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https://indico.bnl.gov/event/11399/

Comments to the "Simulation of pp interactions at the HJET"

A.A. Poblaguev

Brookhaven National Laboratory

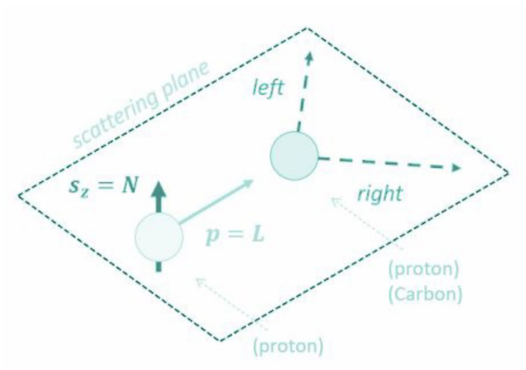
Simulation of pp interactions at the HJet polarimeter at RHIC

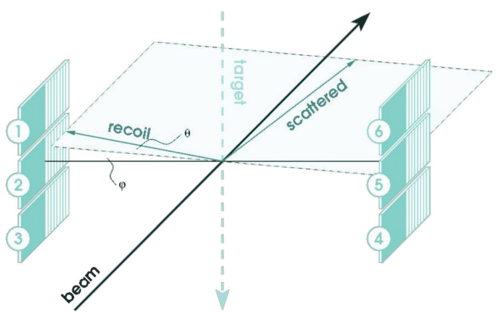
BROOKHAVEN NATIONAL LABORATORY

Ana Sofia Nunes
2021/05/05

BROOKHAVEN NATIONAL LABORATORY

Hadron polarimetry method and data



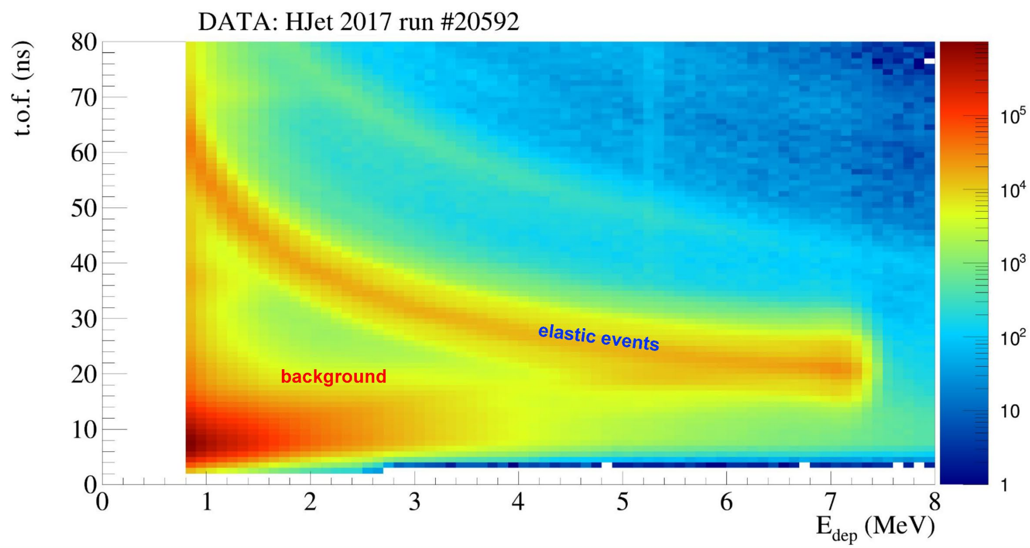


Basis:

Elastic scattering in CNI-region

-> left-right asymmetry of recoil particles: $\epsilon = \frac{N_L - N_R}{N_L + N_R}$

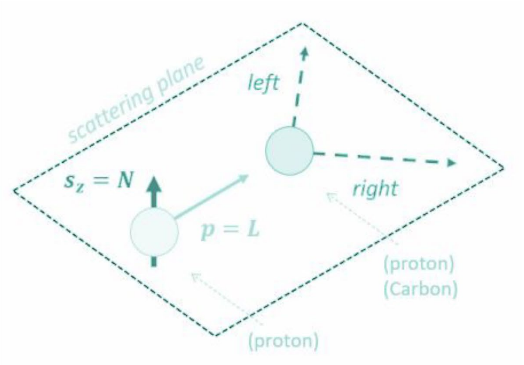
Asymmetry and polarization are related through **analyzing power**: $\epsilon = A_N P$

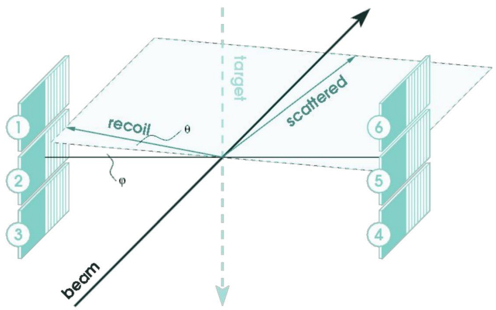


Hadron polarimetry method and da

According to the Convention, for RECOIL particles, the asymmetry is defined as

$$\epsilon = \frac{N_R^{\uparrow} - N_L^{\uparrow}}{N_R^{\uparrow} + N_L^{\uparrow}}$$





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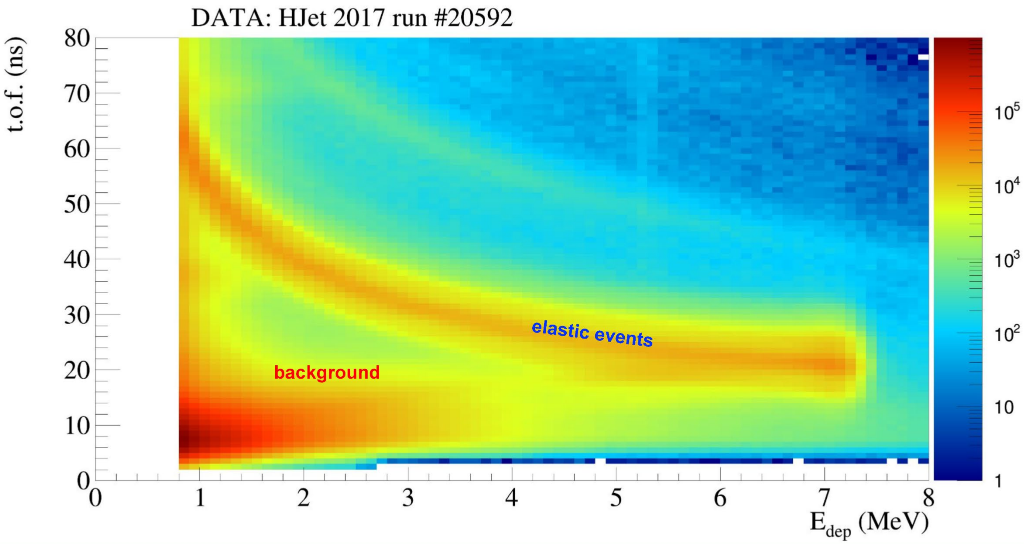

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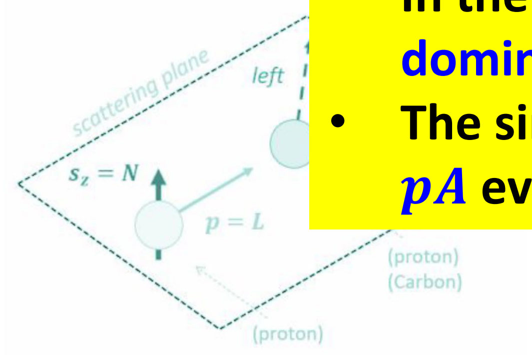
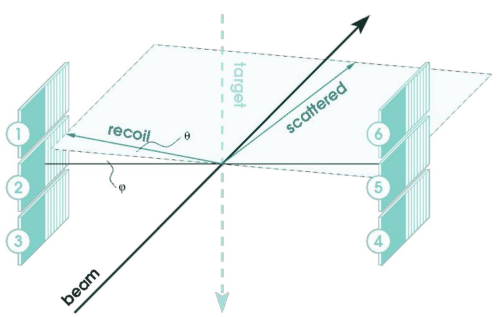
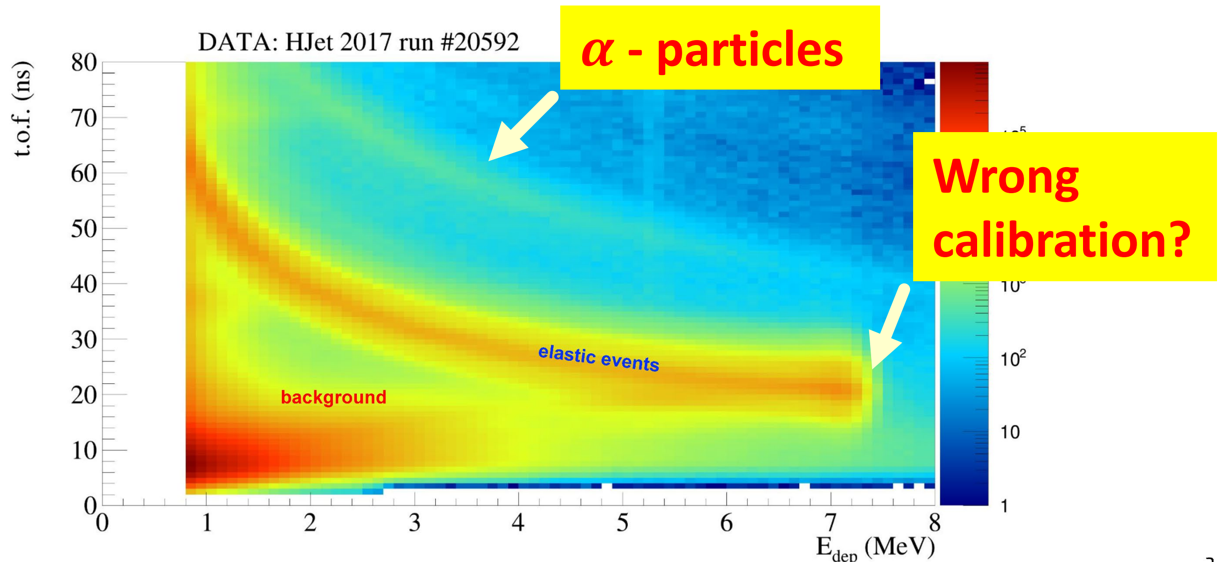
Hadron po

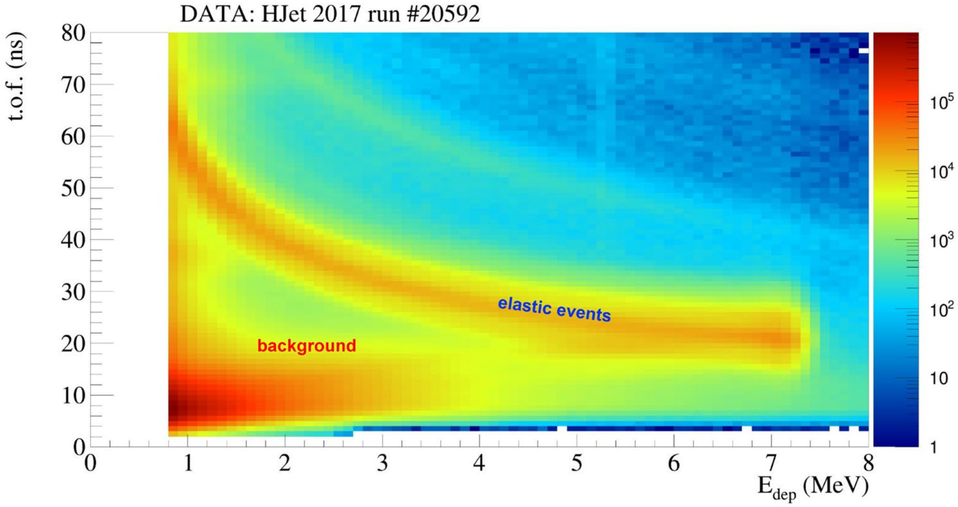
- **Alphas cannot be produced in pp scattering**
- **Most likely, we see a nucleus dissociation: $pA \to pX \to \alpha + \cdots$.**
- **Background protons also can be generated in the dissociation**
- **In the data analysis, it was found that such protons are dominant background at the HJET (for the banana events).**
- **The simulation cannot be considered as complete without such pA events.**

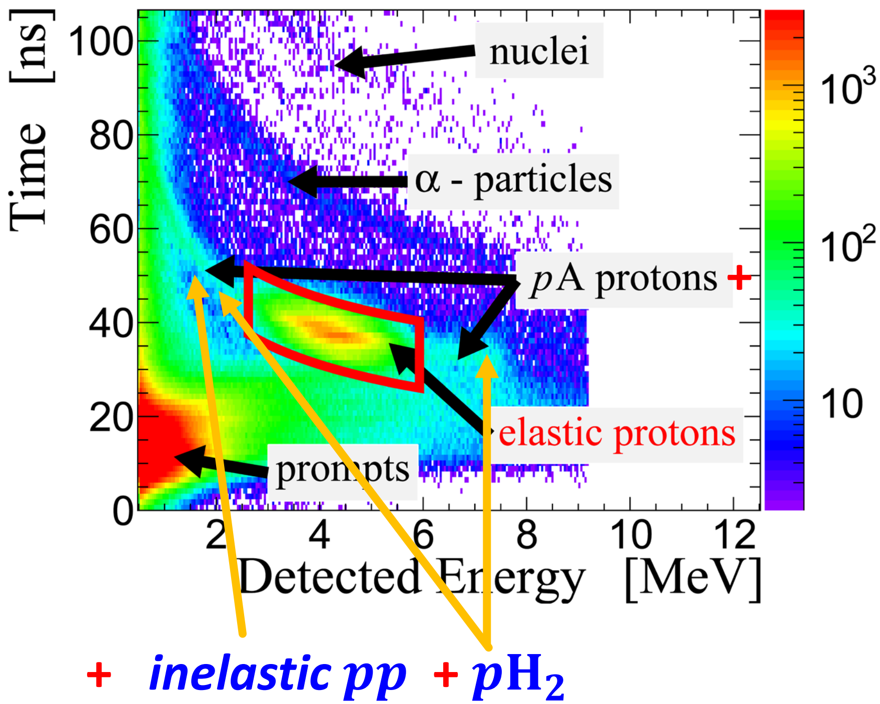






About Time-Amplitude distributions



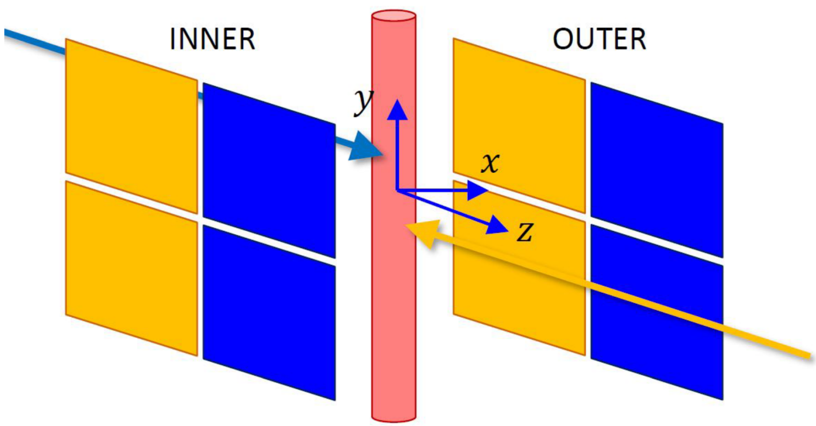


- **A Si detector segmentation by vertical strips, is critically important feature in the data analysis.**
- **Therefore, it is counterproductive to ALWAYS display the time-amplitude distribution integrated over the whole detector (12 strips).**
- **The distribution for a single strip is much more informative.**

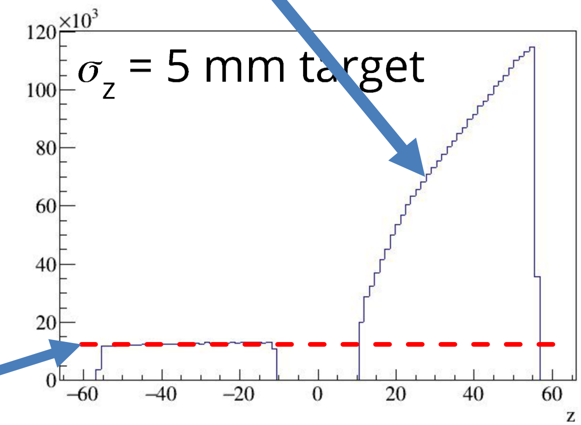
To compare with experimental data, both beams, blue and yellow, should be simulated

The elastic *pp* dN/dx is wrong.
Coulomb part is missed ?
$T_R < 2$ MeV cut off ?

Z hit distribution



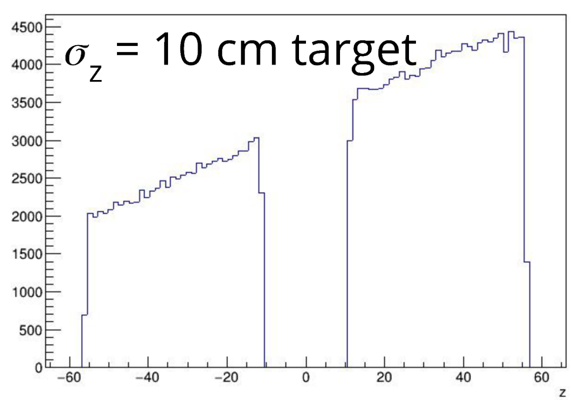
For the HJET:
$\sigma_z = 2.6$ mm

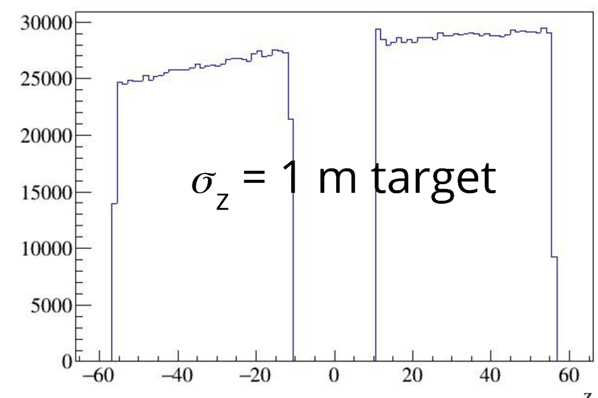


As expected !

For the blue beam:

- z>0 strips include hits from elastic process
- z<0 strips don't include hits from elastic process





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Recoil proton spectra for elastic pp scattering

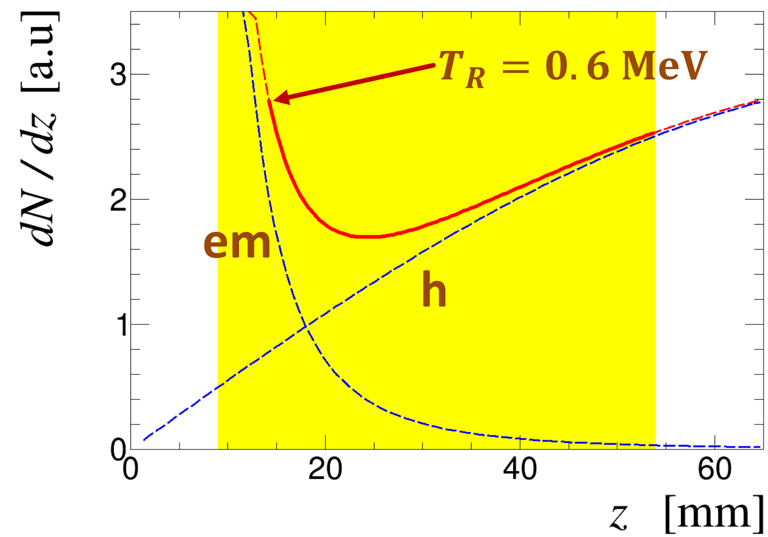
$$\frac{d\sigma}{dt} \propto \left[\left(\frac{t_c}{t}\right)^2 - 2(\rho+\delta_C)\frac{t_c}{t} + 1 + \rho^2\right]e^{Bt}$$

$z_{HJET} = \tilde{z}\sqrt{T_R}, \qquad \tilde{z} = 18\ \mathrm{mm/MeV^{1/2}}$

For 255 GeV proton beam

$T_c = -t_c/2m_p \approx 1\ \mathrm{MeV} \ \rightarrow \ z_c = \tilde{z}\sqrt{T_c} = 18\ \mathrm{mm}$

$$\frac{dN}{dz} \propto \left[\left(\frac{z_c}{z}\right)^3_{em} + \left(\frac{z}{z_c}\right)_h\right] e^{-0.02\left(\frac{z}{z_c}\right)^2},$$

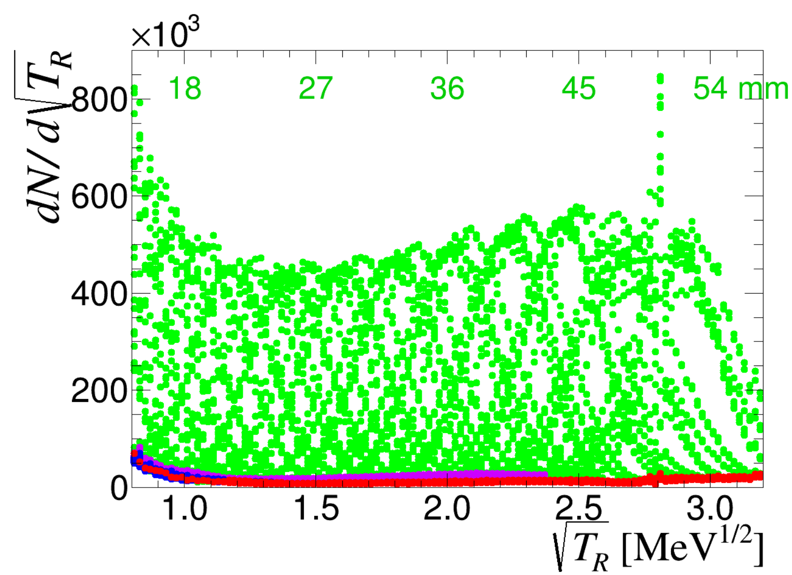


For fixed T_R and $\sigma_z = 0$, the dN/dz reflects the jet density distribution $f_{\text{jet}}(z)$:

$$\frac{dN}{dz}(z) \ \propto \ f_{\text{jet}}\left(z - \tilde{z}\sqrt{T_R}\right)$$

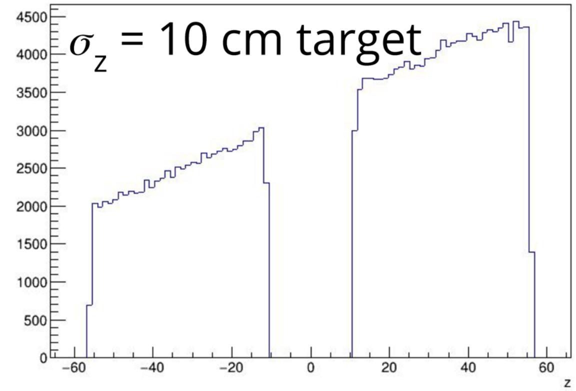
Fixed coordinate z_{strip} in the detector

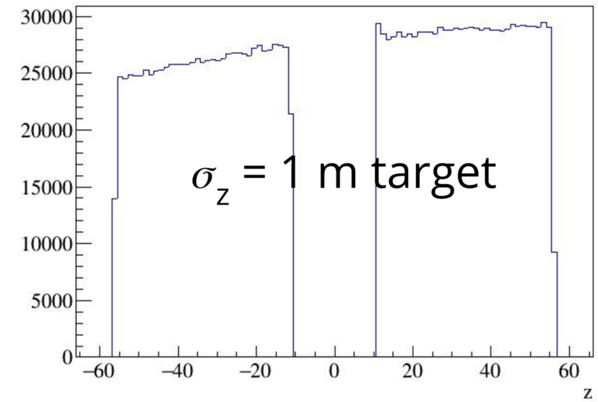
$$\frac{dN}{d\sqrt{T_R}}\left(\sqrt{T_R}\right) \ \propto \ f_{\text{jet}}\left(z_{\text{strip}} - \tilde{z}\sqrt{T_R}\right)$$



Recoil proton tracking in the Holding Field Magnet

I do not see any indication, that, in the simulation, recoil protons are tracked in the magnetic field.

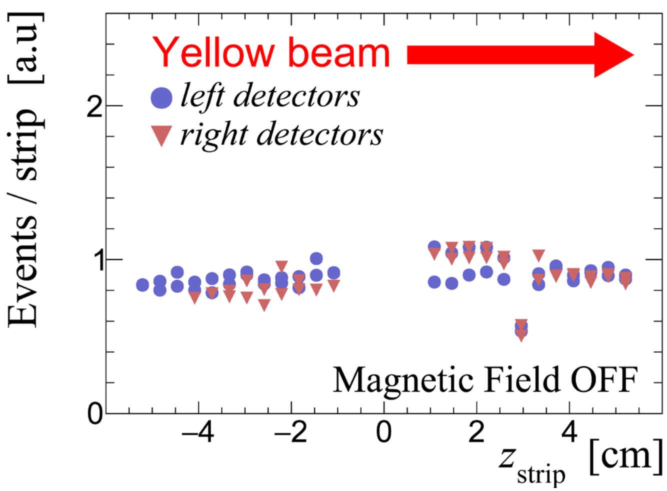


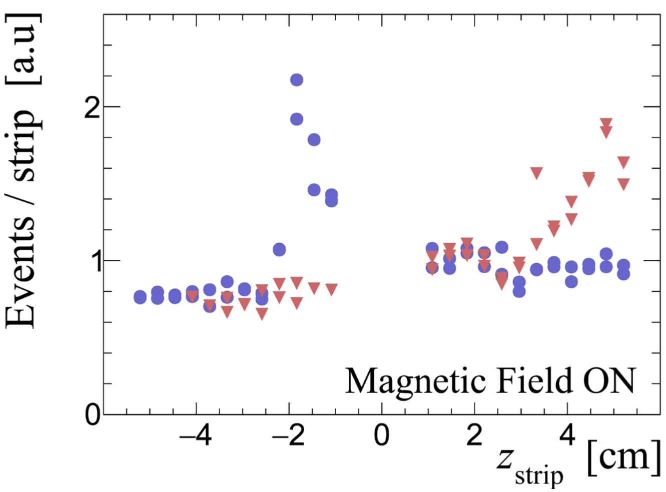


The magnetic field effect is strongly recoil proton energy T_R dependent and is not the same for left/right or upstream/downstream detectors.

Experimental results obtained with the injected hydrogen and one (yellow) beam.

$$T_R = 1.0 \pm 0.1 \text{ MeV}$$





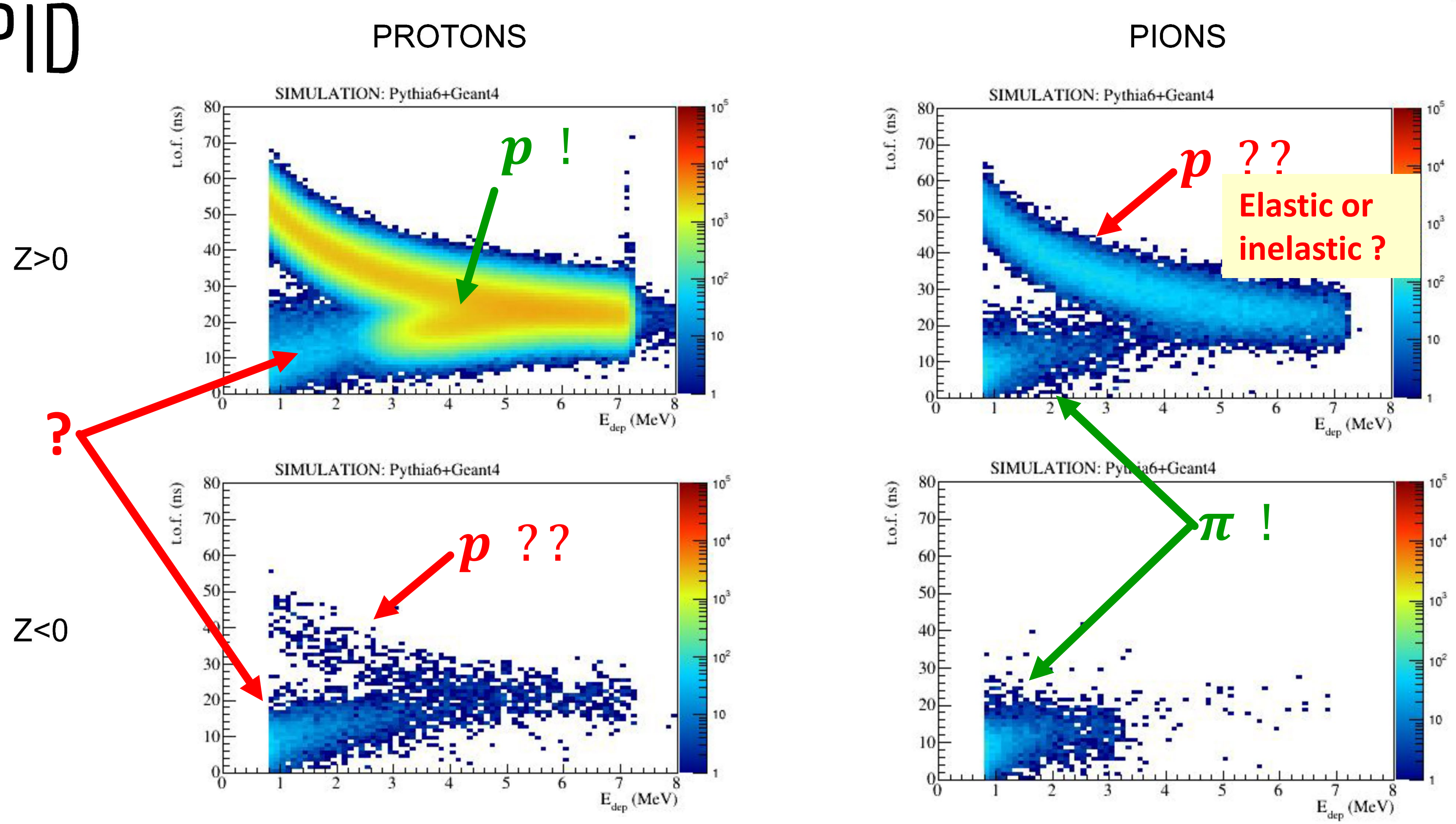
For the pp scattering and $\sigma_z = 0$:

- Recoil protons $(E_{\text{dep}} < 8\ \text{MeV})$ can be detected in the banana area and only at $z > 0$
- Pions $(E_{\text{dep}} < 3.1\ \text{MeV})$ can be seen only in the prompts and the rate is about z-independent.

Page 5

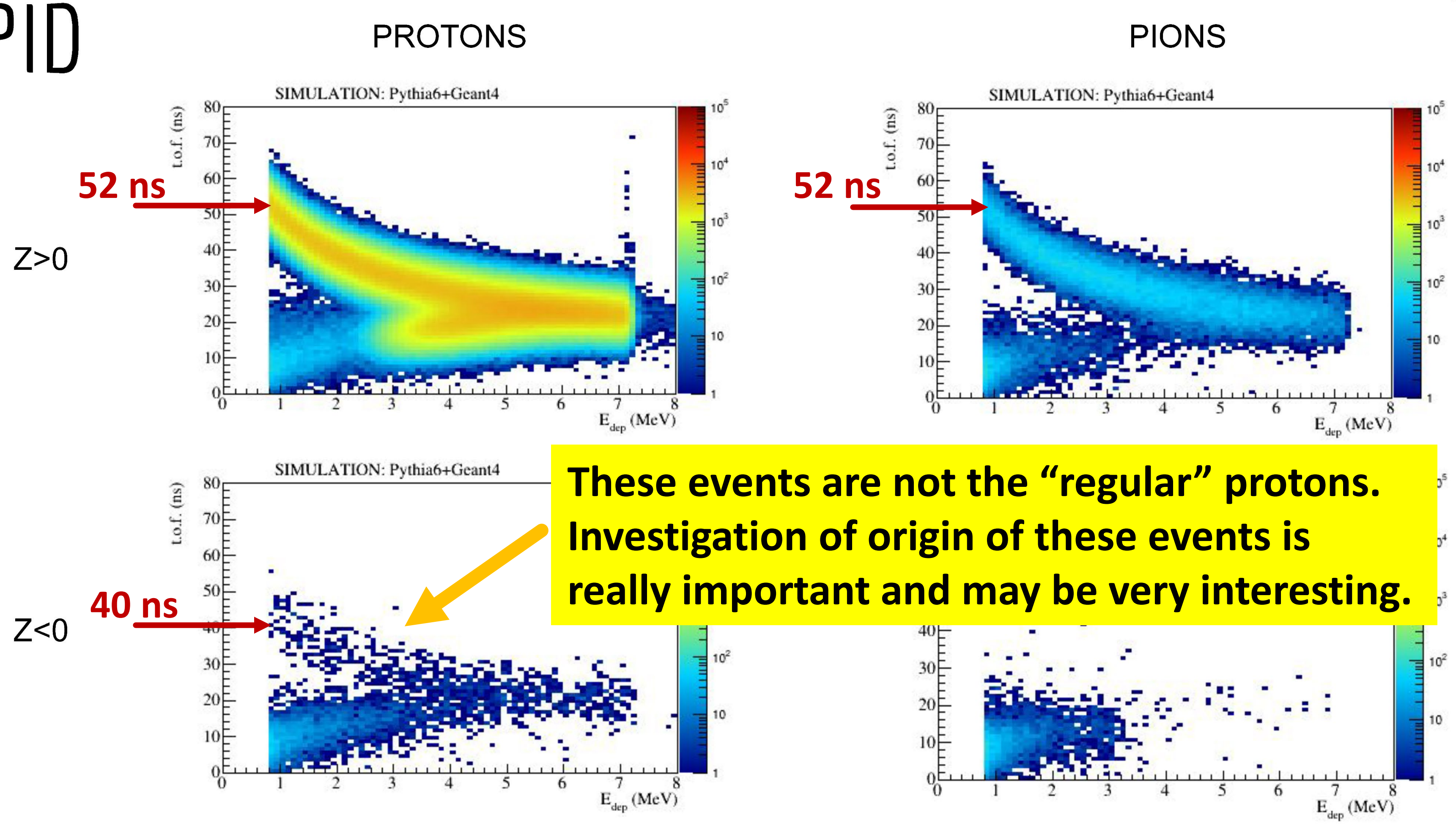
σ_z = 5 mm target

PID



PID

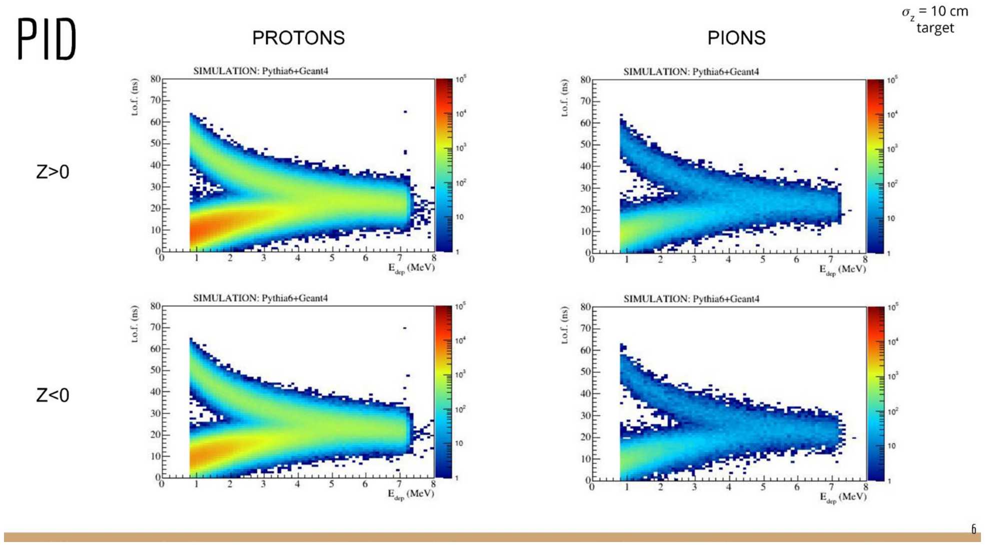
σ_z = 5 mm target

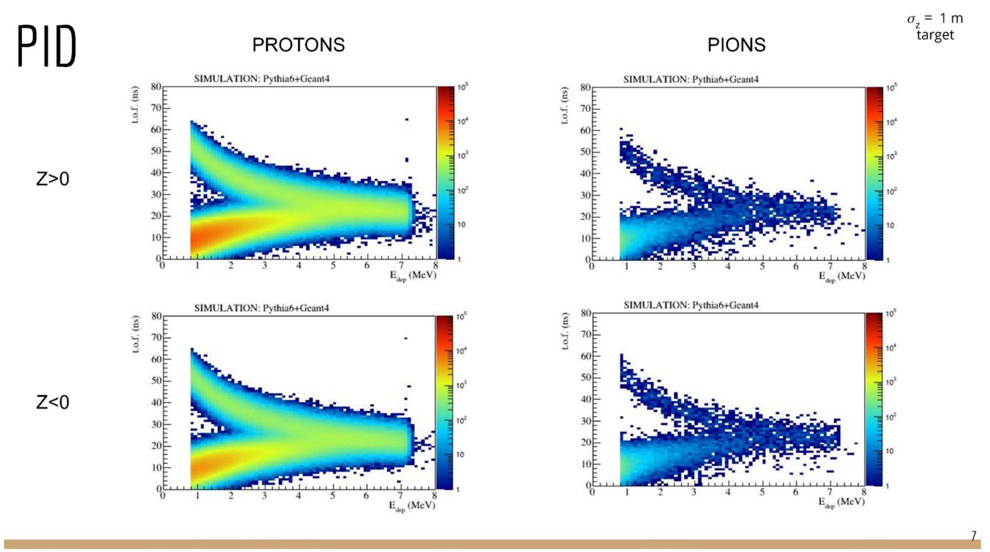


These events are not the "regular" protons. Investigation of origin of these events is really important and may be very interesting.

Pages 6-7

There is no much sense to discuss pages 6-7 ($\sigma_z = 10$ and 100 cm) before we will understand the case $\sigma_z = 2.6$ cm.





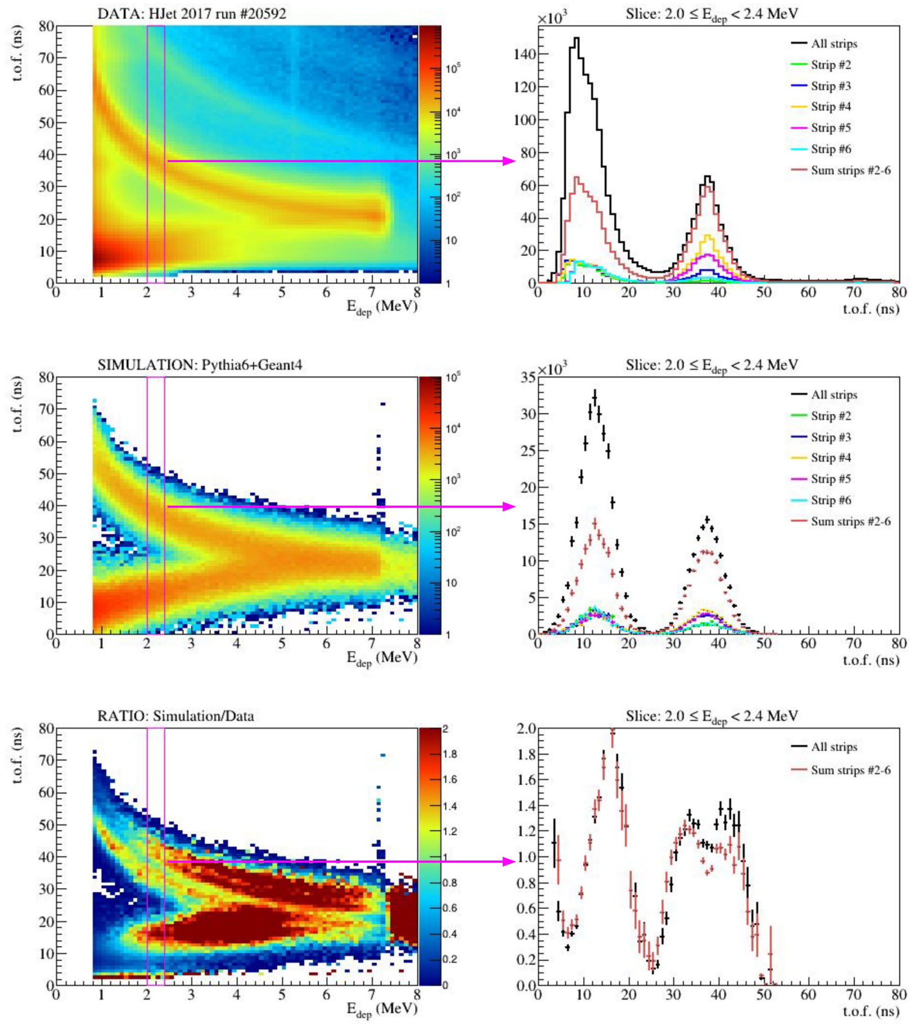
Data vs simulation

DATA: t.o.f. vs E_{dep}

SIMULATION: t.o.f. vs E_{dep}

RATIO (SIMULATION/DATA): t.o.f. vs E_{dep}

1Bevents, σ_z = 5 mm target,
100Mevents σ_z = 10 cm target,
100Mevents σ_z = 1 m target,
background (z<0)
multiplicative factor 45



Data vs simulation

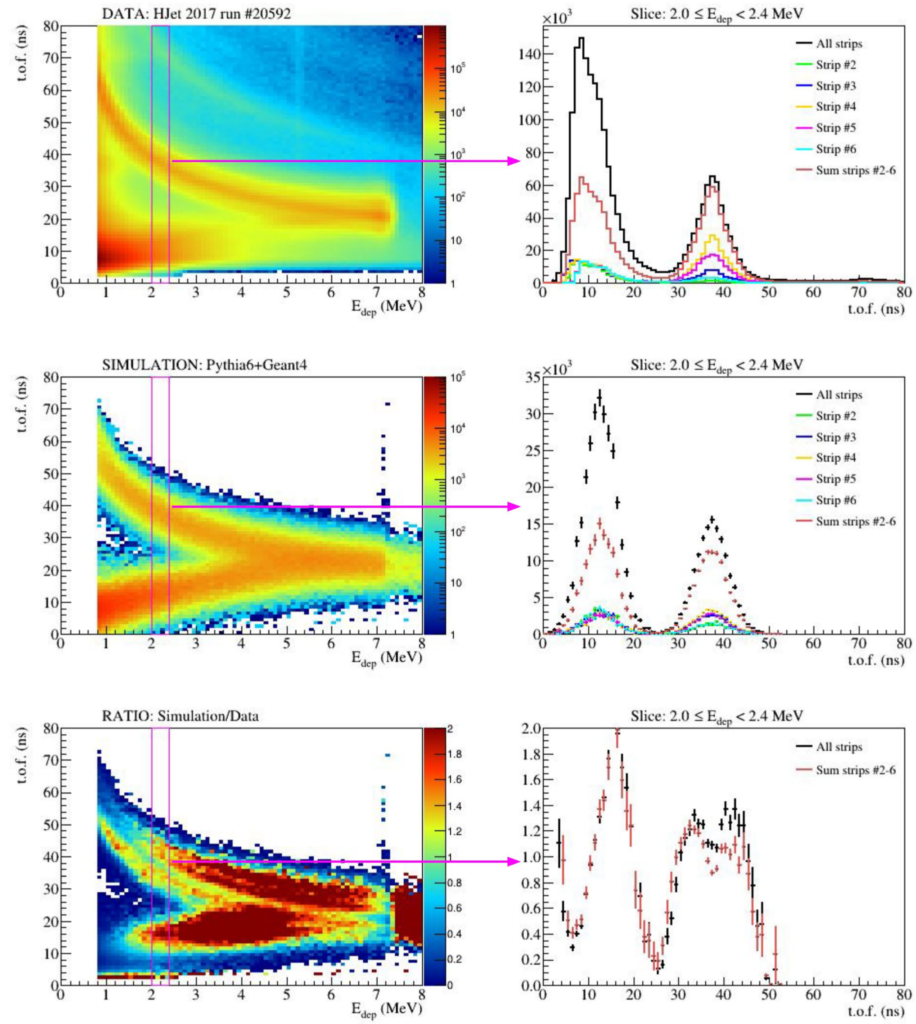
DATA: t.o.f. vs E_{dep}

1B
10
10
ba
mu

For the normalization used, the simulated rate of the elastic protons, $T_R \sim 5$ MeV, is overestimated by factor ~2, while the prompts, $E_{dep} \sim 1$ MeV, are underestimated by factor 5-10.

Thus, the simulation explains no more than 10% of the experimentally observed rate of the prompts.

RATIO (SIMULATION/DATA): t.o.f. vs E_{dep}



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Summary and outlook

The method is not explained. Are there any advantages compared to the injected hydrogen measurement?

The simulation is incomplete yet, *pA*, etc

A reasonable description of the HJet data was achieved using Pythia 6 and Geant 4 / HJetSim, namely:

- Composition of the background (including punch-through particles) to elastic events
- Extended targets allow to emulate molecular hydrogen
- Dead layer allows to reproduce the cutoff in the tof vs E_{dep} plot at E_{dep}~7 MeV
- Delta(tof) ~ 1 ns allows to get an almost symmetric ration for the signal peak

???

7 MeV cutoff is wrong value

Next steps:

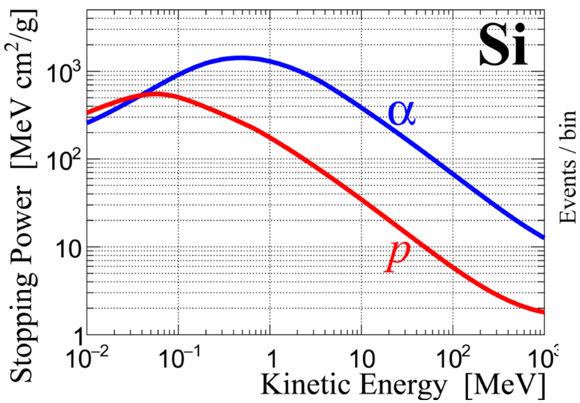
- Second layer of silicon
- pC polarimeter

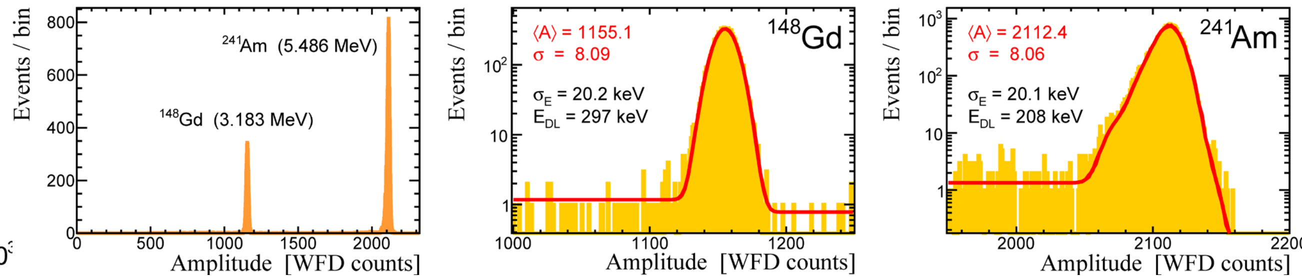
First, adequate simulation of the prompts in a single layer detector should be done

Detector dead-layer and energy calibration

$T_R = 7\ \mathrm{MeV} \rightarrow 380\ \mu\mathrm{m}$ stopping power
$T_R = 8\ \mathrm{MeV} \rightarrow 480\ \mu\mathrm{m}$

The HJET detector thickness is $480\ \mu\mathrm{m}$





Both, gain and dead-layer $x_{DL} \sim 0.37\ \mathrm{mg/cm^2}$ are determined in α-calibration

The recoil proton energy deposited in the dead-layer:
$\sim 70\ \mathrm{keV}\ (T_R = 1\ \mathrm{MeV})$ $\sim 10\ \mathrm{keV}\ (T_R = 8\ \mathrm{MeV})$

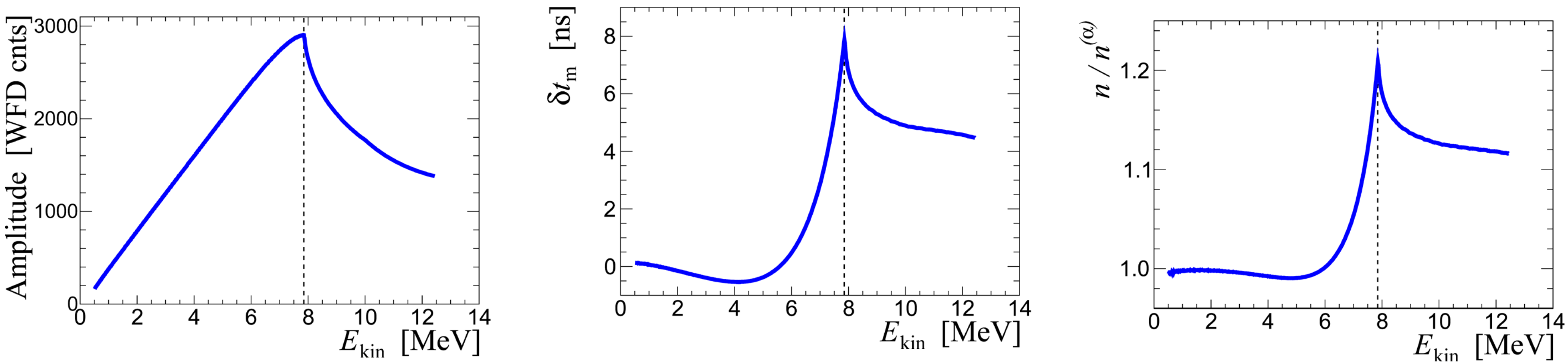
The results of α-calibration were verified in the elastic data analysis.

The evaluated systematic uncertainty in the energy calibration is

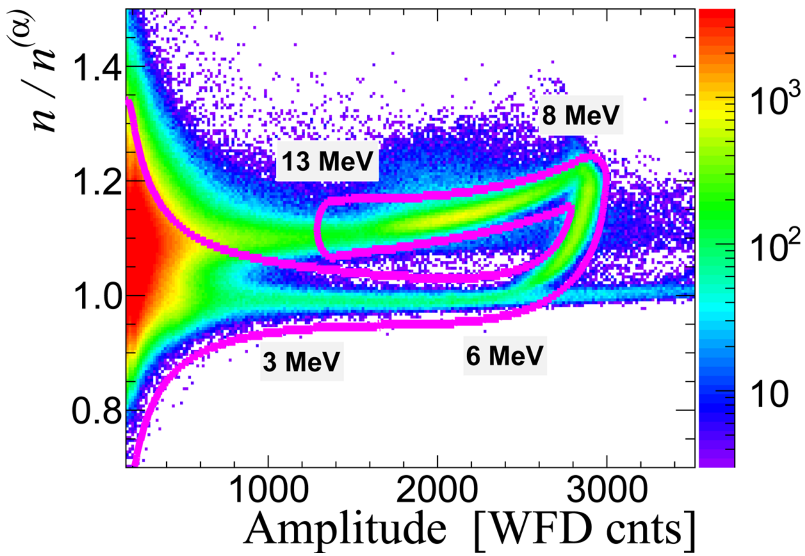
$$\delta T_R = \pm 15\ \mathrm{keV} \oplus (\pm 0.01) \times T_R$$

How can the simulation help the HJET data analysis in RHIC ?

1. Study of the signal waveform shape dependence on p (π, α, …) kinetic energy.



- The main goal of this study is reconstruction of the kinetic energy of a punch through particle.
- The results may be important for understanding nature of the prompts.



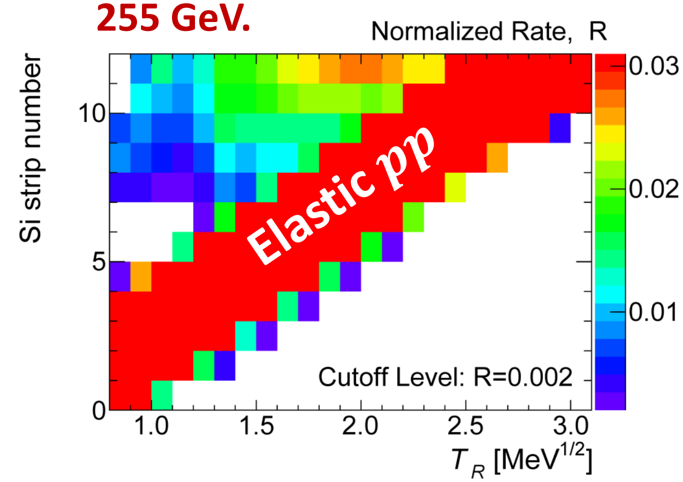
2. Background subtraction

Background subtraction method:
Evaluation of a background out of the elastic pp diagonal in the z-$\sqrt{T_R}$ plot and extrapolation the background to the "diagonal" events.

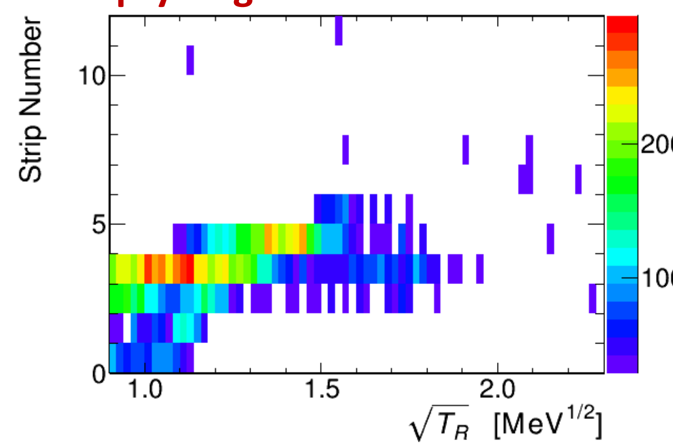
- ***pA* background** is expected to be the same in all Si strips. The extrapolation is trivial.
- **Scattering on the beam gas hydrogen**. The background is the same in all Si strips if no magnetic field. Recoil proton tracking in the magnetic field requires special study.
- **Inelastic *pp* scattering**. The background is essential only above the diagonal and only for E_{beam}>100 GeV.

- For $T_R > 2$ **MeV**, background can be accurately evaluated and subtracted using the data below the elastic pp diagonal
- For $T_R < 2$ **MeV**, simulation of the backgrounds separately in **UL** (Upstream Left), **UR**, **DL**, and **DR** detectors is needed.

Inelastic background. 255 GeV.



Molecular hydrogen background. Empty target measurement.



Standard background subtraction was applied to both histograms

Summary

- **Any, e.g. Geant, simulation is only an approximation of the real experiment. In basic approach, it is crude (if 1% accuracy required) but often can be properly adjusted.**
- **The simulation should be scrupulously compared with relevant experimental data before it can be used in data analysis or to improve the experimental setup.**
- **For the HJET simulation, it is time to begin such a fine tuning.**