Target thickness ↔ A_N

Processes:

- dE/dx energy loss in target → shift in A_N
- multiple scattering in target → broadened hit distributions

Implementation:

- Longitudinally segmented detectors
- Toy MC
- Fits to hit distributions
- Fudge factor

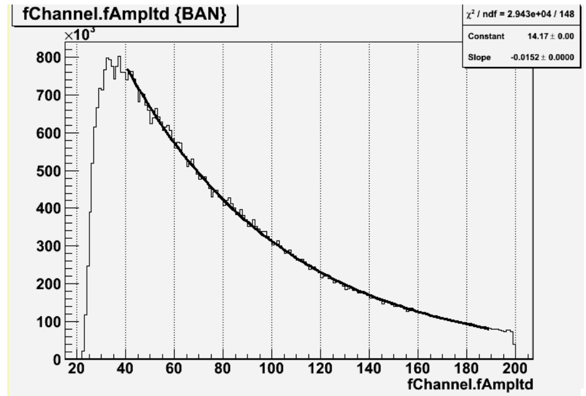
Results:

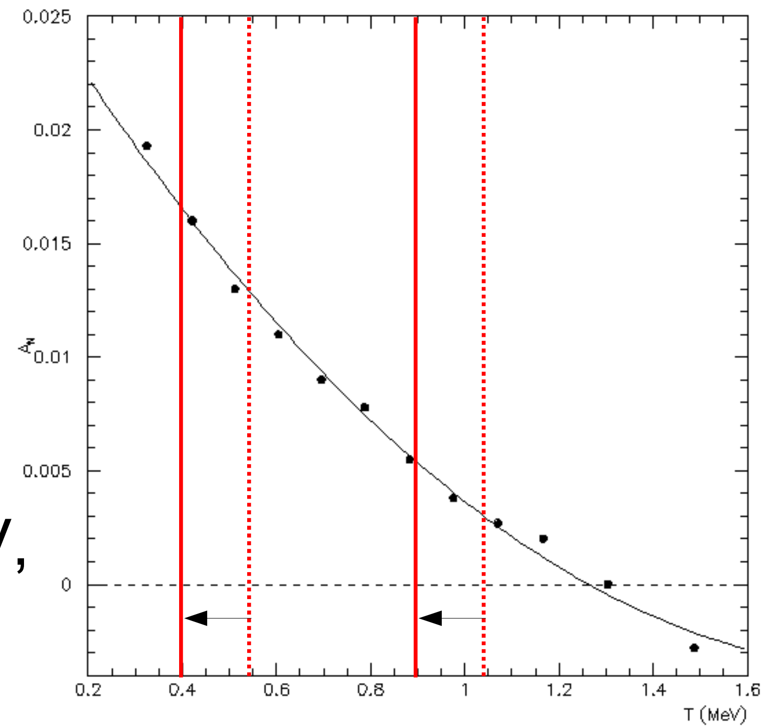
- A_N from pC/Hjet: target thickness dependence
- A_N corrected, Hjet normalization
- Up/Downstream pC comparison?

Final points & remarks

dE/dx → shifted effective A_N

- p↑-carbon scattering $A_N(T)$ (falling) function of kinetic energy T:
- $d\sigma/dT \propto \exp(-B \cdot T)$:





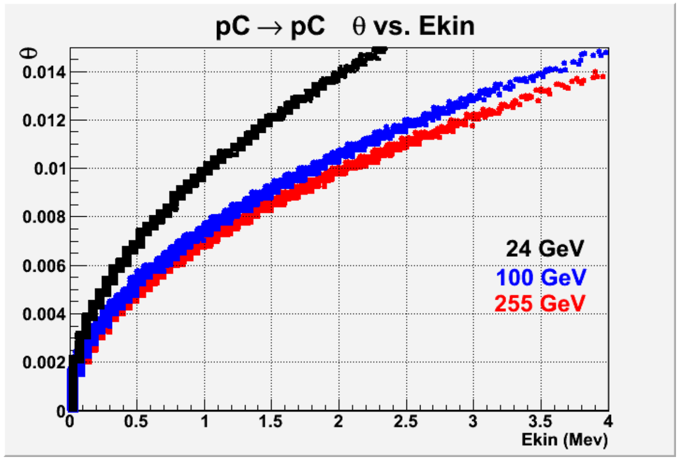
- Detectors measure in window 0.4<T<0.9 MeV, (solid red lines) effective $A_N \propto d\sigma/dT \otimes A_N(T)$
- Finite target thickness: after p-C scattering, recoil C lose energy dE/dx
- Carbons scattered at higher T (dashed red lines) shift down into measured T window (solid red lines)
- These higher T carbons have smaller effective A_N

thicker targets ⇒ lower effective AN

Multiple scattering

Scattered carbons:

- Carbon distribution ~uniform azimuthally: $dN/d\phi \propto 1 + PA_N \cos(\phi)$
- Polar scattering angles ~90°:
  for $0.4<T<0.9$ MeV, θ = 4-6 mrad, narrow range
- Scattered carbons ~ disk around target ⊥ beam



Finite target thickness:

- Multiple Coulomb scattering in target smears θ:
  $RMS(\theta) = K \cdot \sqrt{L}/T$; L = target thickness, T = scattered C k.e.
  K = constant (PDG); **uncertain @ these low energies**
- Width of polar angle distributions ∝ square root of target thickness

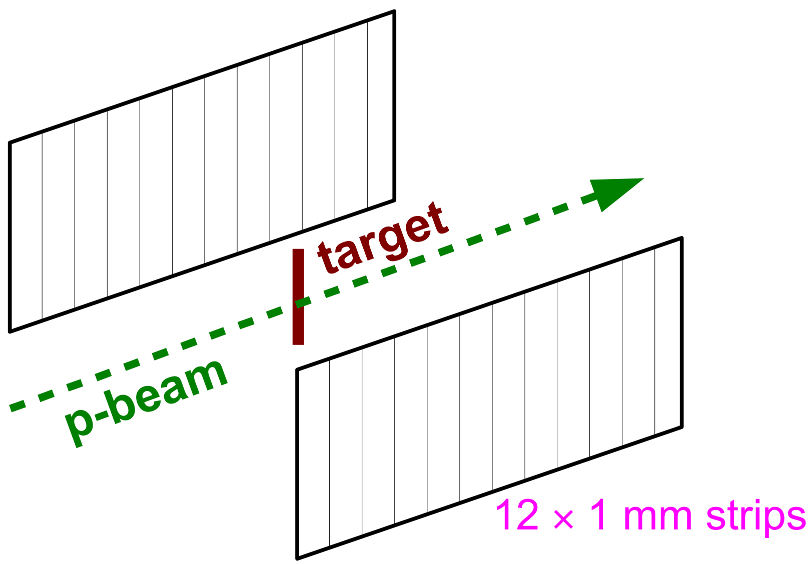
Program:

- Measure: polar angle distributions ⇒ target thickness
- Compare: effective A_N ⇔ target thickness

Longitudinally segmented detectors

- Pair detectors segmented (1mm) along beam
- Strip polar angle $\Delta\theta \approx 5$ mrad

detectors 1&6
top 45°

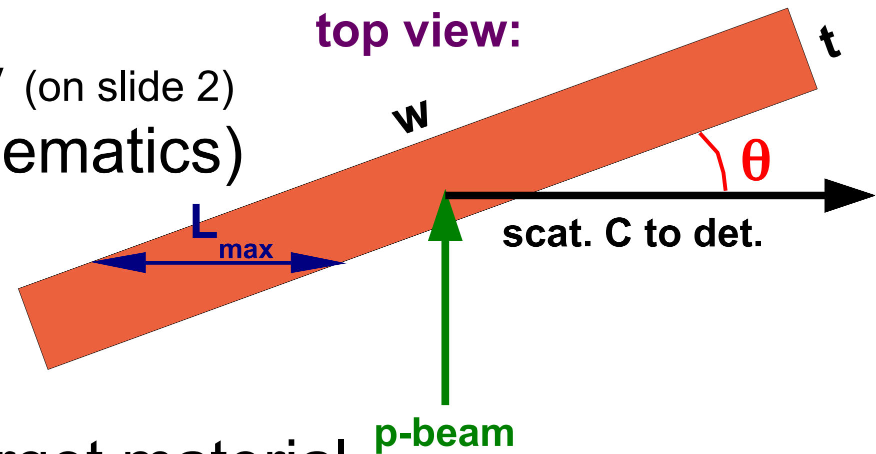


<u>#hits/channel distribution provides info:</u>

- Centroid ⇒ longitudinal (Z) position of target
- Width ⇒ amount of multiple scattering through target

Toy Monte Carlo

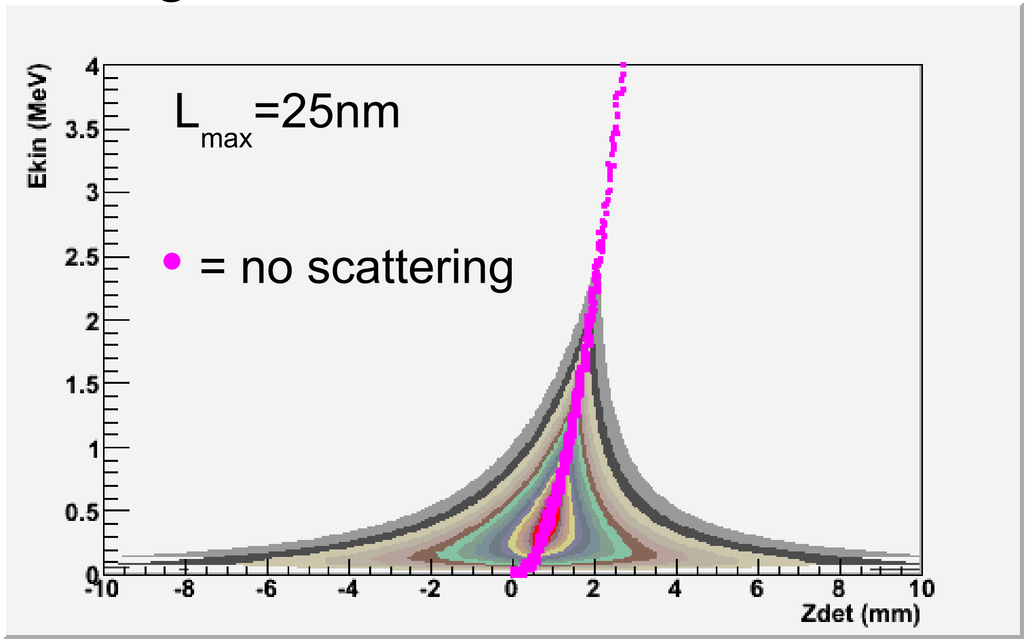
- To extract info from distributions need model: simple Monte Carlo
- <u>Model</u>
  - exponential in scattered carbon energy (on slide 2)
  - E↔θ scattering angle dependence (kinematics)

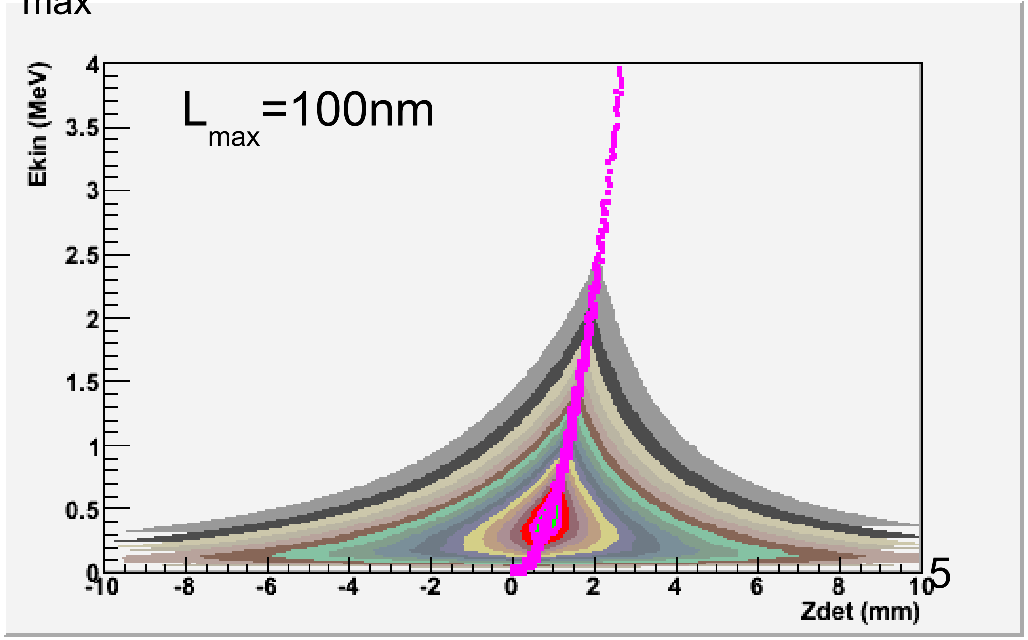


  - passage of scattered carbon through *varying* target material $0<L<L_{max}$ with:
    - → small angle multiple scattering in target material
    - → dE/dx carbon energy loss
  - target → detector flight path 192 mm

each E, L_{max} superposition gaussians $0<RMS<L_{max}$

- e.g. k.e. T vs. Z hit distributions; L_{max} = 0, 25, 100 nm:

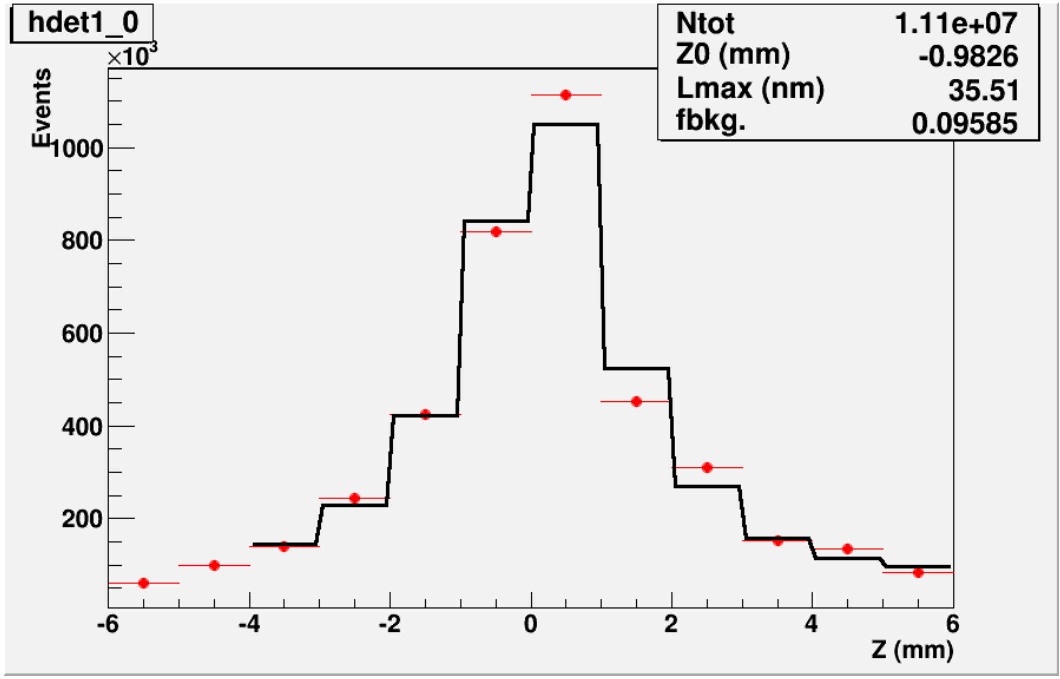




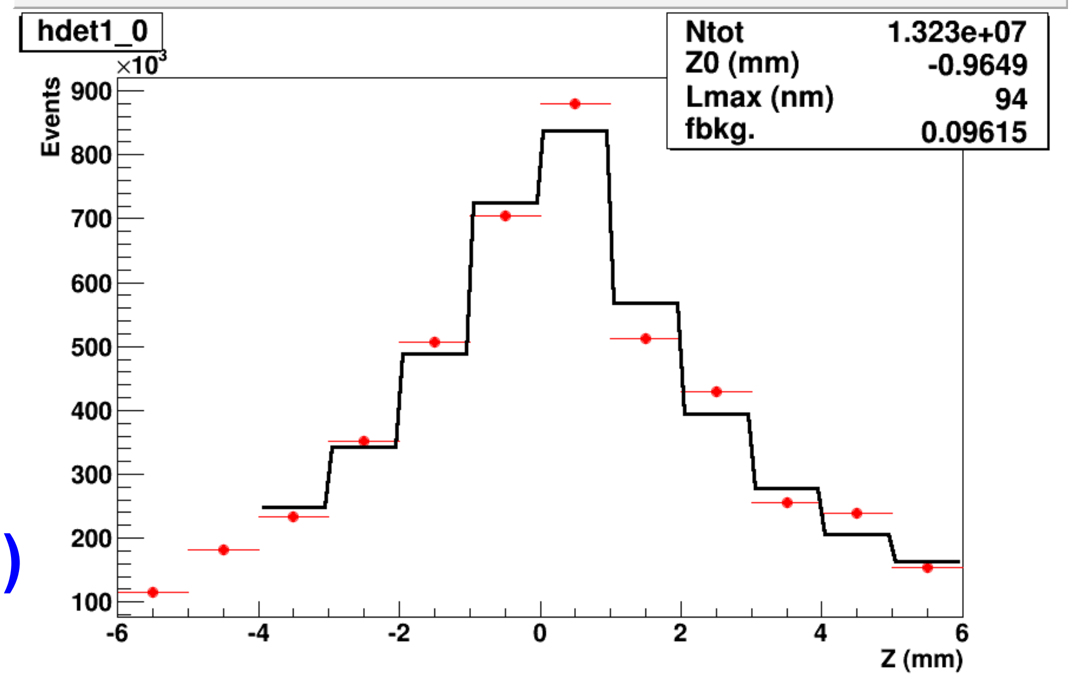
Hit distribution fits

Fit parameters:

- Ntot: total # events (normalization)
- Z0: target longitudinal position
- Lmax: target→detector thickness
- fbkg.: flat background



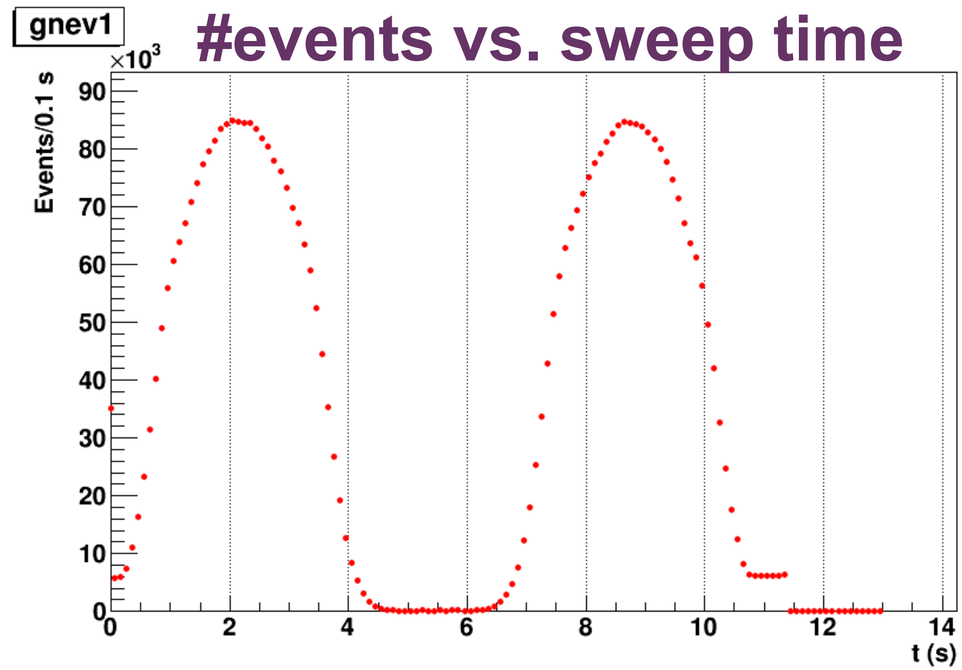
narrower distribution
→ thinner target (36 nm)

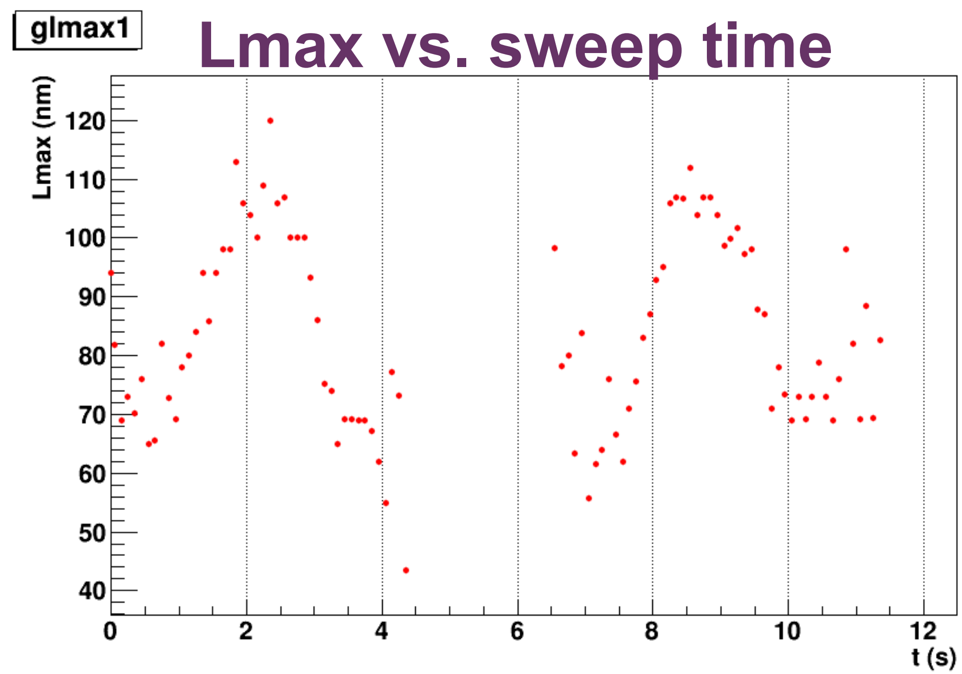


distribution width ~ √Lmax

wider distribution
→ thicker target (94 nm)

Mean Lmax in sweep



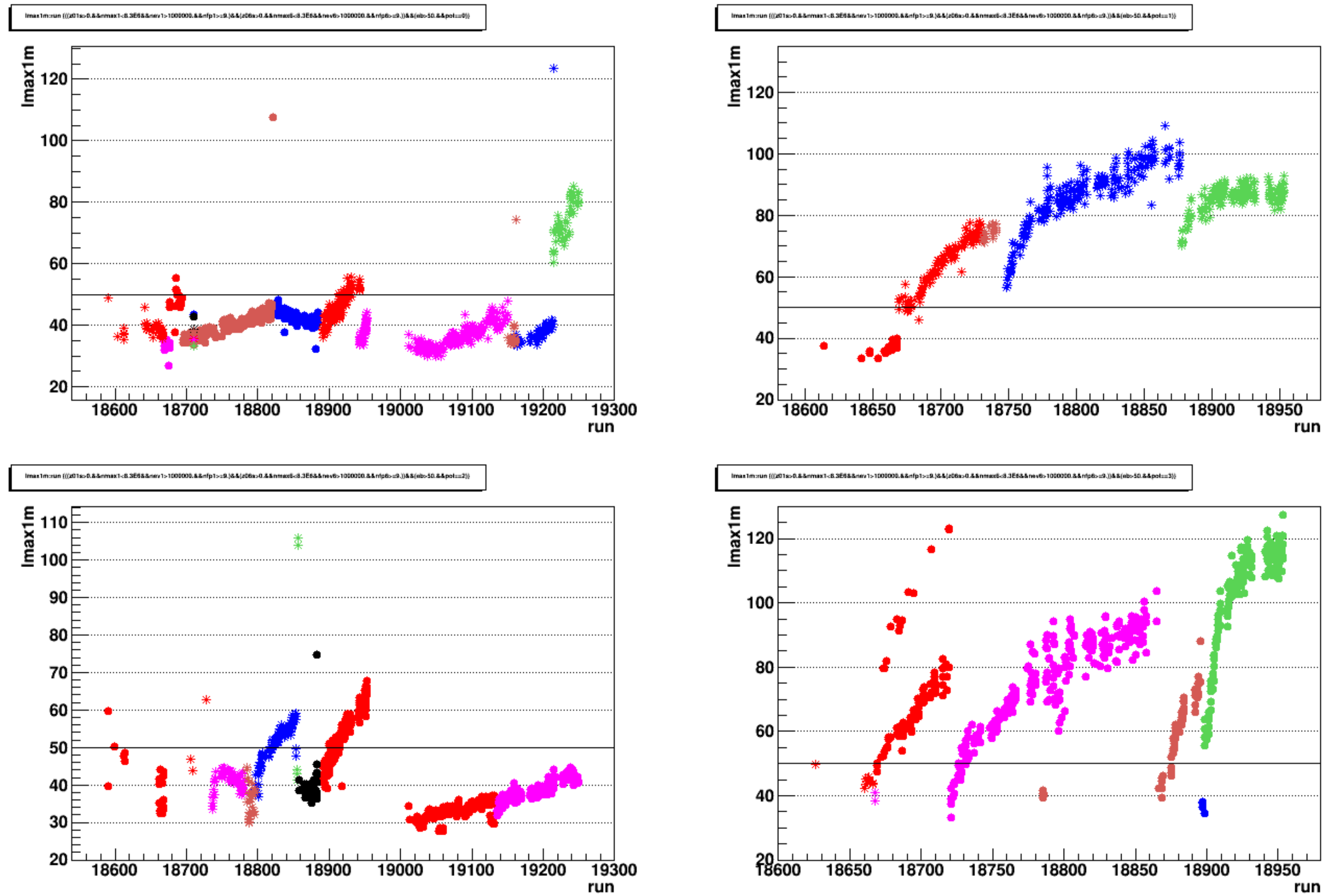


- Target is twisting, turning, …
- Lmax varies as target sweeps across beam
- Take rate averaged Lmax:

Lmax history (Run15)

Run13 similar

- 4 polarimeters, different color each new target:



- Lmax definitely property of target: evolves slowly, jumps new target
- Lmax generally increases with target use; no explanation.
- BUT: - targets manufactured, measured 50±4 nm thick

  - Lmax must be ≥ 50 nm

  - many values here < 50 nm, some < 30 nm

Fudge factor

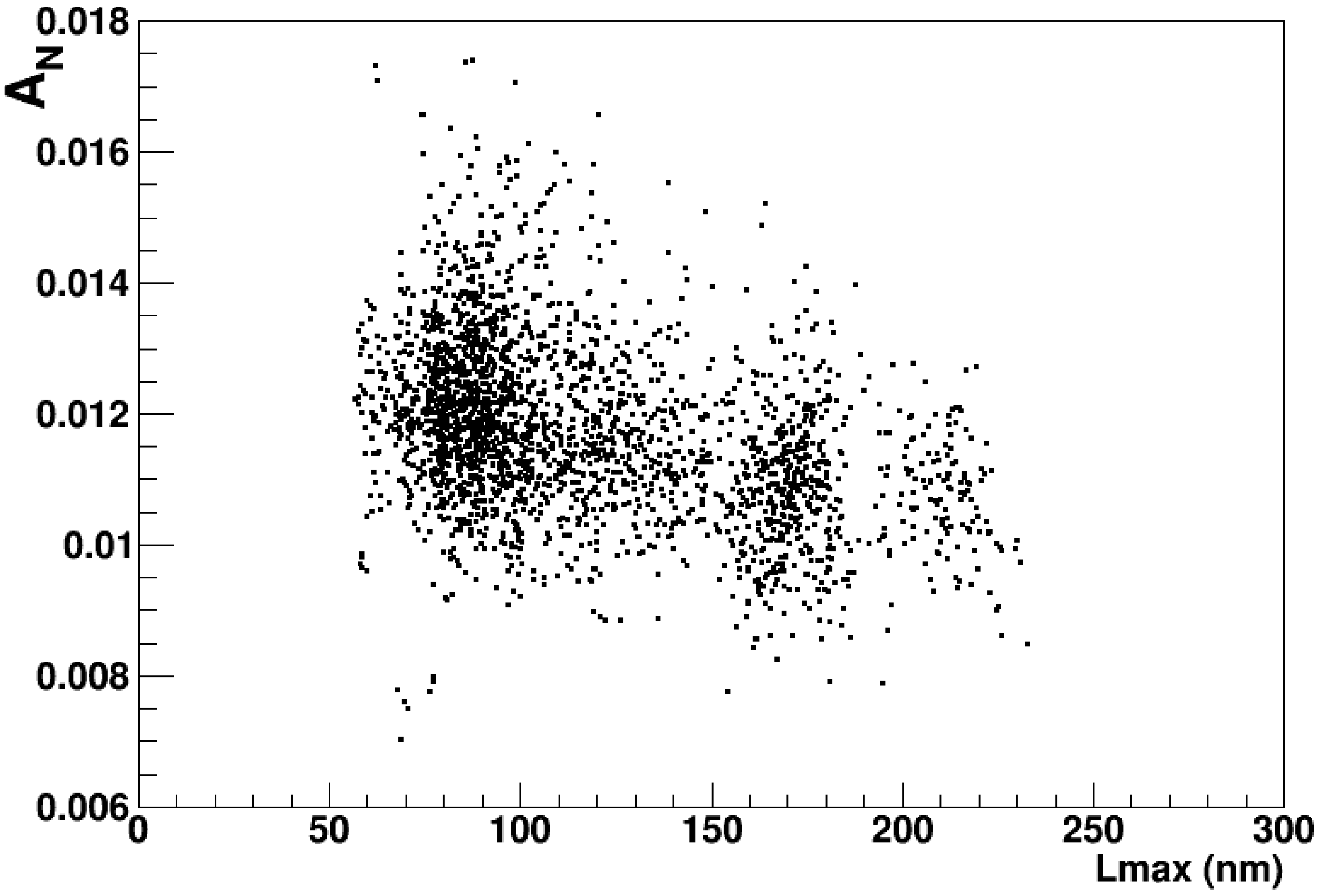
- Multiple scattering:
  $RMS(\theta) = K\cdot\sqrt{L/T}$; L = target thickness, T = scattered C k.e.
  K = constant (PDG)
- Relation said to be valid only down to energies much larger than our ~1 MeV
- Allow to fudge: $L_{max} \rightarrow 2 \times L_{max}$
- Now measured Lmax > 50 nm, consistent with reality
- Corresponds to $K \rightarrow K/1.4$, 40% fudge

A_N from Hjet

- pC measures asymmetry $\epsilon = P A_N$
- Have absolute P from Hjet (per fill)
- Each pC measurement determine: $A_N = \epsilon / P_{Hjet}$
  - no correction of P_{Hjet} for dP/dt (yet)
  - large stat. uncert.: Hjet ~ 7%, pC ~ 4%
- Each pC measurement plot A_N vs. (fudged) Lmax...

A_N vs. Lmax

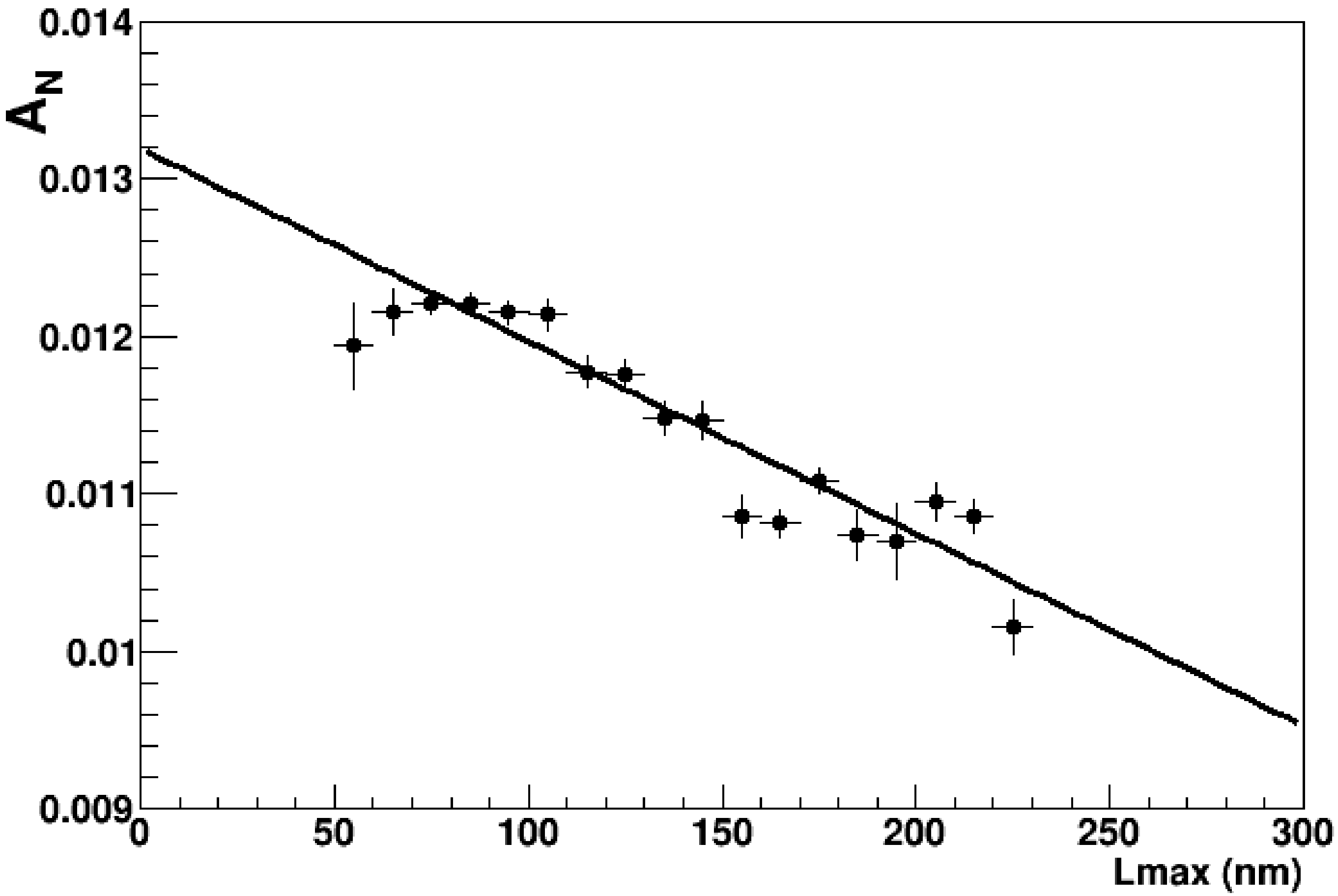
- Take Lmax average from det. 1&6
- Scatter plot:



- A lot of stat. fluctuations, but downward trend apparent

A_N vs. Lmax

- Take Lmax average from det. 1&6
- Profile plot, all polarim., Run15:



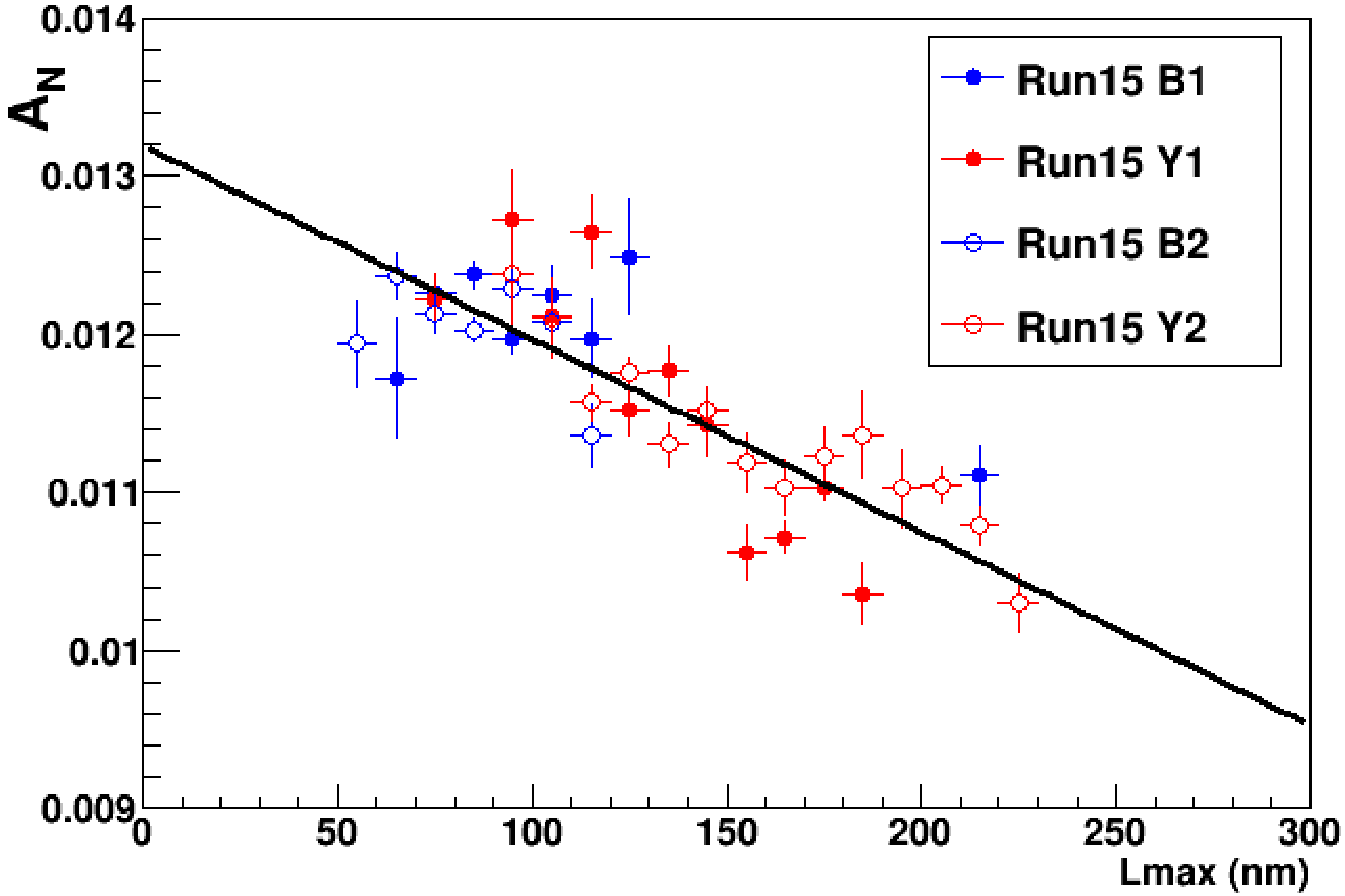
Fit: $A_N = A_{N0}(1-\alpha\cdot Lmax)$

- $A_{N0} \approx 0.0132$
- $\alpha \approx 9\times10^{-4}\ nm^{-1}$

- Downward trend statistically significant
- A_N changes ~10% across 100 nm

A_N vs. Lmax

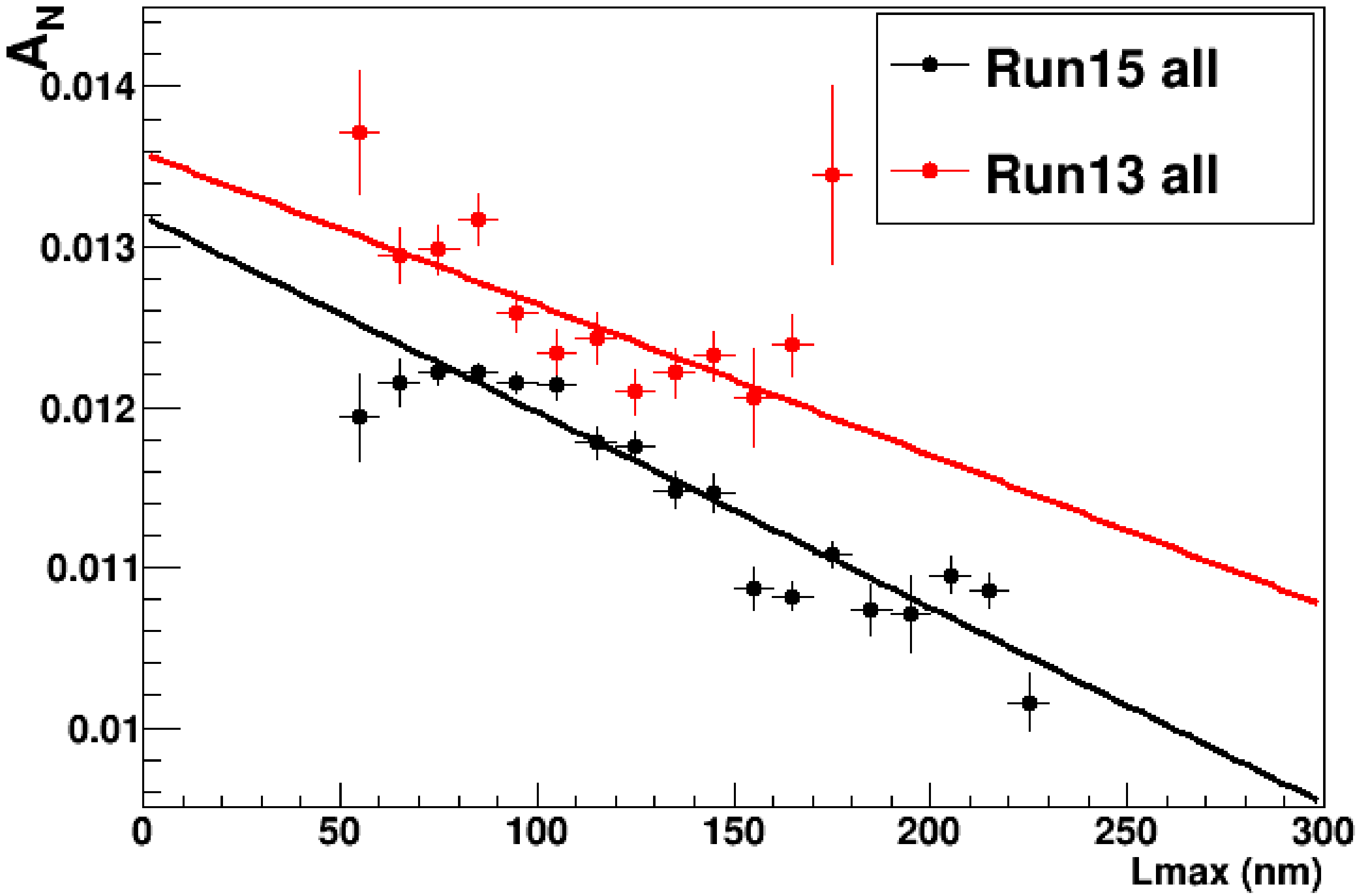
- Run15, each polarim. separately:



- Not all polarim. cover large Lmax range
- But all consistent, lie along fit to all polarim.

A_N vs. Lmax

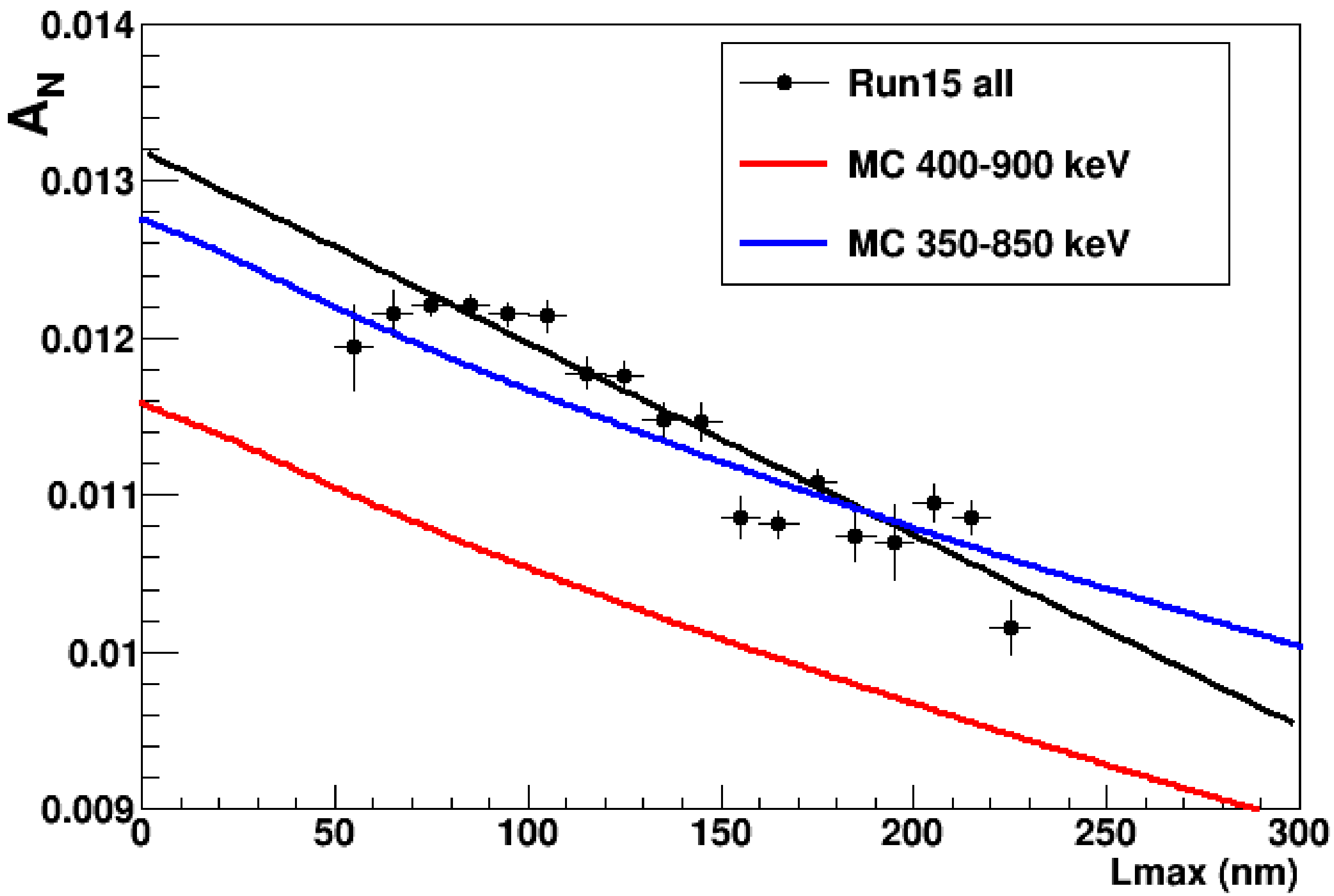
- Run13, Run15 comparison:



- Quite similar, but somewhat different slopes

A_N vs. Lmax

- Get A_N vs. Lmax from the toy MC:

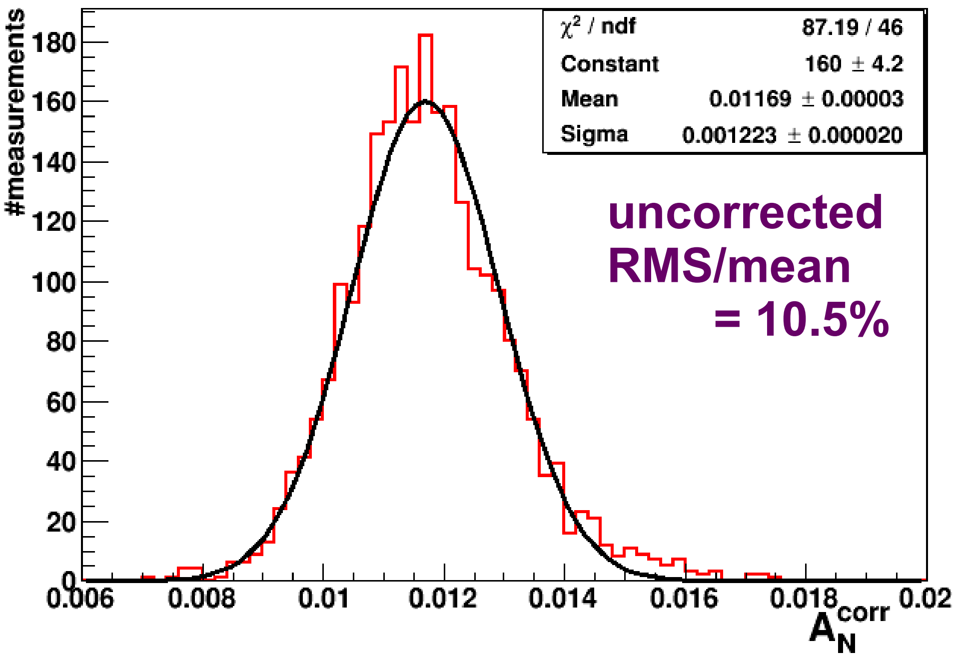


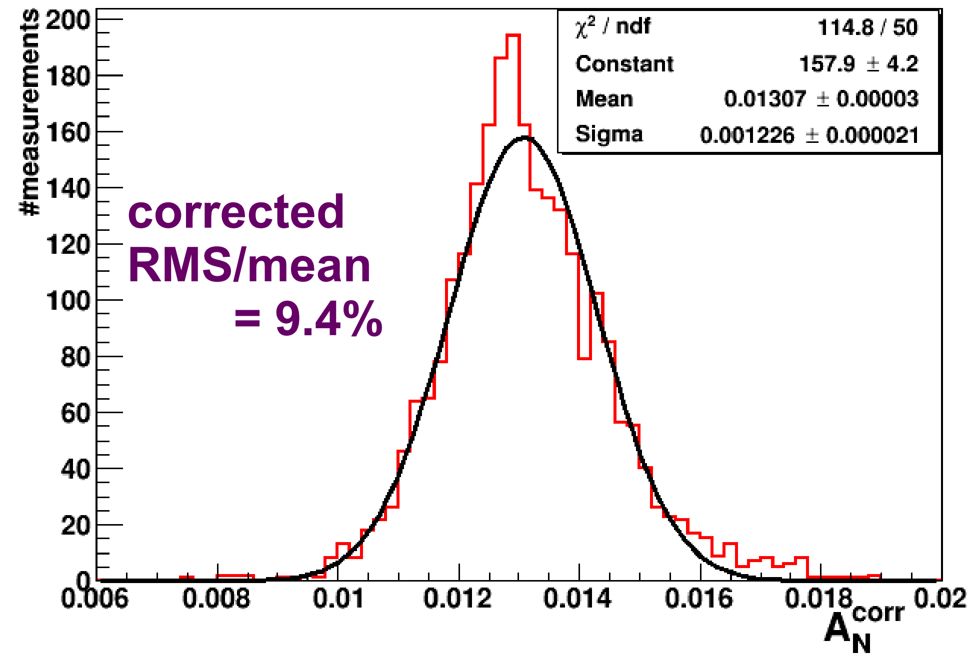
- Shifts in A_N scale, E-window can give good data description
- Overall pretty consistent with the picture

A_N corrected, Hjet normalization

- Correct each measurement for Lmax dependence in Hjet normalization:

$$A_N^{corr} = (\epsilon/P_{Hjet}) / (1-\alpha \cdot Lmax)$$

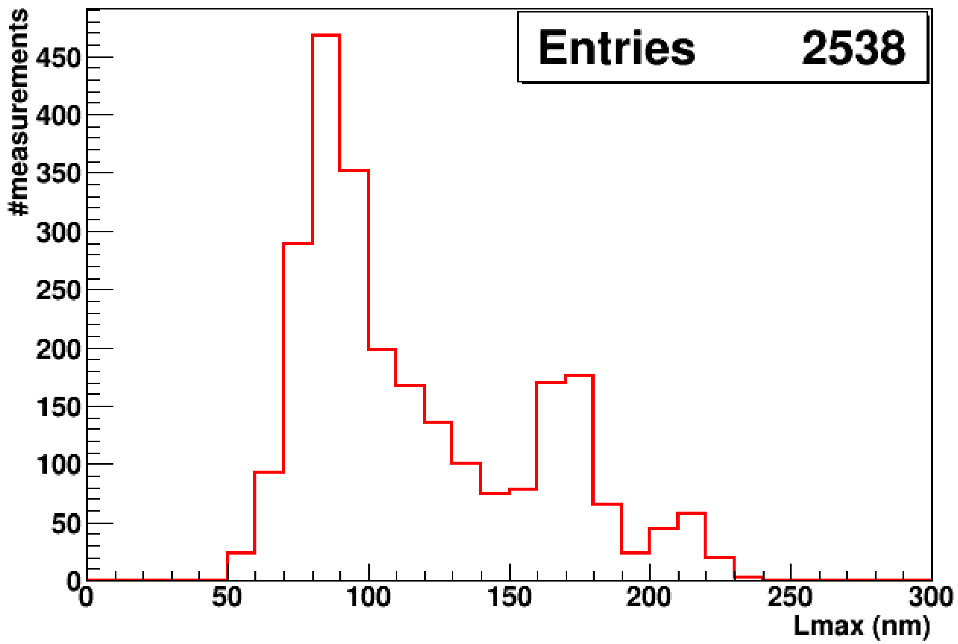


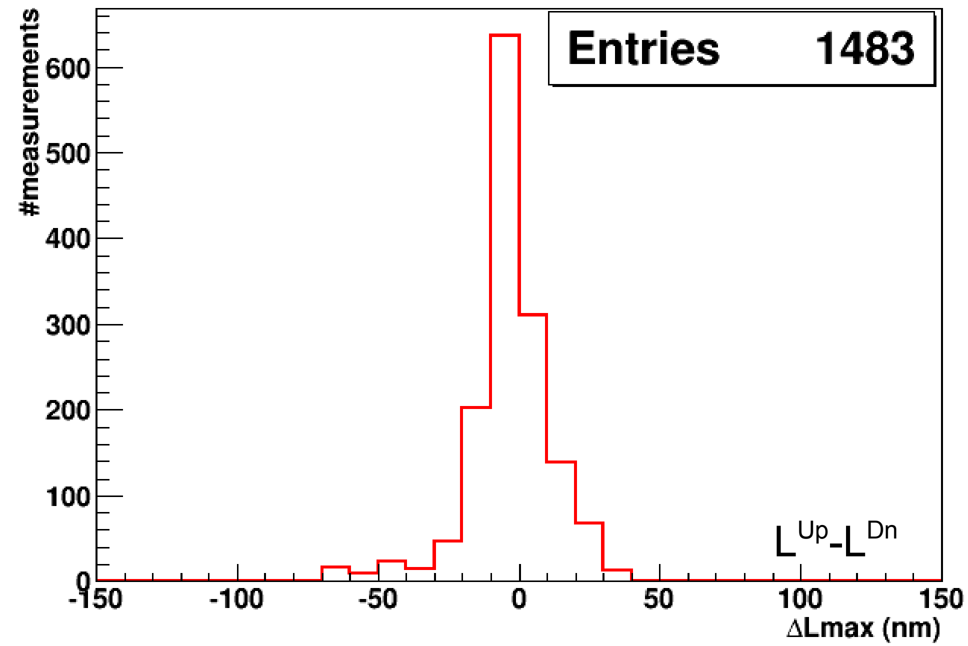


- Modest ~10% improvement in RMS/mean
- Handicapped by Hjet large stat. uncert.
- What about Up/Downstream pC comparison?

Up/Downstream compare?

- Lmax dependent A_N, pC asymmetry: $\epsilon = P \cdot A_{N0}(1-\alpha \cdot Lmax)$
- Take ~simultaneous Up/Dn measurements, P ~constant
- Then: $\epsilon^{Up}/\epsilon^{Dn} = (1-\alpha \cdot L^{Up})/(1-\alpha \cdot \pi^{\infty K}) \approx 1 - \alpha \cdot (L^{Up}-L^{Dn}) = 1 - \alpha \cdot \Delta\pi I \;\in Y$
- Should be able to check with high stat. pC measurements, but:





- Lmax distribution for pC/Hjet vs. Lmax (slide 12)
- Lmax spans >150 nm

- ΔLmax distribution for Up/Downstream comparison (U/D meas. within 10 min.)
- ΔLmax spans <50 nm
- Too small lever arm...

Final points

Use:

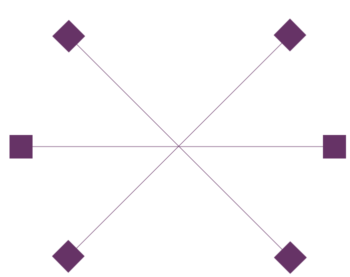
- Whatever theoretical details & parameters, see empirical relation
- Parameterize: $A_N = A_{N0} \cdot (1 + \alpha \cdot Lmax)$
- Determine intercept A_{N0}, slope α from these pC/Hjet studies

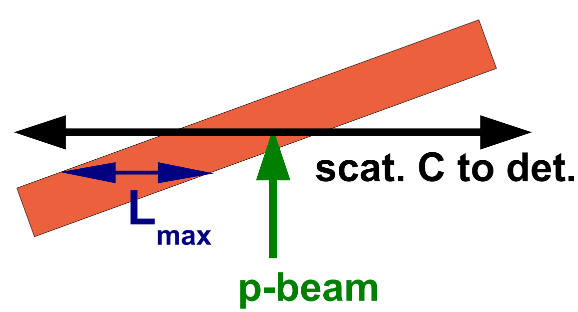
→ this would replace pC/Hjet normalization, with 2 param. all 4 polar.

- Each pC measurement: $P = \epsilon / A_{N0} \cdot (1 + \alpha \cdot Lmax)$

Further improvements:

- So far hit distributions full T range 0.4-0.9 MeV (histograms available)
  - do in more T bins
  - wider distributions @ lower T? Confirm mult. scat.
- If we had stable 1mm detectors:
  - each polarim. all 6 detectors 1mm longitudinally segmented
  - opposite detectors should have same Lmax; confirm hypotheses





Last remark

- This correction takes account of expected target effects
- If we also improved our questionable
  carbon energy energy calibration, absolute E-scale:

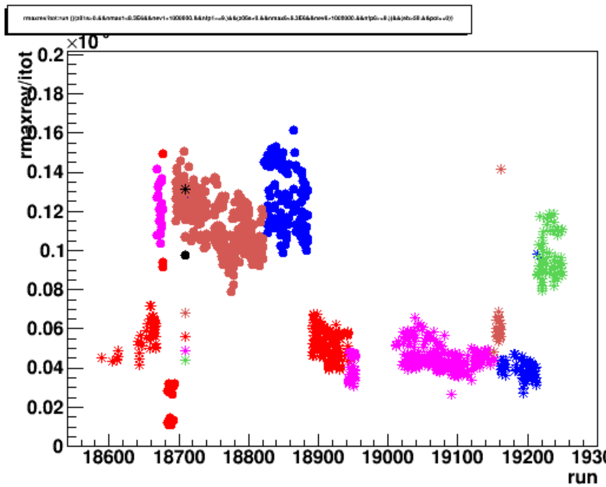
➜ Determine A_{N0}, α for precise energy window(s) with pC/Hjet data

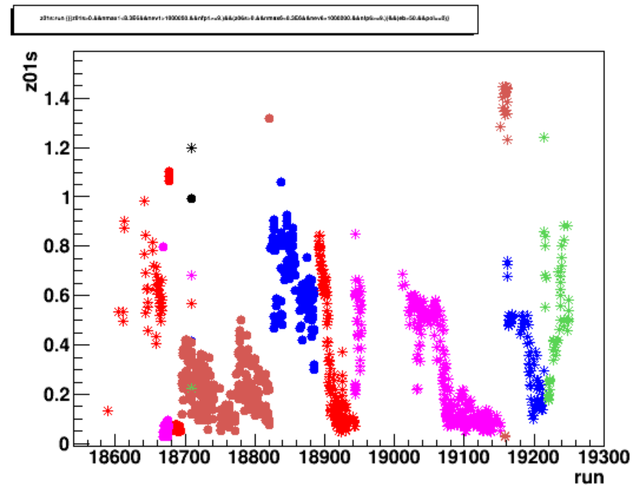
$\Rightarrow$ **Biggest steps to an *absolute* pC measurement, i.e. w/o Hjet**

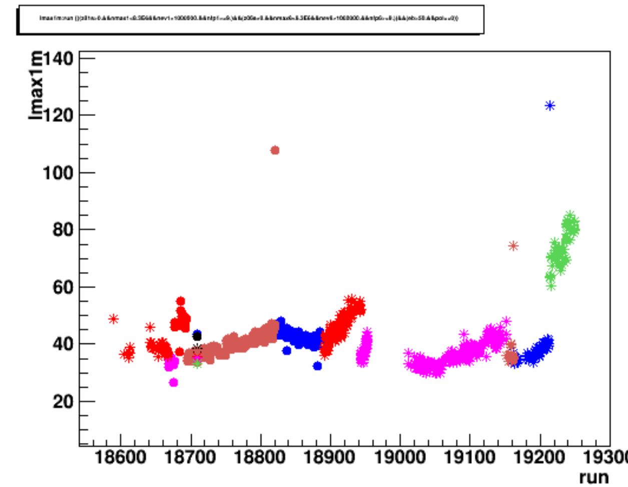
Extras

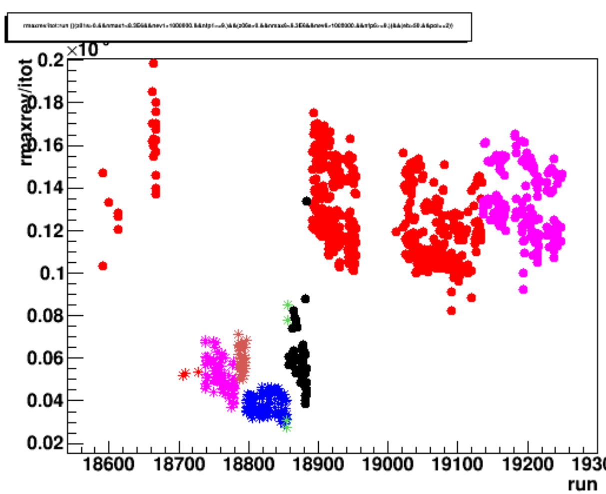
2015 Blue target properties

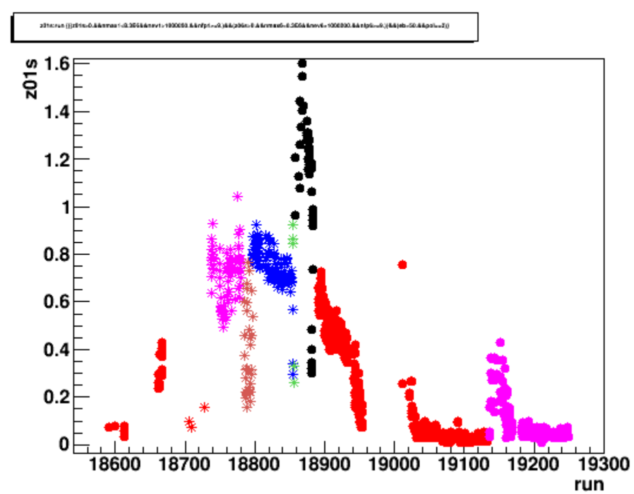
material in beam	longitudinal sway	Lmax

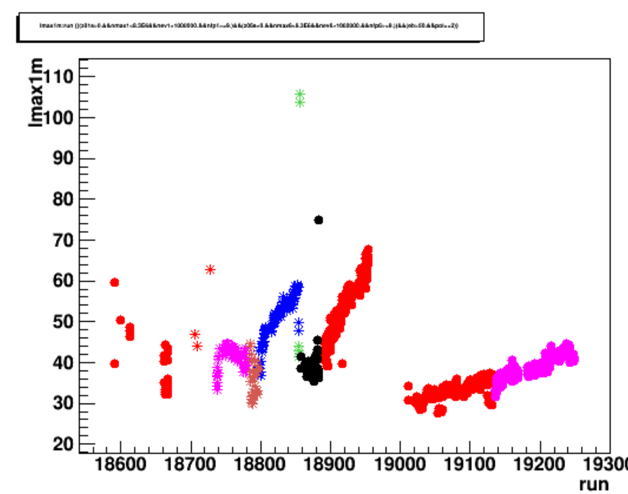












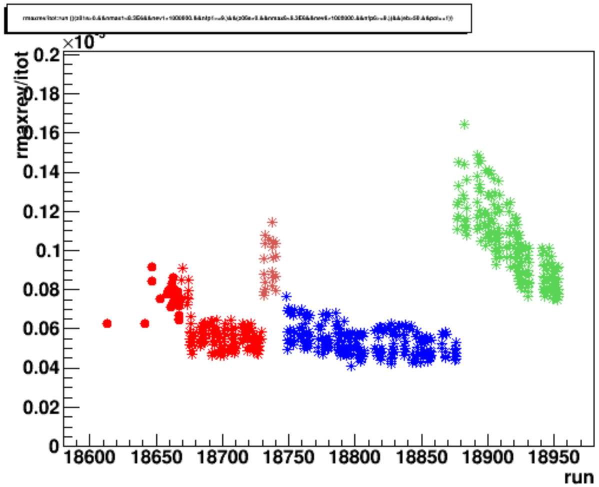
- Take max. rate in sweep
- rate ∝ (material)×(I_p/σ_{beam})

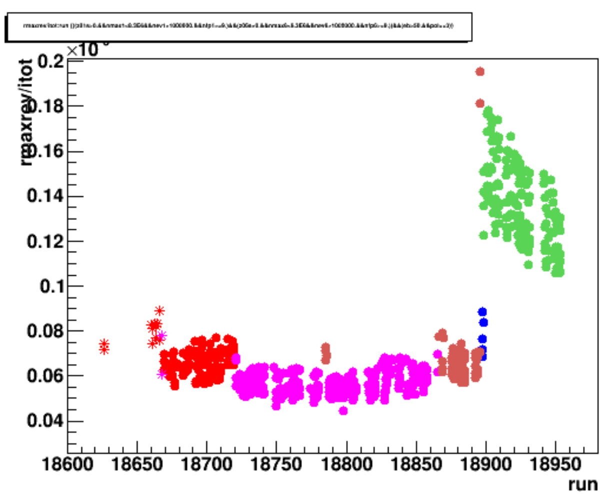
- Variation of Z0 across sweep

- slides 6,7

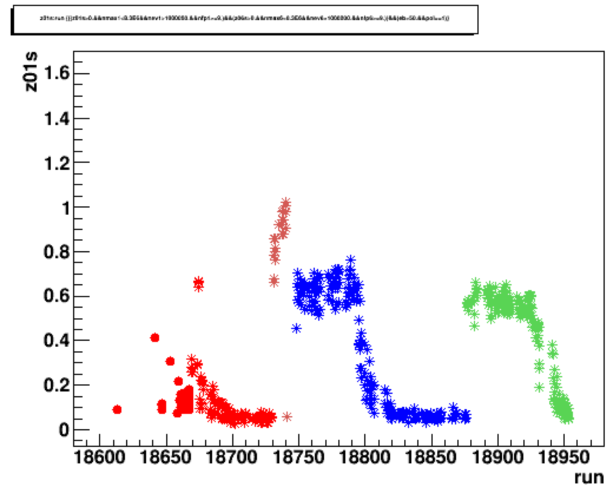
2015 Yellow target properties

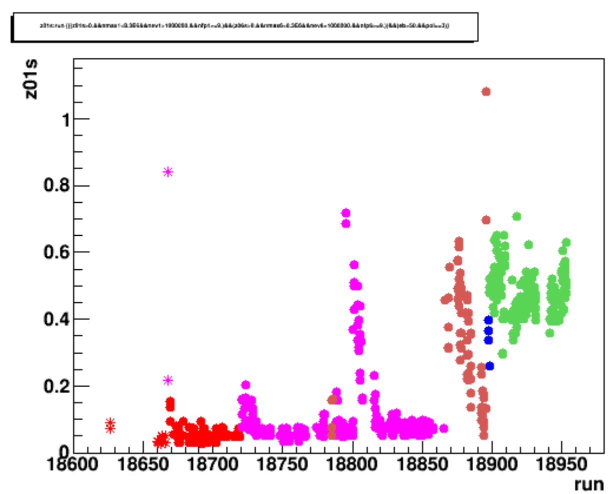
material in beam



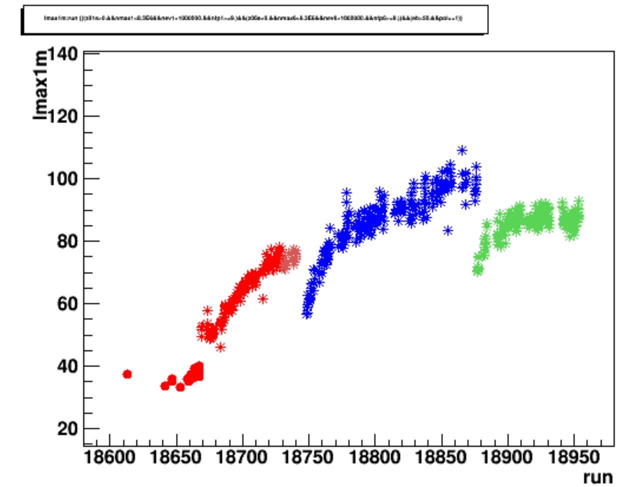


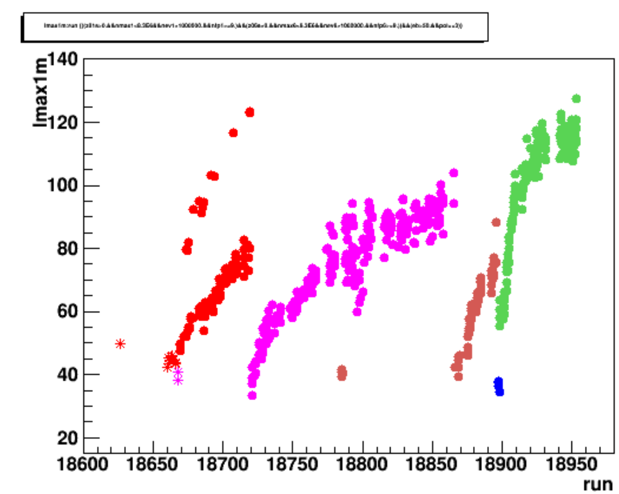
longitudinal sway





Lmax





- Take max. rate in sweep
- rate ∝ (material)×(I_p/σ_{beam})
- Variation of Z0 across sweep
- slides 6,7