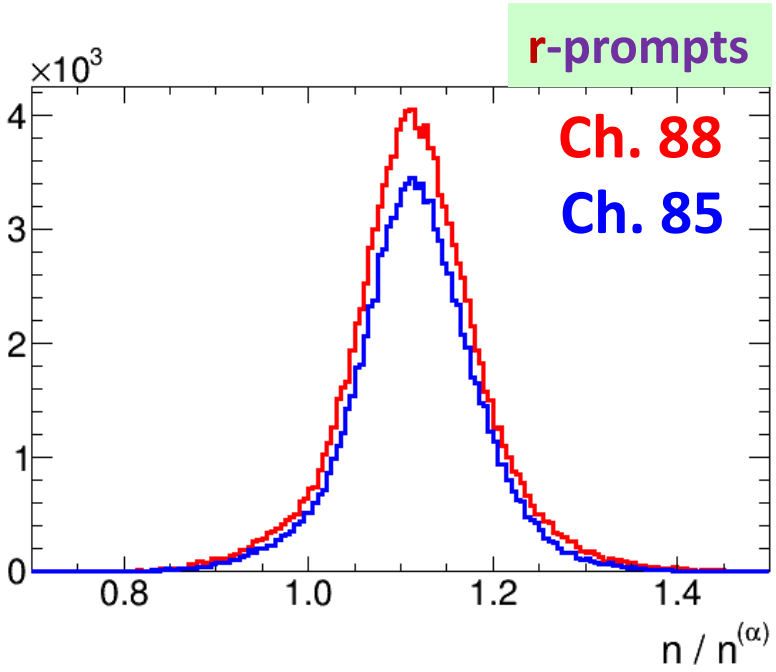
- $A(t) \propto At^n e^{-t/\tau}, \quad t > 0$
- **All events, including prompts, are displayed**

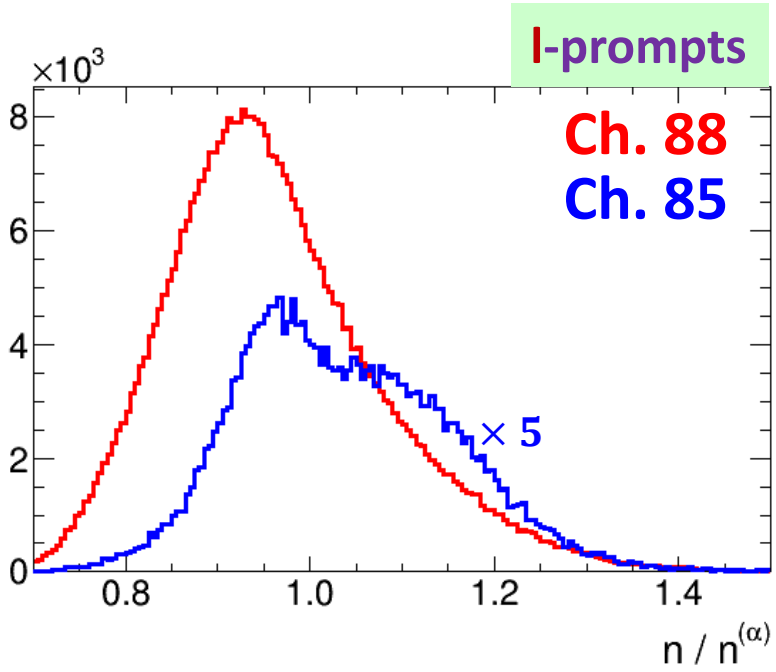



**Waveform shape analysis allows one to separate different types of the signal in a Si strip.**
**In particularly, stopped and punch through particles**

# *Fills 25121-25153* (Au, *5.76* GeV/*n*)

**Waveform shape parameter $n/n^{(\alpha)}$ distributions**



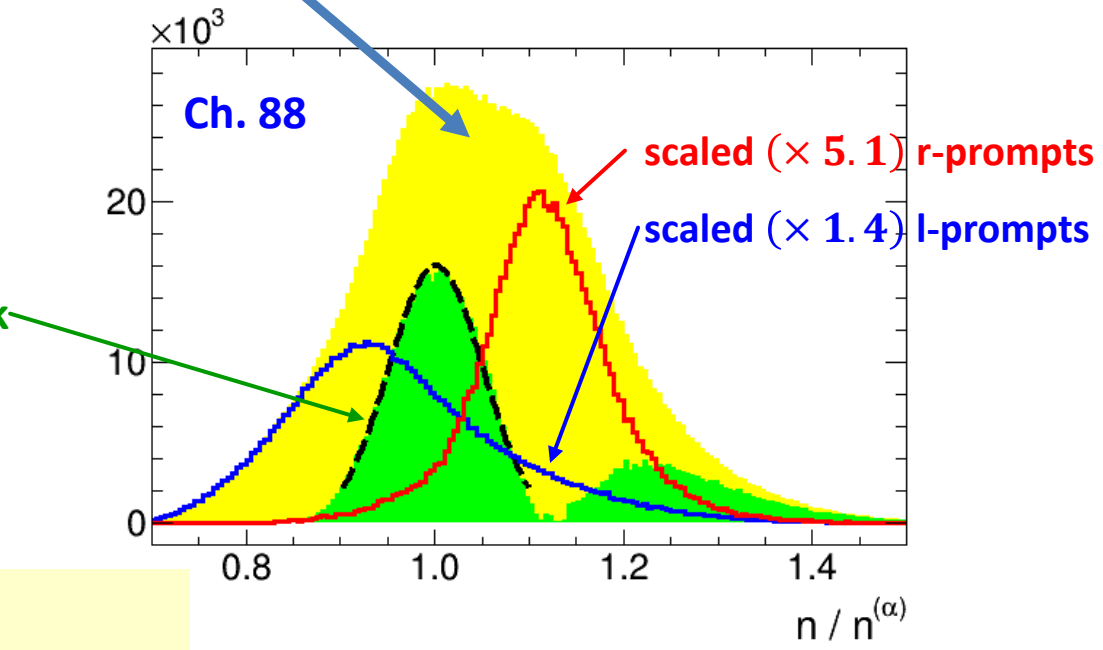




- **The distributions for r-prompts and l-prompts are significantly different**
- **L-prompts distributions in the front (ch. 88) and back (ch. 85) layers are not the same (r-prompt contamination in ch. 85 data ?)**
- **l-prompt rate in the back-layer is much lower than in the front one (inconsistency with identification of l-prompts as the beam halo events)**

# *Fills 25121-25153* (Au, *5.76* GeV/*n*)

## Analysis of the prompts $n/n^{(\alpha)}$ distributions

- The l-prompts and r-prompts distribution were scaled as much as possible (to avoid negative rates)
- The residual distribution peak is consistent with a stopped particle distribution



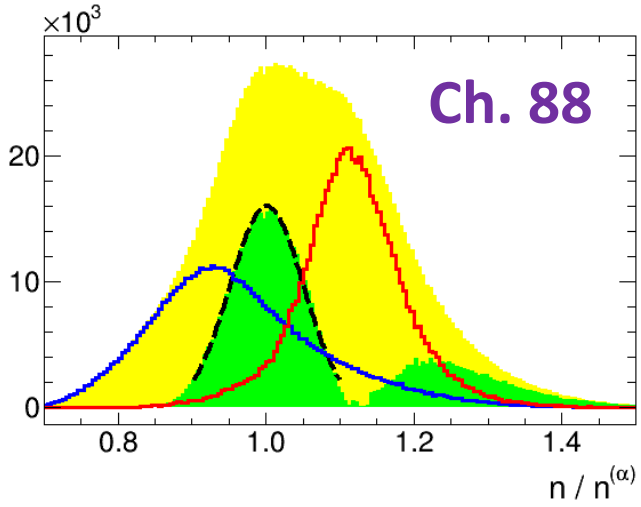

**Event fractions:**

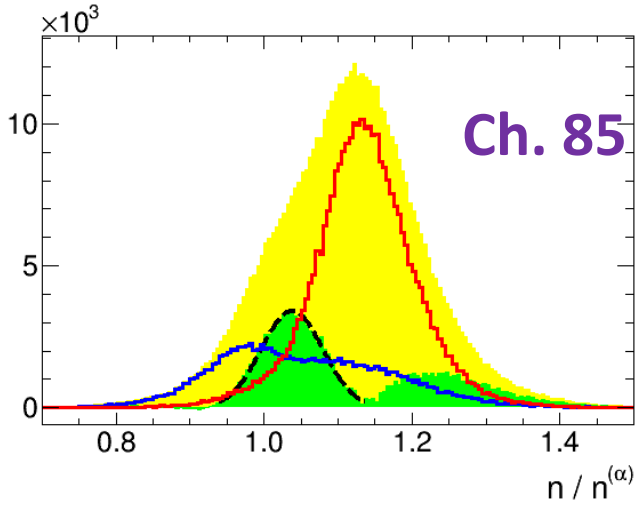
- l-prompts 33%
- r-prompts 36%
- residual 31% (24%+7%)

**The prompt data contains significant contribution of the stopped like events**

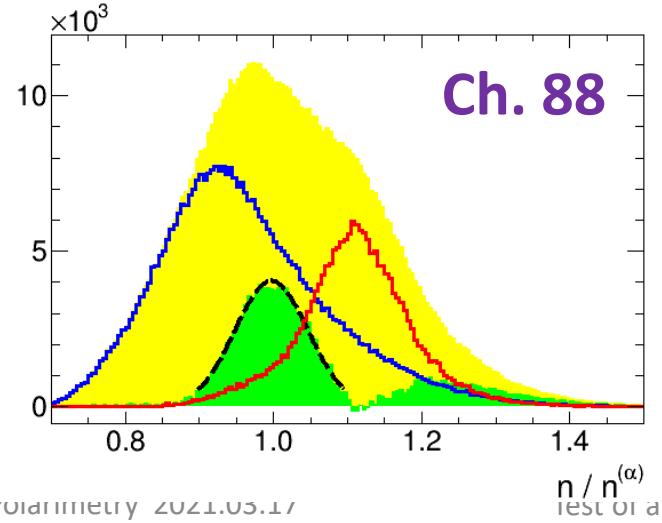
# Comparison different Au 5.8 GeV distributions

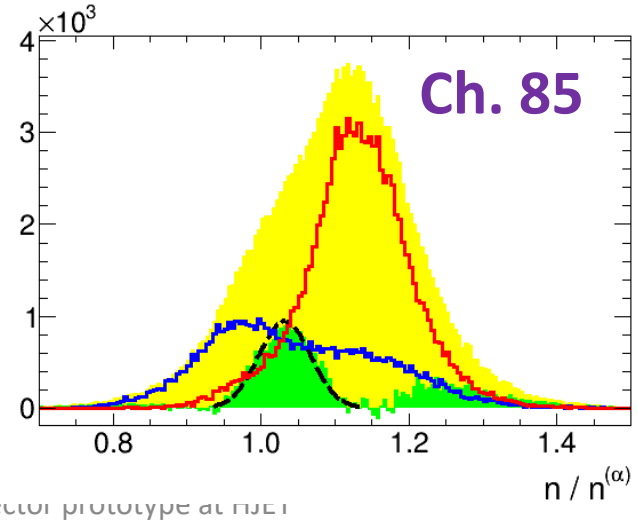
## Fills 25121-25153



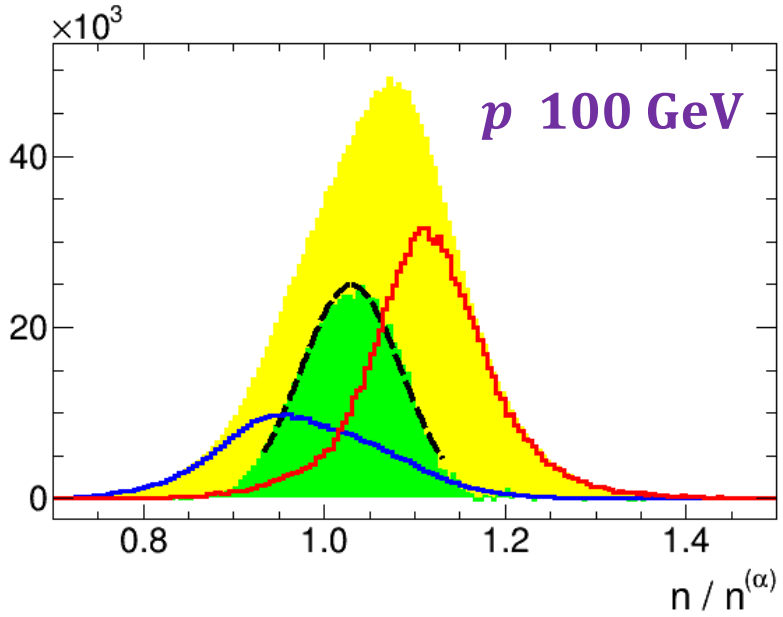

## Fills 25156-25188 Empty Target



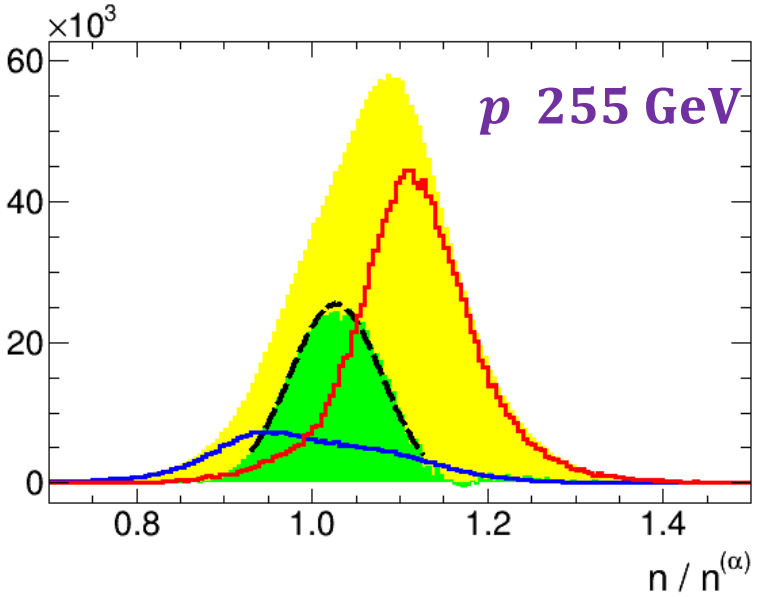



# Proton beam

*Fills 18950-18953 (2015)*

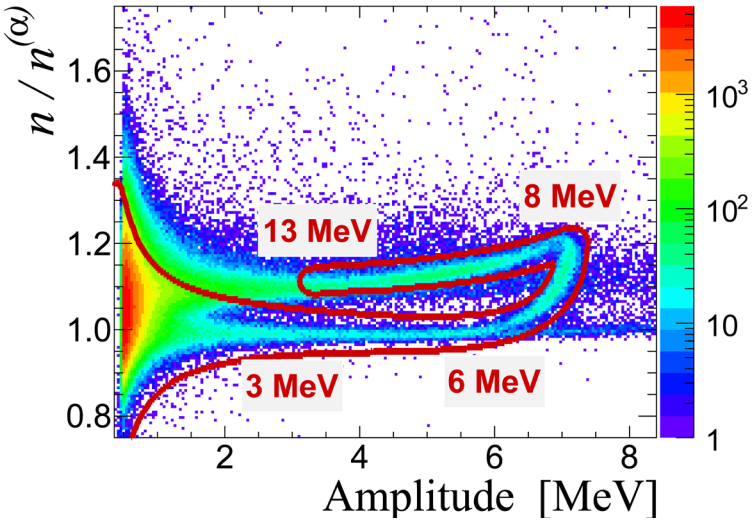


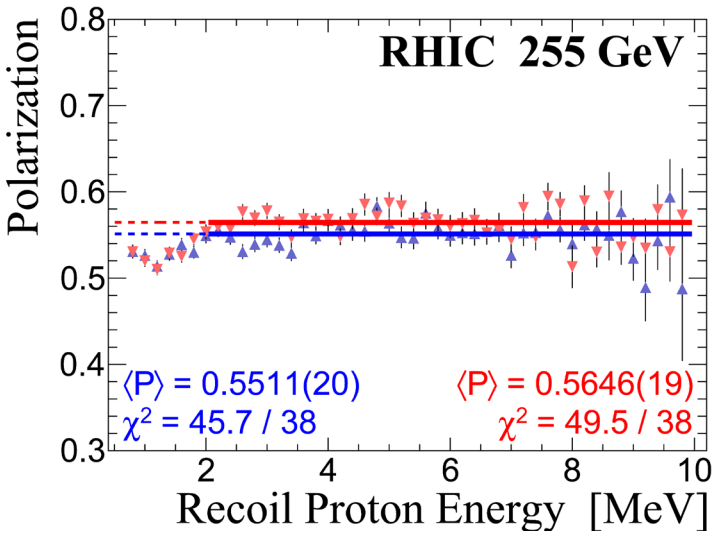

*Fills 20894-20898 (2017)*



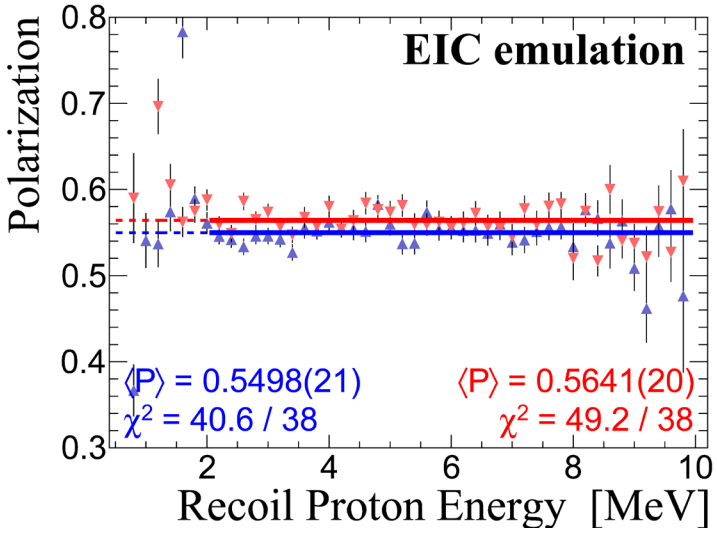

- **The l-prompt distribution was found from the pp data**
- **The r-prompt distribution was taken from 2020 Gold beam measurements**
- **Significant "stopped particle" component is also seen in the proton beam data.**

# *Another evidence of the "stopped prompts"*




- The signal waveform shape analysis allows one to efficiently separate stopped protons from the punch through (including prompts) signals.
- This allows one, to suppress the 10 ns bunch spacing problem for the elastic recoil protons with kinetic energy $T_R > 2$ MeV.
- Looking on the picture above, one can conclude that tighter event selection cuts can reduce the energy threshold to 1.5 MeV or lower.
- This assumption, however, does not work
- It really confused me. But now I can attribute this result to the presence of **"stopped prompts"** in the experimental data.



# *What t-prompts are ?*

**Minimum ionization in Si:**
$3.876\ \mathrm{MeV/cm}$

**t-prompts: 0.19 MeV**
**l-prompts: 1.45 MeV**

**Minimum ionizing t-prompts are invisible at HJET (for 0.5 MeV threshold)**

**Evaluation of the particle momentum ranges for the considered prompts $0.6 < E_{\mathrm{dep}} < 1.0\ \mathrm{MeV}$**

| | Front Layer | | | Back Layer | | |
|---|---|---|---|---|---|---|
| | $E_{\mathrm{dep}}$ [MeV] | $T_R$ [MeV] | $p_R$ [MeV/$c$] | $E_{\mathrm{dep}}$ [MeV] | $T_R$ [MeV] | $p_R$ [MeV/$c$] |
| π | 0.6 | 18 | 71 | 0.65 | 15 | 65 |
| | 1.0 | 9 | 50 | 3.20 | 3 | 30 |
| p | 0.6 | 120 | 475 | 0.61 | 117 | 469 |
| | 1.0 | 60 | 336 | 1.06 | 56 | 323 |
| d | 0.6 | 170 | 800 | 0.61 | 167 | 793 |
| | 1.0 | 84 | 561 | 1.05 | 80 | 545 |

✓ **The t-prompt protons and deuterons are expected to come from a target nuclei breakup and, thus, should have momentums typical for the Fermi motion, $\sim 250\ \mathrm{MeV}/c$.**

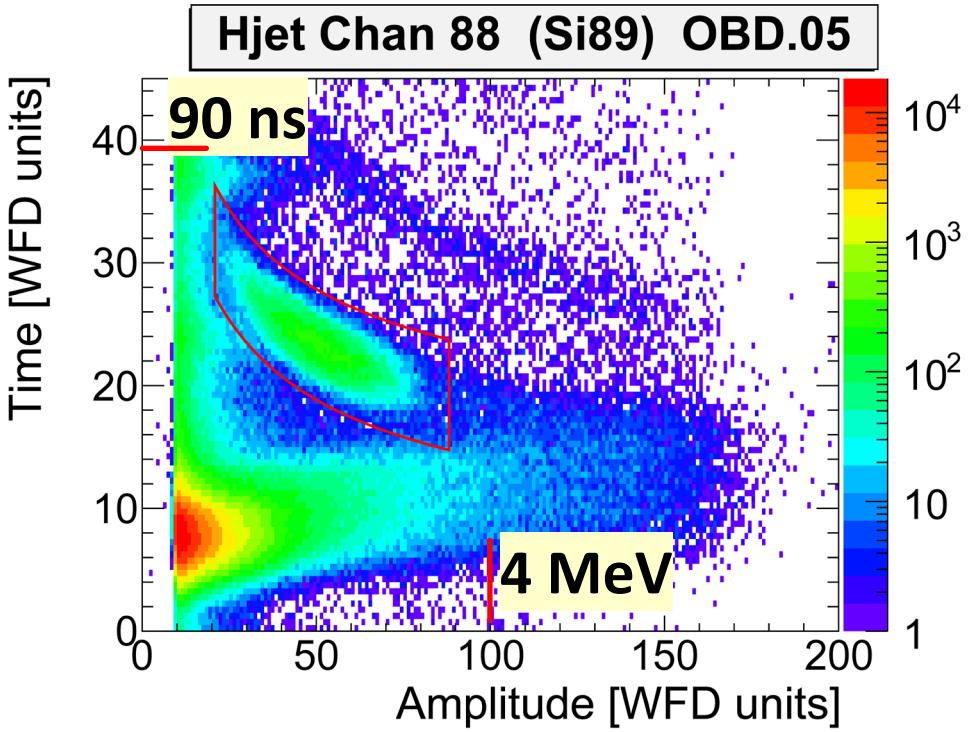
**A guess: the "stopped prompts" observed are due to photon and/or minimum ionizing pion inelastic scattering in Si detectors (or ceramics) or around.**

- **No realistic model is available yet.**
- **No understanding of the lower l-prompt rate in the second layer.**

# *Summary*

- **A prototype of the double layer Si detector for HJET was tested using 5.76 GeV/n Au beam**
- **The result obtained appeared to be inconsistent with the expectations. Punch through $\pi, p$, … originated in the scattering point can not be considered as the only contribution to the prompts.**
- **Significant "stopped like" component was found both in Gold (2020) and proton (2015, 2017) beam data.**
- **No good understanding of the prompt components yet.**
- **Unless a way to eliminate "stopped prompts" signals, in apparatus or in analysis, will be found**
  - **The effective threshold $T_R > 2$ MeV for the recoil protons cannot be lowered.**
  - **For the HJET, the double-layer detectors are not essential for solving the 10 ns bunch spacing problem at the EIC.**

# The prompts at HJET




**Possible contributions to the prompts:**

- For the $pp$ scattering
  - pions, $p_{\text{jet}} \rightarrow \pi + X \quad (T_R < 3\ \text{MeV})$
  - photons, $\pi^0 \rightarrow \gamma\gamma$
- For the $pA$ scattering
  - "target ion" dissociation
    $A \rightarrow (p, d, \alpha, \dots) + X$
- Beam halo
- Induced pulses (must not be seen at HJET)
- Optical photons (???)

**The prompts rate is reduced by factor 3-4 if the jet is OFF**

- For 107 ns bunch spacing at RHIC, prompts are not real problem. However, it may be an issue at EIC with 10 ns bunch spacing
- Due to relatively low rate, $< 100\ \text{Hz/strip} \quad (T_R > 0.5\ \text{MeV})$, of the prompts, the problem can be solved by *hardware* and/or *software* elimination of prompts.