A. Poblaguev

A precise in-situ calibration of the H-Jet

Do we need a precize calibration for the H-Jet?

• In the H-Jet, beam polarization is measured by comparison beam and jet asymmetries and , thus, result is irrelevant to the actual calibration (unless we want to publish he dependence of analysing power on the momentum transfer.

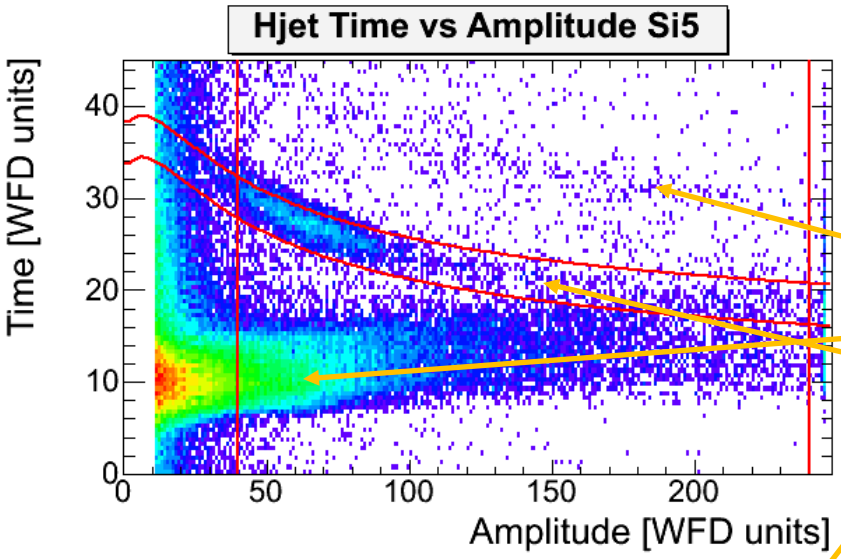
but

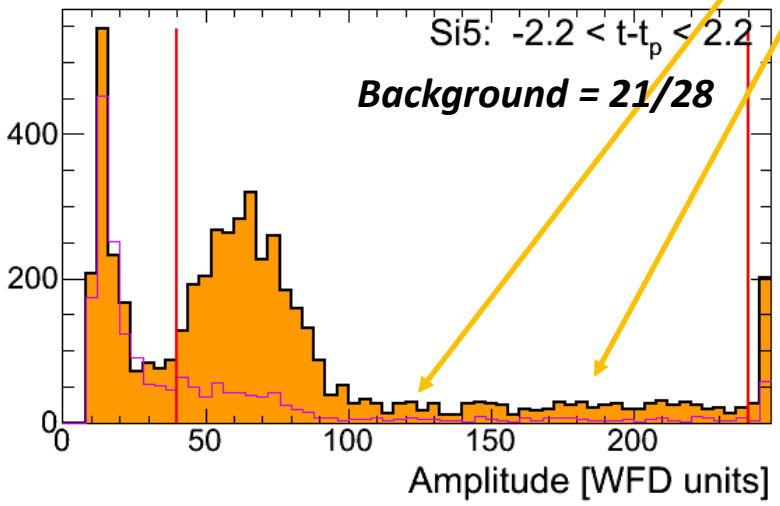
• Calibration procedure allows us to verify that we understand the performance of our detector.
• An accurate calibration allow us to apply tighter cuts and, thus, to reduce background
• In the H-jet background is expected to be the same in all strips. We can use one strip to evaluate background in other strip if all strips are properly calibrated.

If we can we must calibrate the detector!

The proton banana

x1903.902 (March 19, pump problem) IT=28





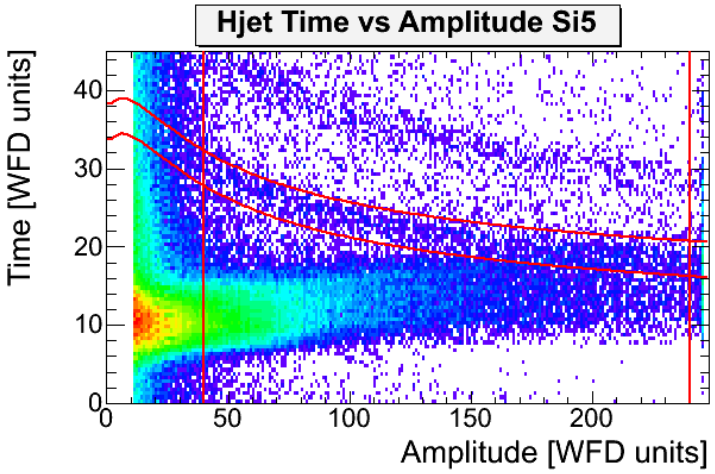
The Time-Amplitude distribution indicate processes beyond the simple pp – interaction model:

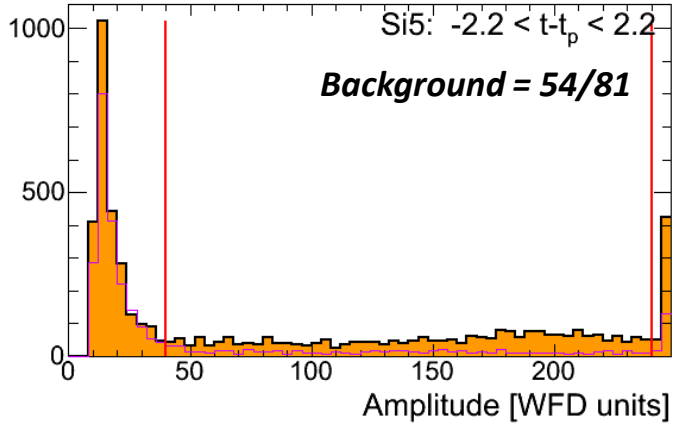
- Alphas
- Prompt
- Tails in the proton energy distributions
- Unidentified background in the elastic pp events is too big 5-10%

We see alphas, protons, and prompts in the no-jet runs

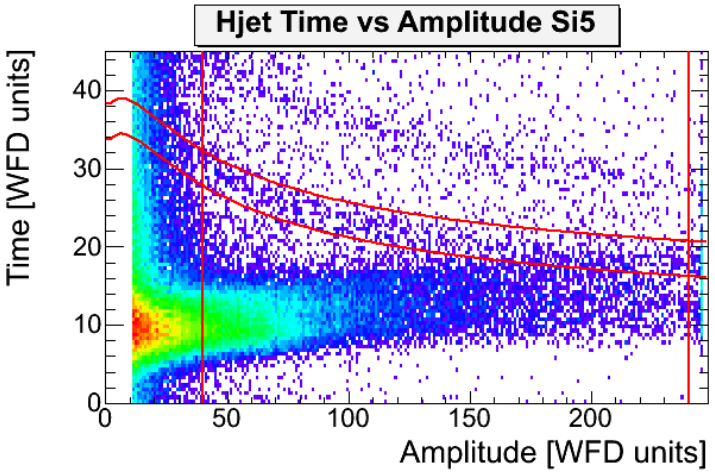
There is a significant contribution from the *pA→pX* interaction in the beam-line gas.

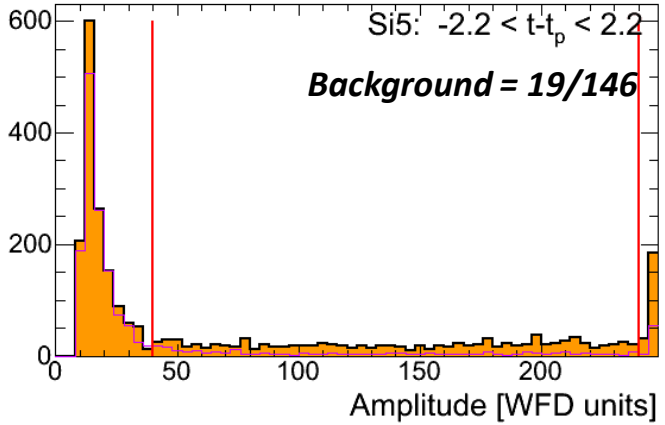
Empty Target Fills





Fill 17250 (March 20, pump problem) IT = 82

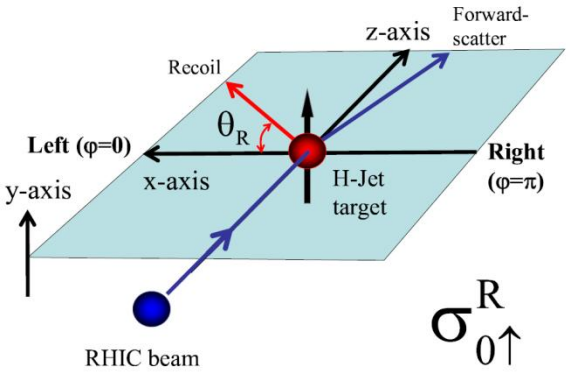




Fill 17474 (May 8) IT = 146

IT = Intensity × Time (arbitrary units)

Proton energy spectrum in elastic pp interaction



$$\frac{z}{L} = \tan\theta_R = \sqrt{\frac{T}{2M_p}\frac{E_{\text{beam}} + M_p}{E_{\text{beam}} - M_p}} \Rightarrow z = \zeta\sqrt{T}$$

$$\frac{dN}{dt} \propto \frac{d\sigma_{pp}}{dt}\int dz n(z) A(z, z_d, T)$$ ← **Acceptance**

$$\sigma^{\text{R}}_{0\uparrow}$$

$$t = -2M_pT \qquad n(z) \propto \exp\frac{-0.5z^2}{(2.7\ \text{mm})^2}$$ ← **Jet Density**

For a narrow Si strip: $A(z, z_d, T) = \delta(z_d - z - \zeta\sqrt{T}) \Rightarrow \frac{dN}{dt} \propto \frac{d\sigma_{pp}}{dt} \times n(z_d - \zeta\sqrt{T})$

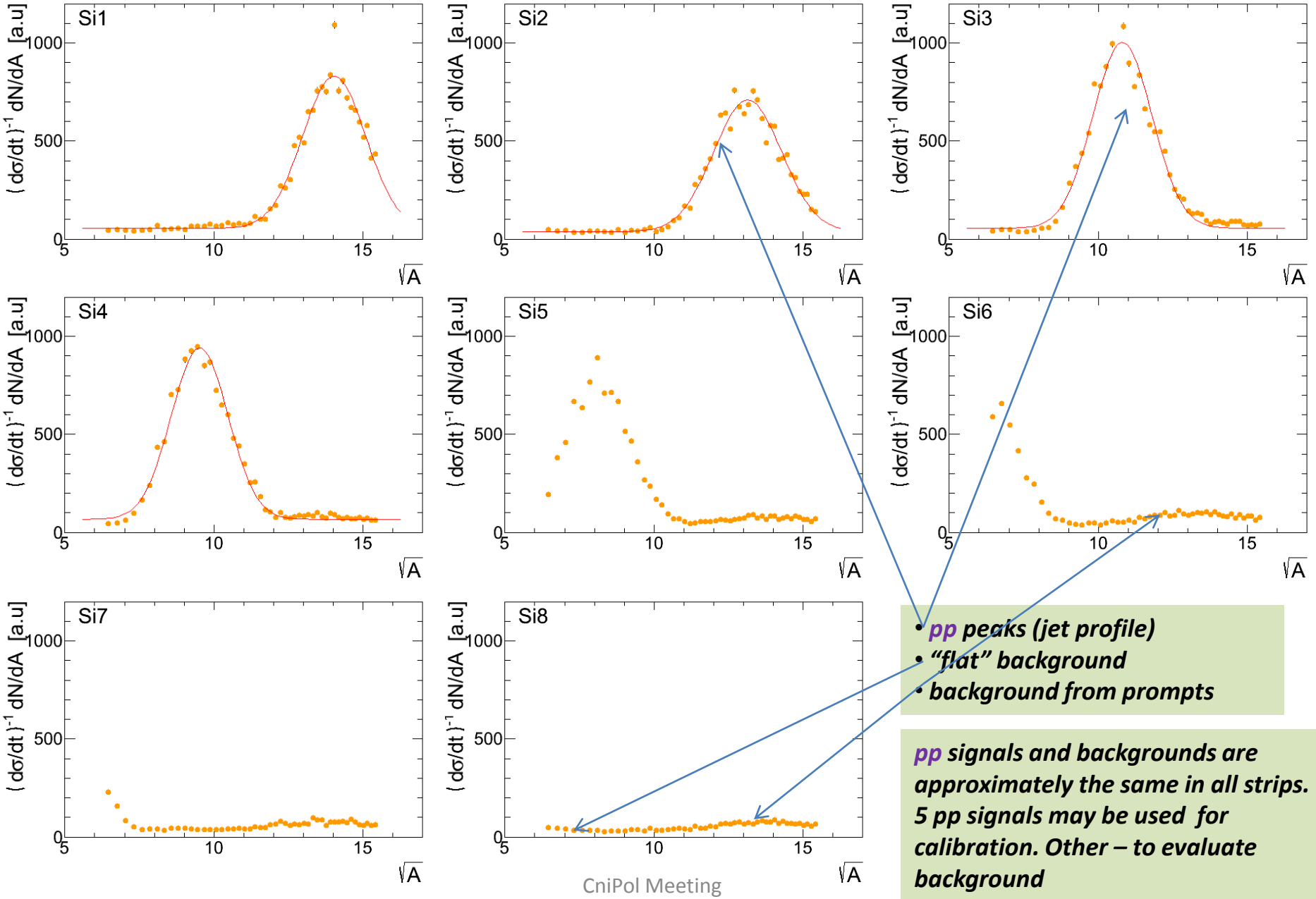
For a 4.44 mm strip: $n(z) \Rightarrow n_{\text{eff}}(z) \propto \exp\frac{-0.5z^2}{(3.0\ \text{mm})^2}$

For elastic pp-interactions , the function $\eta(\sqrt{A}) = \left(\frac{d\sigma_{pp}}{dt}\right)^{-1}\frac{dN}{dA}$

where A is signal amplitude, gives the image of the jet concentration along z-axis. The value of A at the maximum may be associated with a well defined (from the detector geometry) energy.

A beam gas background is expected to be the same for all strips. This background may be amplitude (energy dependent).

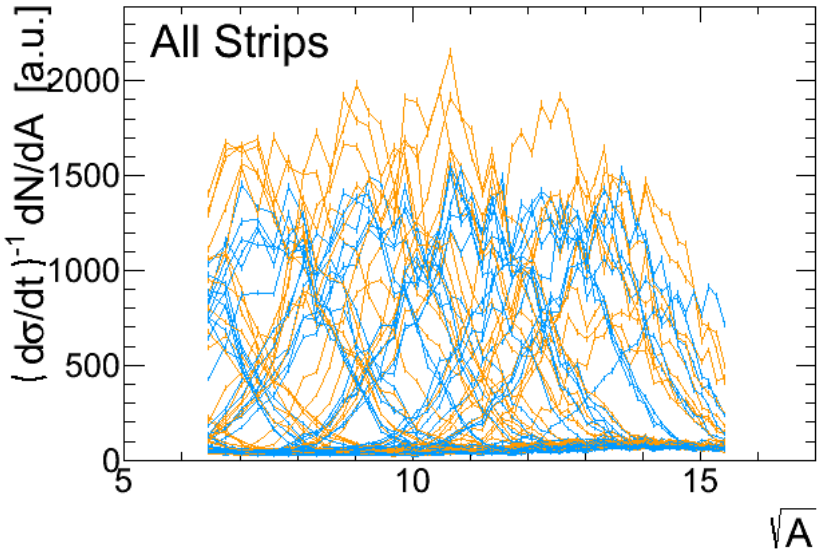
$\eta(\sqrt{A})$ for eight (yellow) strips of the detector 1 (Fill 17600)

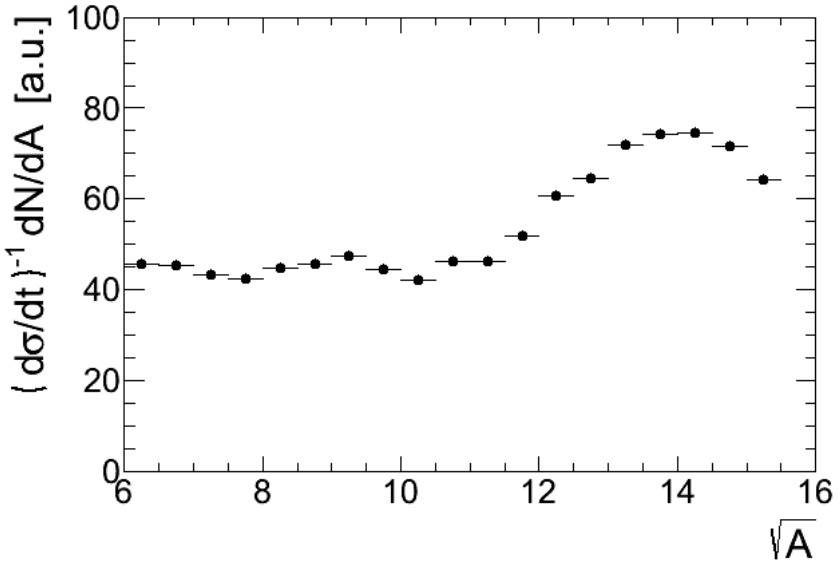


- *pp peaks (jet profile)*
- *"flat" background*
- *background from prompts*

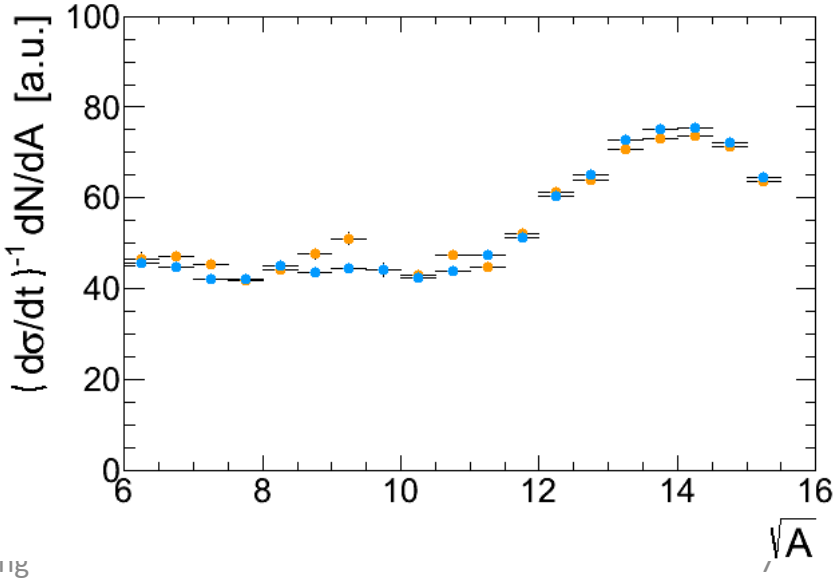
pp signals and backgrounds are approximately the same in all strips. 5 pp signals may be used for calibration. Other – to evaluate background

Background Evaluation (Fill 17600)

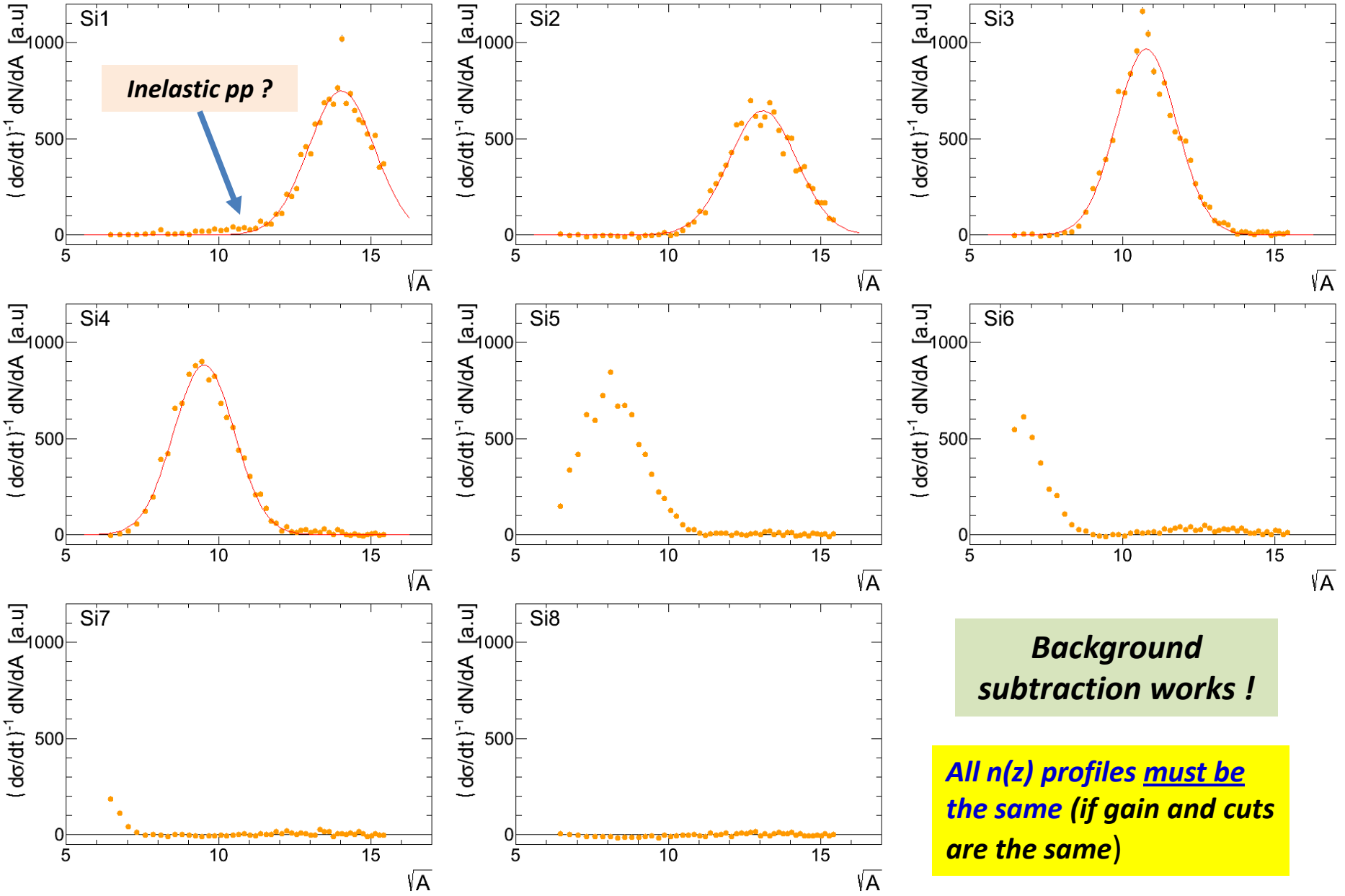




- ***The algorithm is satisfactory for the calibration purposes.***
- ***To study background asymmetry, an improvement is still needed.***



Detector 1 after background subtraction (Fill 17600)



Background subtraction works !

All n(z) profiles must be the same (if gain and cuts are the same)

Background correction to the measured polarization

(A brief comment)

$$A_N^{eff} = \frac{A_N + r A_N^{bgr}}{1+r} = A_N \frac{1+\alpha r}{1+r}; \qquad \alpha = A_N^{bgr}/A_N$$

***r ~ 5%** is background level*

For Jet asymmetry α=0. For beam asymmetry α is unknown and may be as large as 1.

$$P_{meas} = P_{beam}(1+\alpha r)$$

In the above example, background level was suppressed (by subtraction) by about factor 5. The correction to the measured polarization should also be suppressed by factor 5. Moreover by comparing measured polarization before and after background suppression we may evaluate the remaining correction.

Advantage of the method:

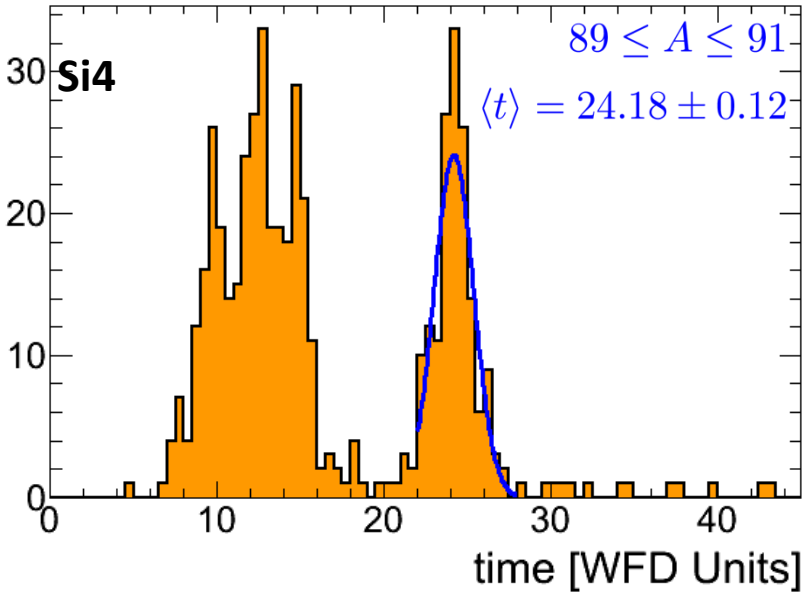
- *The background statistics available (by product)for the evaluation is about 20-30% of good event statistics.*
- *The dependence of the background analyzing power on amplitude etc is automatically accounted.*

To be done:

- *The method have to proved (more study is still needed).*
- *Background subtraction should be done separately for every combination of the Beam/Jet Polarity and left/right selection of detectors.*

The calibration schema

$$E_{\mathrm{strip}}(z) \equiv \sqrt{A_{\max}} \Rightarrow A(E_{\mathrm{strip}}) \Rightarrow t_{\mathrm{meas}}(E_{\mathrm{strip}}) \Rightarrow t_0 = t_{\mathrm{meas}} - L\sqrt{\frac{M_p}{2E_{\mathrm{strip}}}}$$



t_0 is measured in a model independent (almost) way, without any knowledge about gain and dead-layer.

If we measure the dependence t=t(A) (banana), then for every amplitude we may calculate the energy:

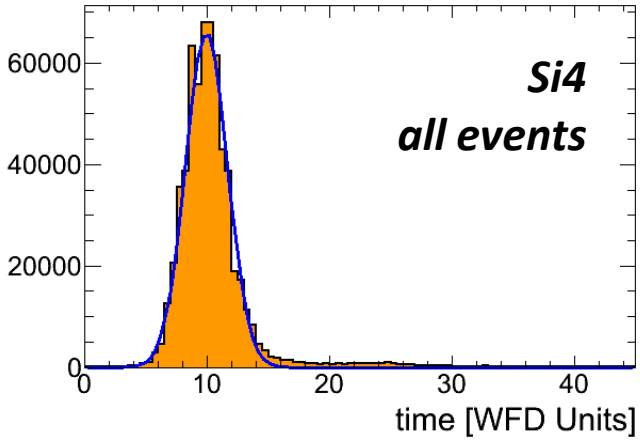
$$E = \frac{M_p}{2}\left(\frac{L}{t(A) - t_0}\right)^2$$

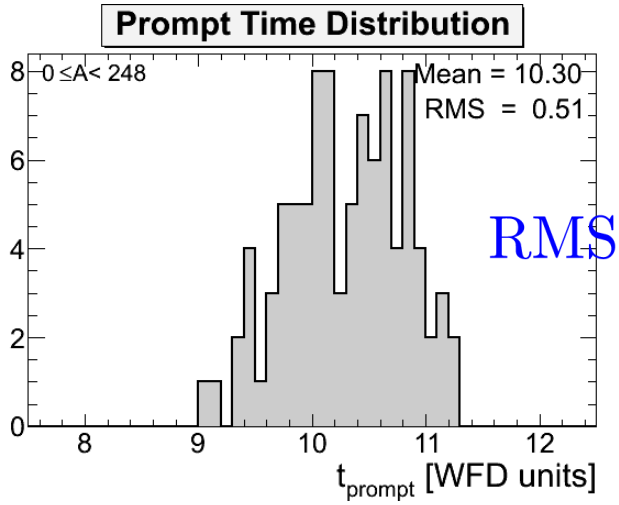
Gain α and dead-layer d are only one of the possible parameterizations of t=t(A)

$$\frac{\delta T}{T} = -\frac{2\delta t}{t} \approx -\frac{2\sqrt{T/\mathrm{MeV}}}{57.7\,\mathrm{ns}}\delta t; \quad \text{For } \sigma_t = 0.5\,\mathrm{ns} \text{ and } T = 5\,\mathrm{MeV} \;\Rightarrow\; \sigma_T/T = 3.9\%$$

Accuracy of the t_0 determination is crucial for the calibration. We must evaluate it !

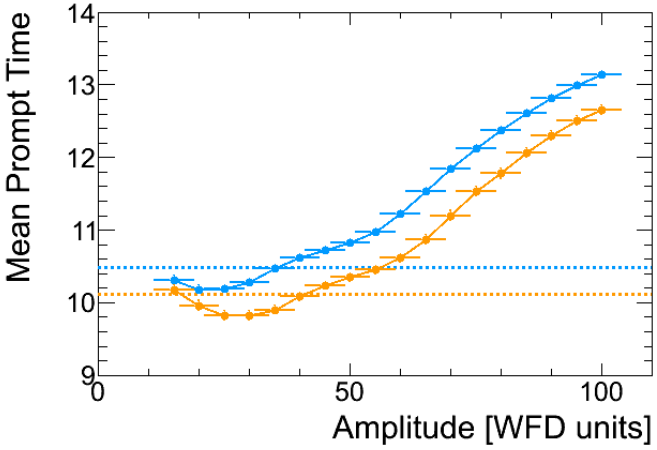
Determination of t_0 from the prompt events

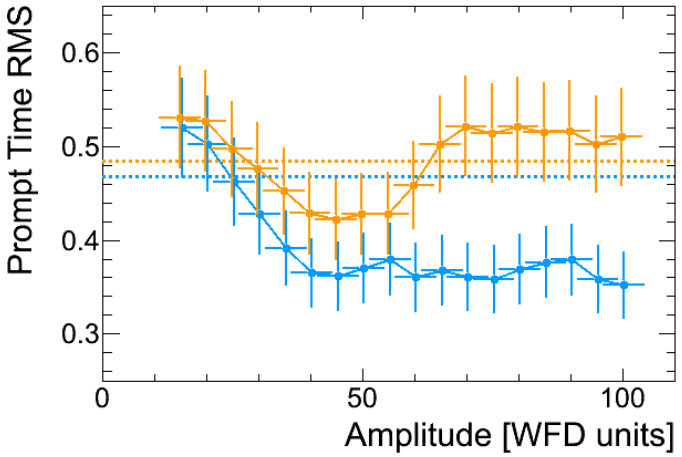




$$\mathrm{RMS} = \sigma_{\mathrm{delay}} \oplus \sigma_{\mathrm{meas}}$$

Amplitude selection for the prompt t_0 determination.



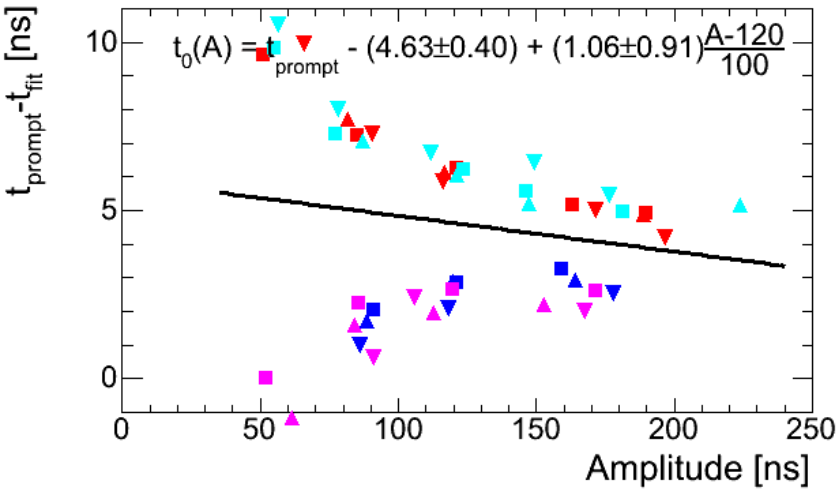


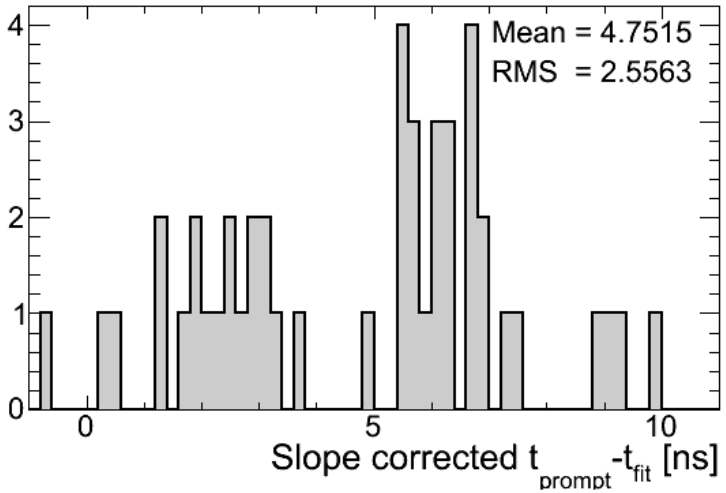
Prompt RMS includes variation of delays in the strips

Prompt Time should be measured with 40<A<50 cut.

A naive estimate $t_{prompt} = t_0 + L/c = t_0 + 2.7$ ns does not work well

First Results (Run 17600)



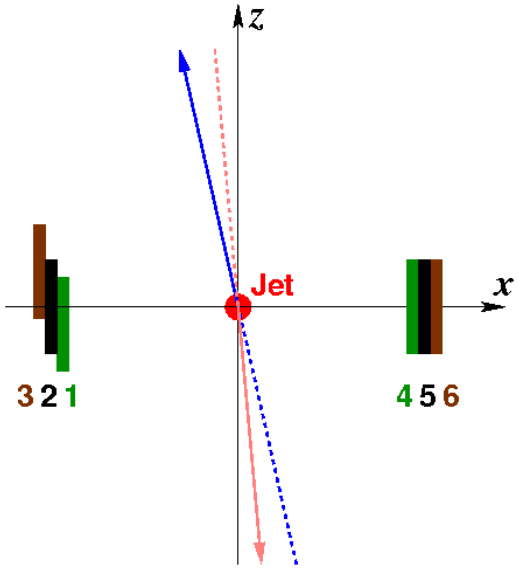


Very poor consistency between two method of determination t_0.

Results for different beam/side strips are shown by different colors.

A geometrical alignment (in software) is needed !

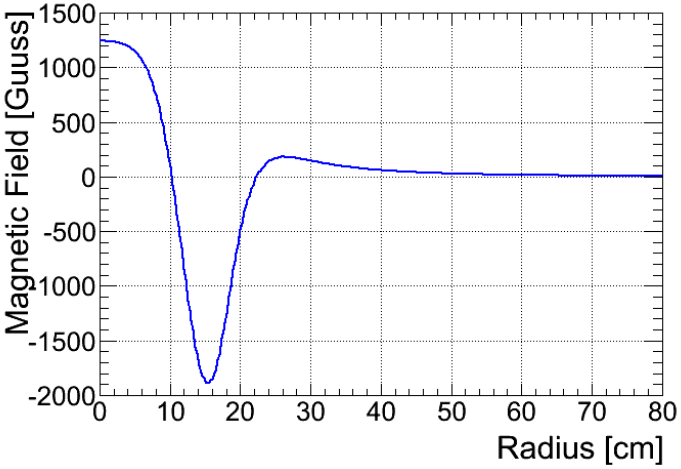
Geometrical Alignment



Coordinate selection: x-axis goes through centers of detectos **2** and **5**
z-axis perpendicular to x (and horizontal)

Alignment parameters: ***z1, z3, z4, z6, zJet***
$\theta = (\theta_B + \theta_Y)/2$
$\delta\theta = \theta_B - \theta_Y$

Holding Field Correction:



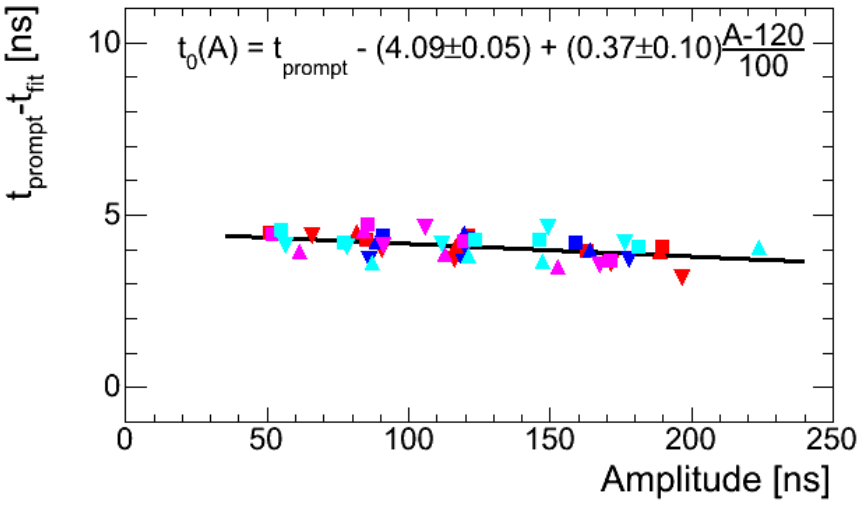
$$\frac{z}{L} = \sqrt{\frac{T}{2M_p}\frac{E_{\text{beam}} + M_p}{E_{\text{beam}} - M_p}} \pm \frac{b}{L\sqrt{2M_pT}}$$

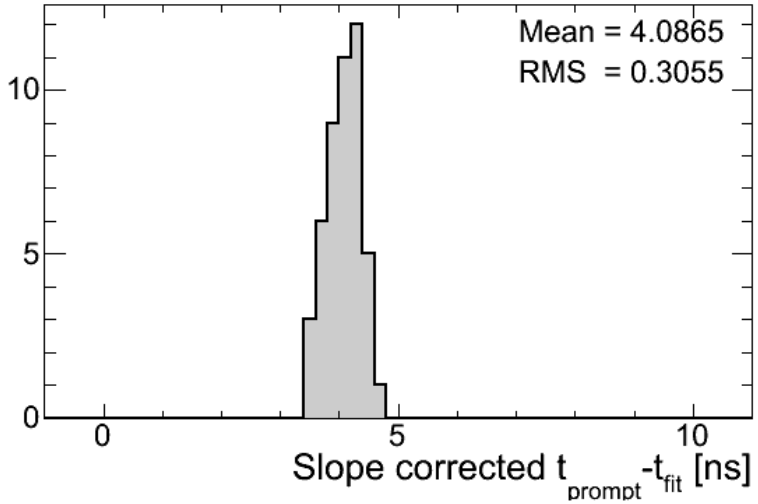
$$b \propto \int_0^L H(r)(L-r)dr$$

Online software: $b = 9\ \text{MeV} \cdot \text{cm}$
Calculation: $b = 27\ \text{MeV} \cdot \text{cm}$

Calculation may be inaccurate. We should determine b from the fit. b is strongly correlated with θ.

Results After Alignment





Accuracy of the t0 determination:

$$\sigma_{\text{prompt}} \oplus \sigma_{\text{geom}} = 0.31 \text{ ns}$$
$$\sigma_{\text{prompt}} \oplus \sigma_{\alpha} = 0.78 \text{ ns}$$
$$\sigma_{\text{geom}} \oplus \sigma_{\alpha} = 0.75 \text{ ns}$$

$$\sigma_{\text{prompt}} \approx \sigma_{\text{geom}} \approx 0.22 \text{ ns}$$

α – calibration is very preliminary. Here it is used to compare the **prompt** and **geometrical** calibrations only.

The combined accuracy of the t0 determination:

$$\sigma_{t0} \approx 0.15 \text{ ns}$$

Contribution to the energy calibration:

$$\sigma_T / T \approx 0.5\sqrt{T/\text{MeV}}\ \%$$

Alignment:

Results for March 25 and June 8 are consistent

		Fill 17247	Fill 17600
z1	(mm)	0.17 ± 0.24	0.33 ± 0.16
z3	(mm)	-0.09 ± 0.27	0.07 ± 0.17
z4	(mm)	-0.38 ± 0.22	-0.36 ± 0.14
z6	(mm)	-0.64 ± 0.22	-0.54 ± 0.24
zJet	(mm)	0.13 ± 0.11	-0.05 ± 0.07
θ	(mrad)	0.35 ± 0.60	-0.10 ± 0.39
δθ	(mrad)	0.07 ± 0.18	-0.04 ± 0.12
b	(MeV cm)	9.7 ± 2.8	12.4 ± 1.9

Topics for discussion and further study

1. *Amplitude A is not necessary proportional to the kinetic energy T (dead-layer, non-linearity)*
2. *t_{prompt} – t0 ≈ 4.5 ns*
3. *t_0 depends on Amplitude !?*
4. *Signal waveform is amplitude dependent !?*
5. *Waveforms for banana protons and prompts are different !!!???*
6. *Determination of the dead-layers.*
7. *Gains for "empty" strips*
8. *Comparison with alpha – calibration*
9. *Detailed study of the background.*

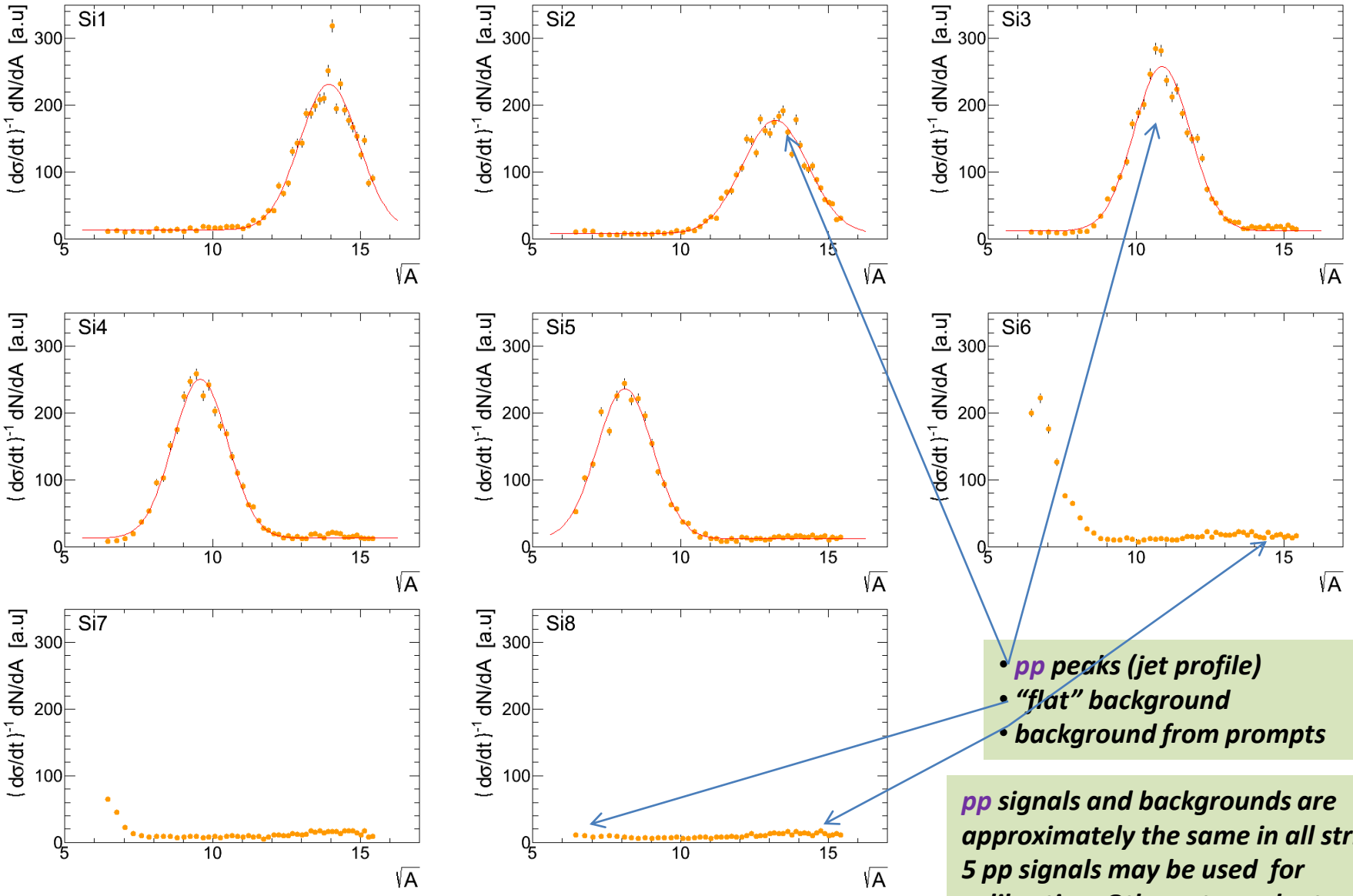
(To be presented at next meetings.)

Summary

• The new methods of determination of t0, (i) prompt study and (ii) geometry correlations, were tested.
• Both method allows to determine t0 with accuracy about 200 ps.
• This allows us to control the energy scale with a 1% accuracy.
• t0 dependence on the signal amplitude was observed.
• The second method (geometry correlations)
    - provides tools for detector monitoring
    - allows us to measure gains with high accuracy
    - give hints to the solving the “background problem”
• More work is still needed to implement the “alpha-less” method of calibration.

Backup

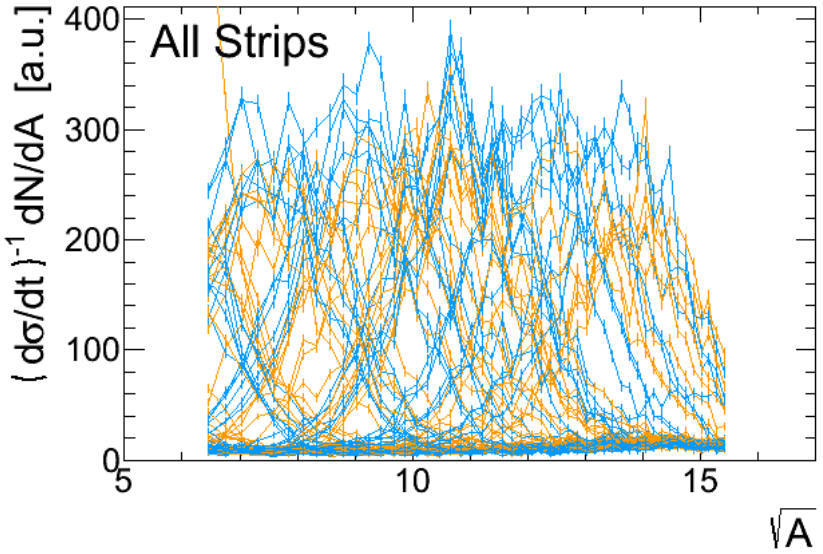
$\eta(\sqrt{A})$ for eight (yellow) strips of the detector 1 (Fill 17273)

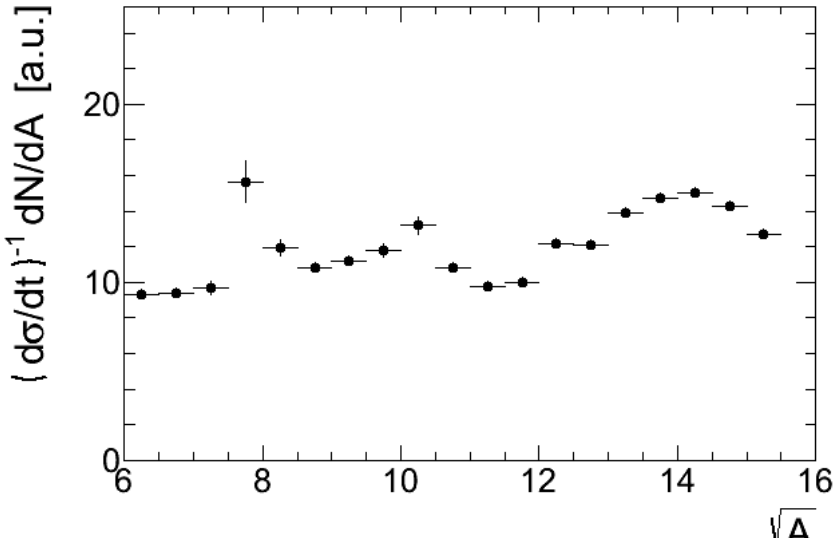


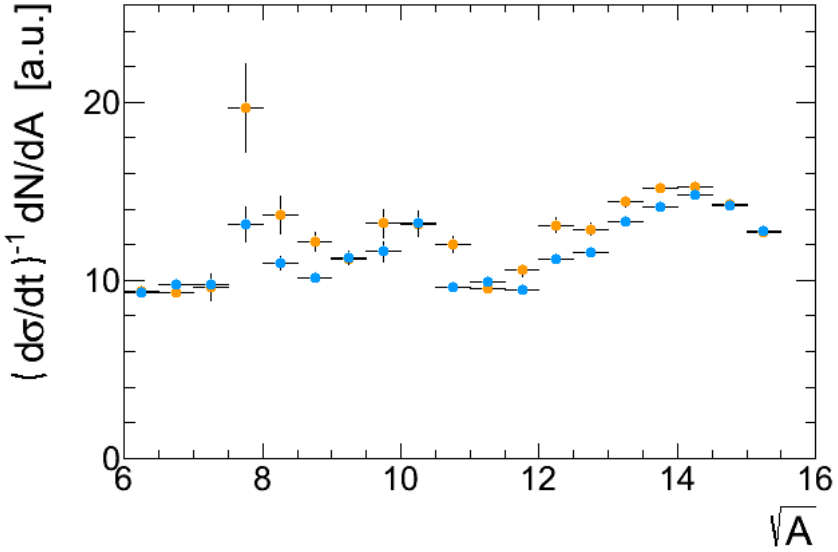
- *pp* peaks (jet profile)
- "flat" background
- background from prompts

pp signals and backgrounds are approximately the same in all strips. 5 pp signals may be used for calibration. Other – to evaluate background

Background Evaluation

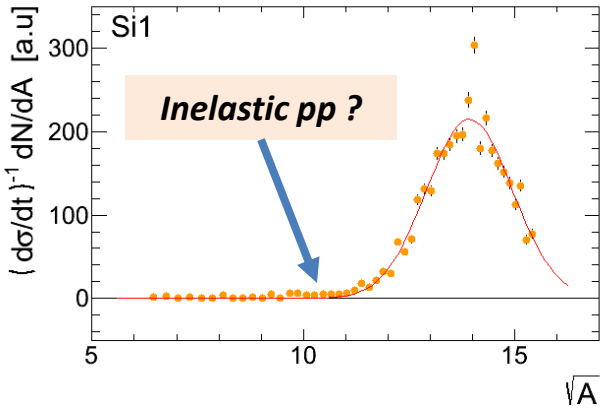


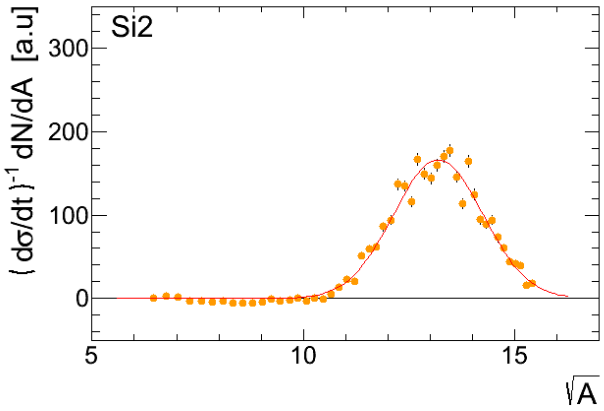


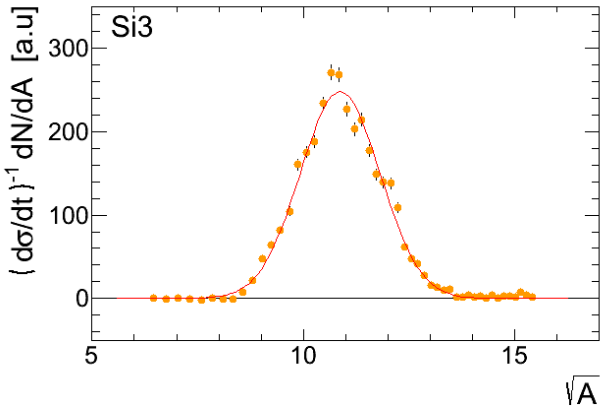


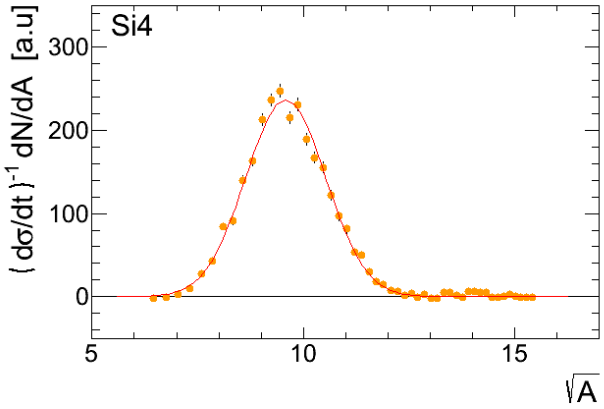
- ***The algorithm is satisfactory for the calibration purposes.***
- ***To study background asymmetry, an improvement is needed.***

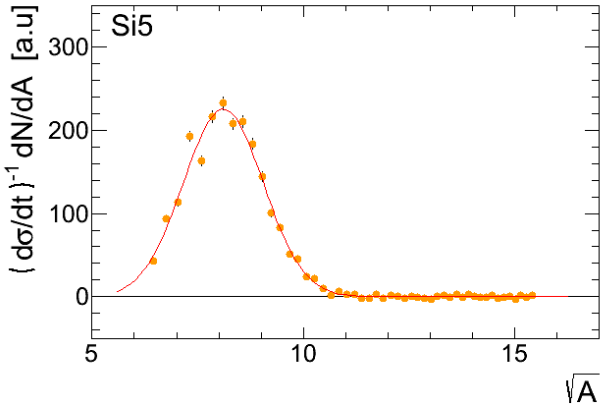
Detector 1 after background subtraction

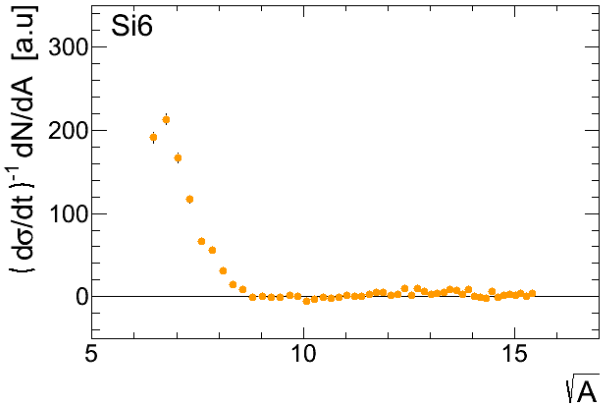


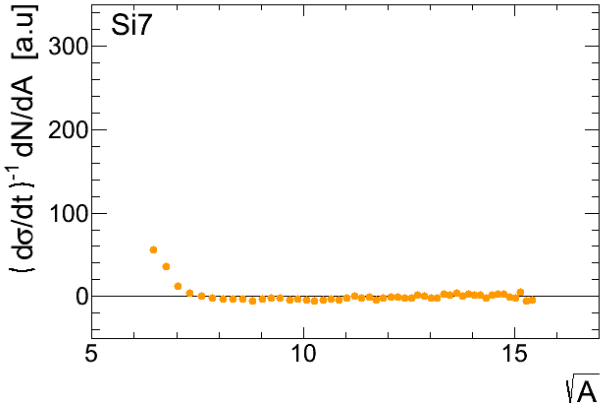


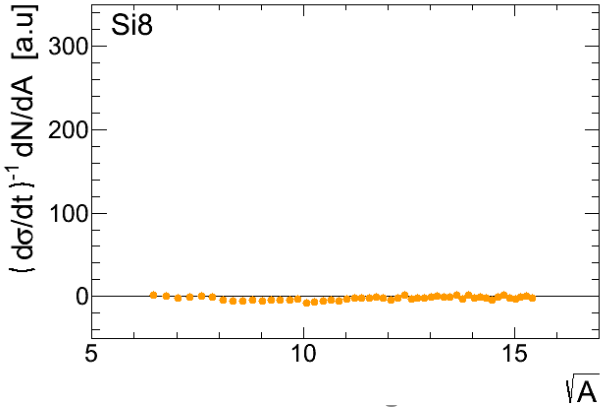












Background subtraction works !

All n(z) profiles must be the same (if gain and cuts are the same)