RHIC polarization: Run9,11,12 results; Run13 plans

W. Schmidke – BNL
on behalf of the
polarimetry group

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Results Runs 9 (100 GeV reanalyzed), 11 & 12:

- New feature: time dependent P(t), R(t) ⇒ $P_{SSA}(t)$
- Assessment of uncertainties
- summarized in document:
  https://wiki.bnl.gov/rhicspin/upload/6/68/Run91112_results.pdf

note: numbers given for uncertainties are relative $\sigma(P)/P$

Run13 plans:

- Steps to mitigate Run12 problems: RF pickup, target mortality
- New features

Polarimeters

<u>p-carbon (pC) polarimeters (2 each RHIC ring):</u>

- Measure mean P across beam, profile $R = (\sigma_I/\sigma_P)^2$
  $\Rightarrow$ polarization for collisions e.g. for SSA $P_{SSA} \approx (1+½R)P$
- Short (<1 min.) measurements, few % stat. uncert., few (~4) per fill
  $\Rightarrow$ time evolution P(t), R(t)
- Measure asymmetry ϵ, $P=\epsilon/A_N$
  A_N not known *a priori* $\Rightarrow$ normalize to H-jet P measurements

<u>Polarized hydrogen jet (H-jet) polarimeter:</u>

- Target polarization P_{jet} measured w/ Breit-Rabi polarimeter (BRP)
- Measure jet $\Uparrow/\Downarrow$, beam $\Uparrow/\Downarrow$ asymmetries: $P_{beam} = -(\epsilon_{beam}/\epsilon_{jet})P_{jet}$
  $\Rightarrow$ absolute polarization scale determined w.r.t. Breit-Rabi polar., P_{jet}
- Low rate, over entire fill stat. uncert. few %
  $\Rightarrow$ combine many (all available) fills to normalize pC/H-jet

New polar. results: P(t), R(t), ...

- Now for each fill param.:

  $P(t) \approx P_0 - P'{\cdot}t$ (after A_N determined↘)

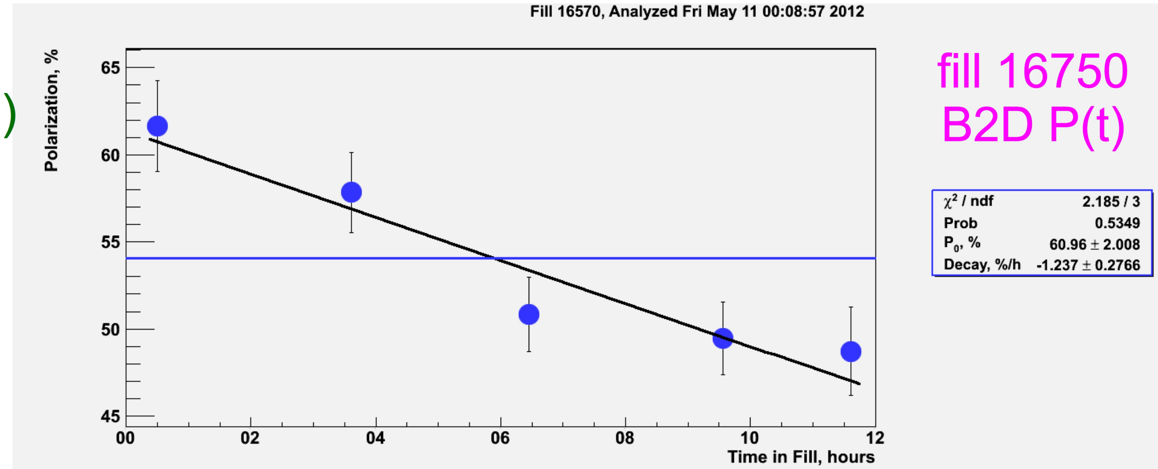
  $R(t) \approx R_0 + R'{\cdot}t$ (profile param.)

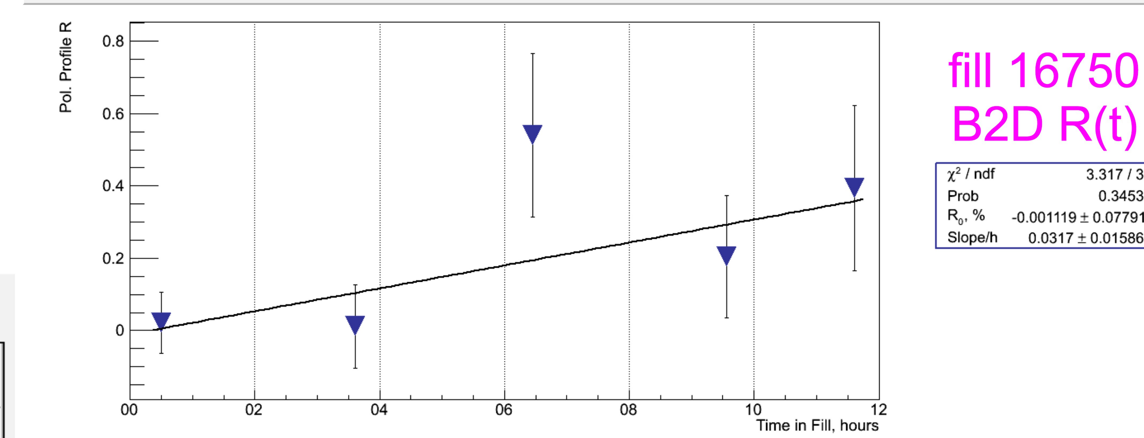
- And for experiments:

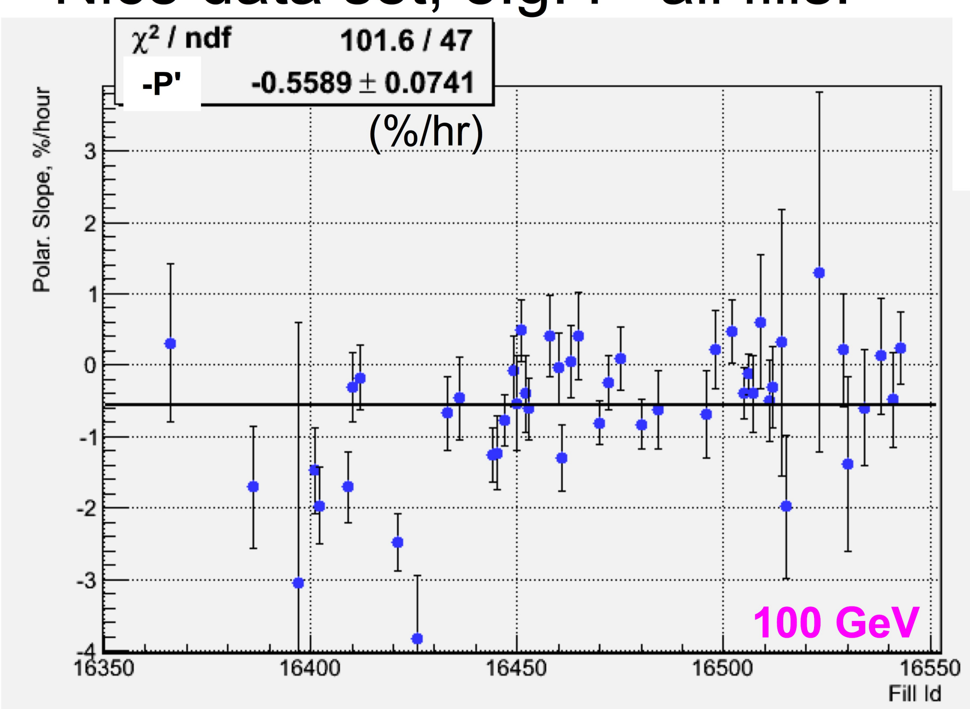
  $P_{SSA}(t) \approx (1 + \frac{1}{2} R(t))\, P(t)$

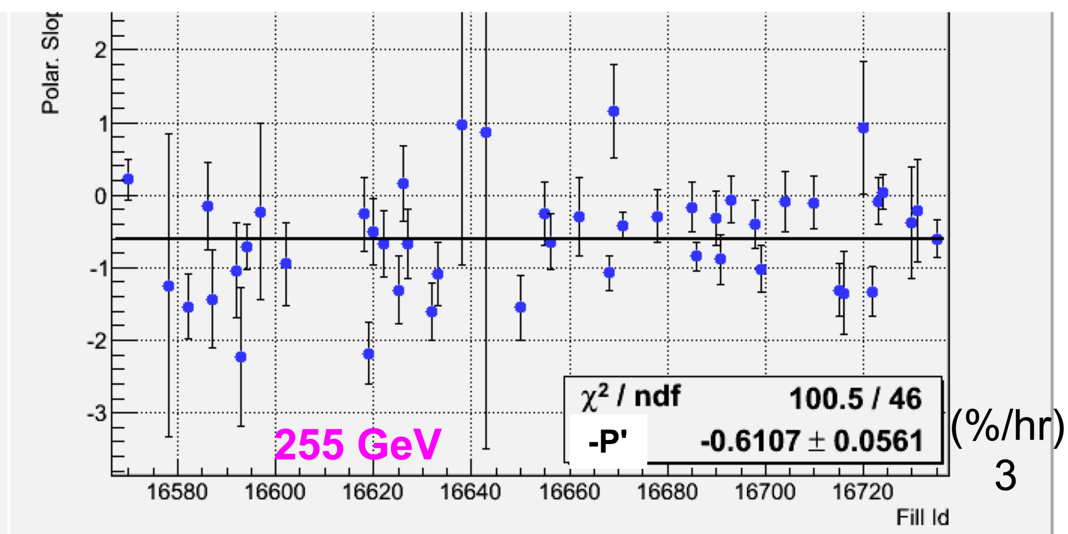
  $= P_{0,SSA} - P'_{SSA}{\cdot}t$

- Important: not all physics data collected uniformly thru fills
- Nice data set, e.g. P' all fills:









Use: time dependent P(t)

- For a fill must have time dependence of luminosity L(t) describing:
  - beam current decay
  - turning on/off of relevant trigger, prescales
- The the mean polarization for this fill is lumi-weighted P_{SSA} (t):

$$\begin{aligned}\langle P_{SSA}\rangle &= \frac{1}{\int dt L(t)}\int dt L(t) P(t) \\ &= P_{0,SSA} + \frac{\int dt\, t\, L(t)}{\int dt L(t)} P'_{SSA}\end{aligned}$$

pC/H-jet normalization $\Rightarrow A_N$

- H-jet measures beam intensity weighted mean polarization through fill:

$$\overline{P^{jet}} = \frac{\int dt I(t) P(t)}{\int dt I(t)}$$

- In terms of the pC measured asymmetry $\epsilon(t) = \epsilon_0 - \epsilon' \cdot t$:
  I(t) from RHIC archive

$$\overline{\epsilon^{pC}} = \left(1 - \left(\frac{\epsilon'}{\epsilon_0}\right) \cdot \frac{\int dt\, t I(t)}{\int dt I(t)}\right) \epsilon_0$$

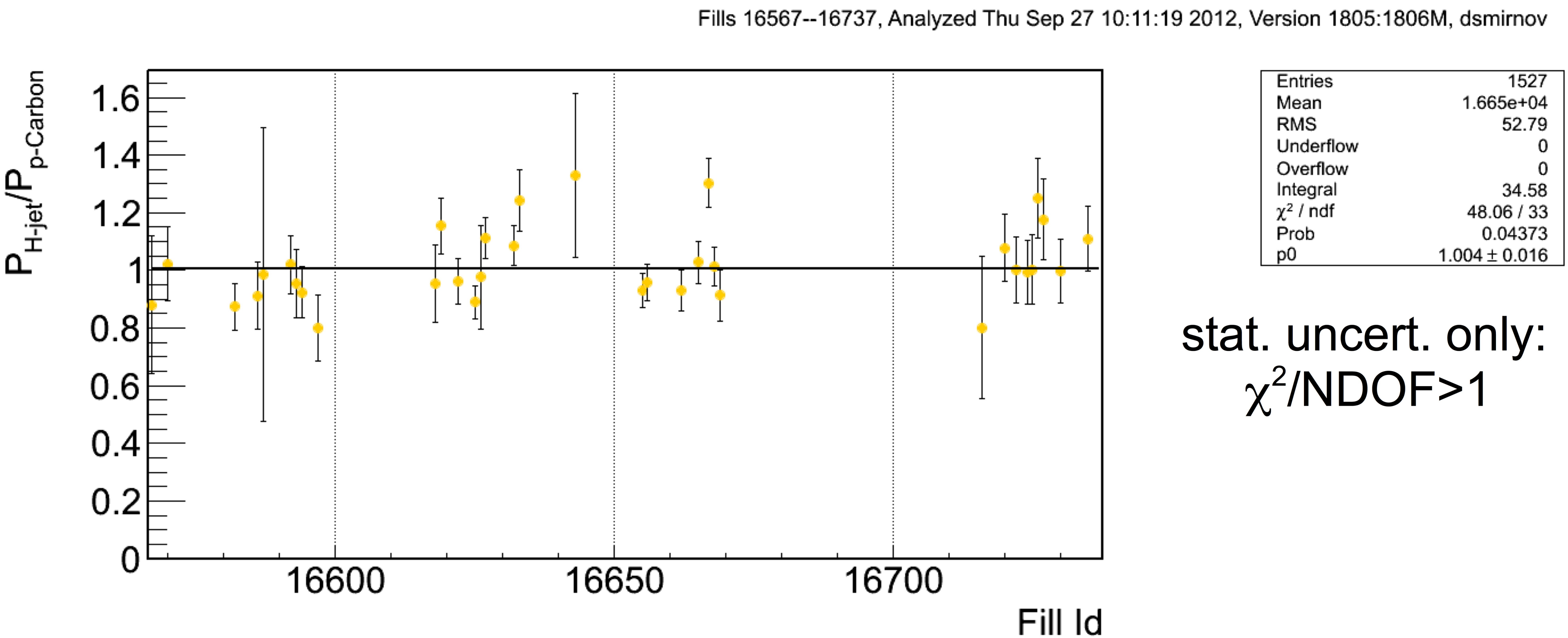
- Then over a set of fills determine:

$$A_N = \left\langle \frac{\overline{\epsilon^{pC}}}{\overline{P^{jet}}} \right\rangle_{\text{fills}}$$

- We measure A_N for each pC polarimeter (4×) and period (year, energy)
- Then all pC measurements: $P = \epsilon / A_N$
- And: uncertainty on A_N is a scale uncertainty on P

Uncertainty on A_N

- e.g. pC/H-jet ratio for Y2U 2012 255 GeV fills, should be constant:



stat. uncert. only:
χ^2/NDOF>1

- Consider fill-to-fill systematics H-jet $\oplus$ pC
- Estimate: add in quadrature to stat. uncert. so χ^2/NDOF=1
- For this set sys. uncert. = 5.6%
- All sets H-jet $\oplus$ pC syst. uncert.: ~ ½ of cases are zero: stat. dominated non-zero cases are 2.5-6.5%, almost all when known pC problems

Uncertainty on A_N

- Add so determined syst. uncert. (if any) to stat. uncertainties
- From pC/H-jet ratios with these inflated uncertainties redetermine A_N (P0 fit $\Rightarrow$ uncertainty on A_N)
- Uncertainties A_N each pC polarimeter 1.1-2.2%
- With 2 pC measurements each ring: uncert. 0.8-1.3%
- The uncertainty on A_N from this fit includes

  uncertainties from the full data set:
  - H-jet statistics
  - H-jet fill-to-fill systematics
  - pC statistics
  - pC fill-to-fill systematics

<u>Repeating:</u>

- All pC measurements: $P = \epsilon/A_N$
- Uncertainty on A_N is a scale uncertainty on P

P scale uncertainty from H-jet

<u>BRP:</u>

- P_{beam} scale set by B-R polarimeter measurement of P_{jet}
- BRP measures atomic H in jet target
- Jet may have some contamination from H_2, not measured in BRP
- H_2 contamination measured in test bench in 2004;
  from long ago measurement estimate uncertainty 3%
  DOMINANT UNCERTAINTY ALL P MEASUREMENTS

<u>Backgrounds:</u>

- Backgrounds in H-jet measurement (e.g. inelastic pp → X) can invalidate relation $P_{beam} = -(\epsilon_{beam}/\epsilon_{jet})P_{jet}$
- Upper limit on backgrounds ~1%; take as additional scale uncert.

Overall P scale uncert.

<u>SSA:</u>

- Polar. uncert. evaluated are for single beam i.e. for SSA (Profile correction $P \rightarrow P_{SSA}$ mentioned shortly)
- Contributions in quadrature:

  $\sigma(A_N) \oplus \sigma(\text{BRP } H_2 \text{ contamination}) \oplus \sigma(\text{H-jet backgrounds})$
- Result: all years, each ring $\sigma(P_{SSA})/P_{SSA}$ = 3.3-3.4%

<u>DSA:</u>

- To lowest order in profile parameter R: $P_{DSA} \approx P_{SSA,Blue} \cdot P_{SSA,Yellow}$
- The scale uncertainties from H-jet fully correlated

  between the two rings (same H-jet used both rings)
- Scale uncert. from A_N each ring uncorrelated
- Result: all years $\sigma(P_{DSA})/P_{DSA}$ = 6.5%

Entire / partial data sets

Scale uncertainties so evaluated include:

- All H-jet normalization scale uncert.
- All H-jet stat. uncert. (via A_N uncert.)
- All H-jet fill-to-fill syst. uncert. "
- All pC stat. uncert. "
- All pC fill-to-fill syst. uncert. "

When using all or almost all of a data set (year, energy):

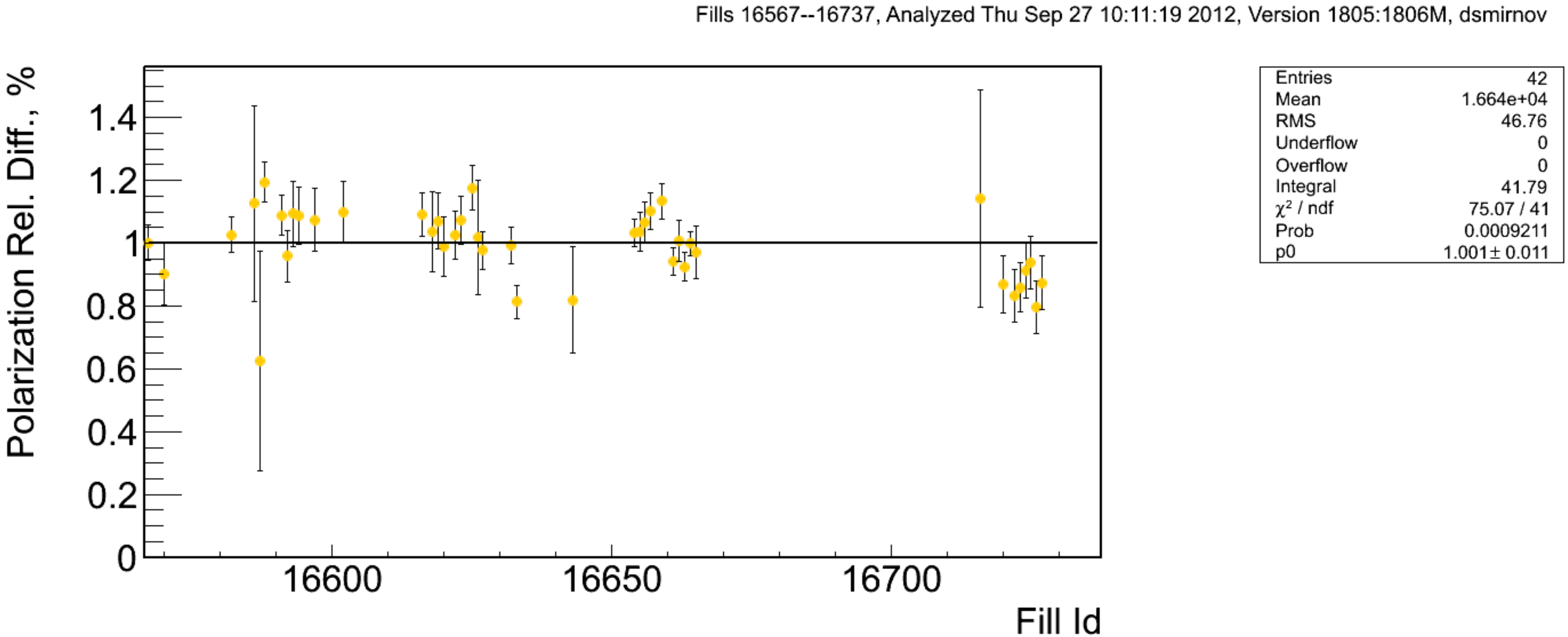
- That's it for $\sigma(P)/P$; we're pretty much done

When using fraction of a data set, say N fills:

- Fill-to-fill systematic uncertainties contribute $\propto 1/\sqrt{N}$
- As N gets large contribution negligible compared to scale uncert.
- Fill-to-fill uncertainties evaluated:
  - pC systematics
  - systematics of profile correction P, R $\Rightarrow P_{SSA}$

pC fill-to-fill syst. uncert.

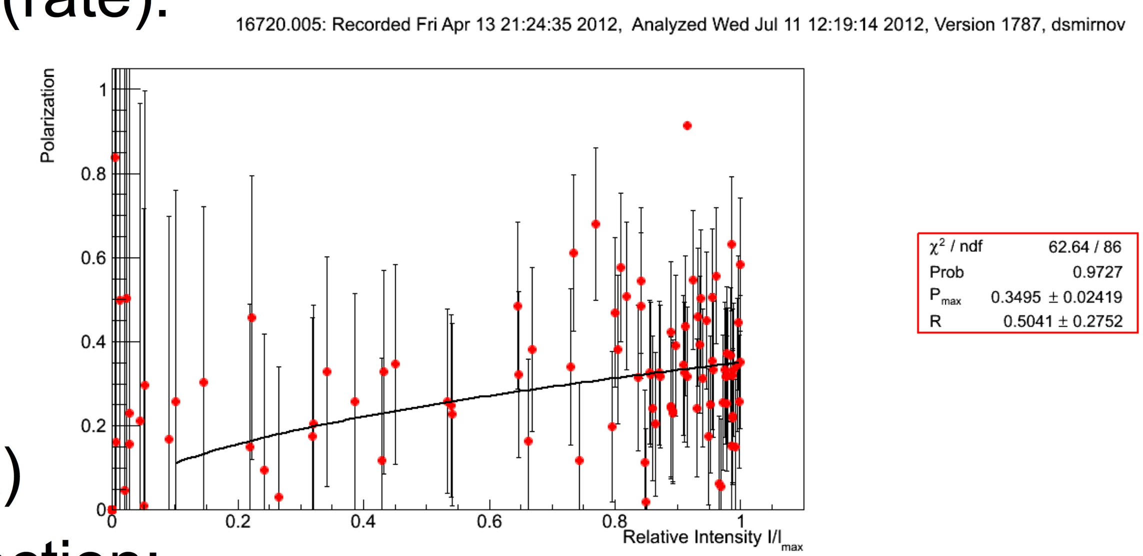
- For most fills have 2 P measures each ring: up/downstream pC polarim.
- They measure the same beam, should be same
- Here ratio Yel UP/DN for 2012 255 GeV:



- Estimate syst. uncert.: again do the χ^2/NDOF=1 thang
- pC fill-to-fill syst. uncert. 0-3.2%; non-zero usually known pC problems for N fills large, negligible w.r.t. scale uncert.
- Some overcounting of uncert. here (already in overall scale uncert.) → see summary document for details

Profile correction systematics

- Profile parameter $R = (\sigma_I/\sigma_P)^2$
- Measure R from P vs. Intensity (rate):
  $P(I) = P_{max} \cdot (I/I_{max})^R$

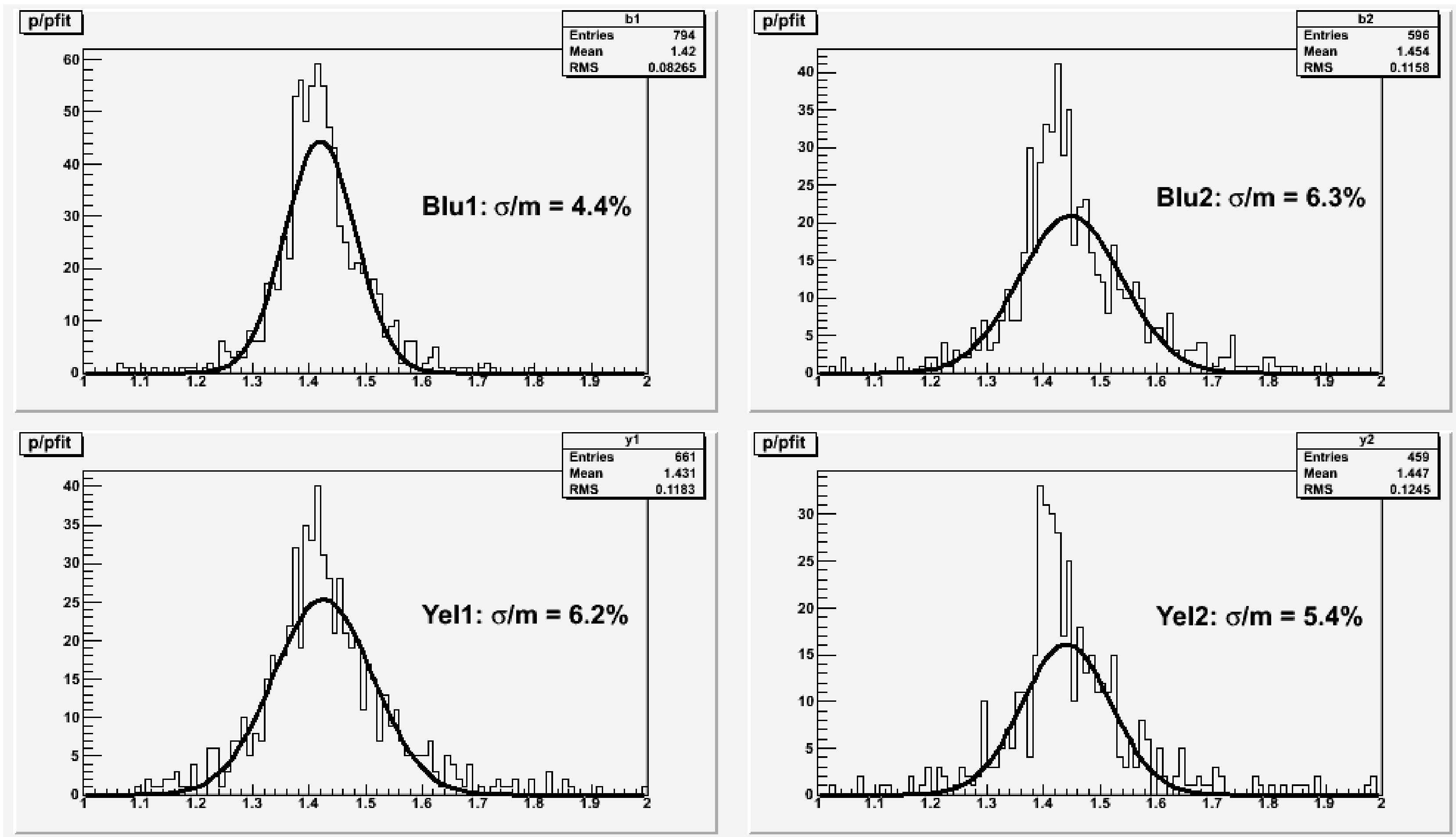


- In terms the (fit) parameters
  P_{max} & R , mean P of a target
  sweep across beam is:
  $\langle P \rangle_{fit} = P_{max}/\sqrt{(1+R)} \approx P_{max} \cdot (1-½R)$
- Very similar to SSA profile correction:
  $P_{SSA} \approx \langle P \rangle_{sweep} \cdot (1+½R)$

- We measure directly (& use for results) sweep mean $\langle P \rangle_{sweep}$
- Comparing $\langle P \rangle_{fit}$ & $\langle P \rangle_{sweep}$ sheds light on precision of SSA correction

Profile correction systematics

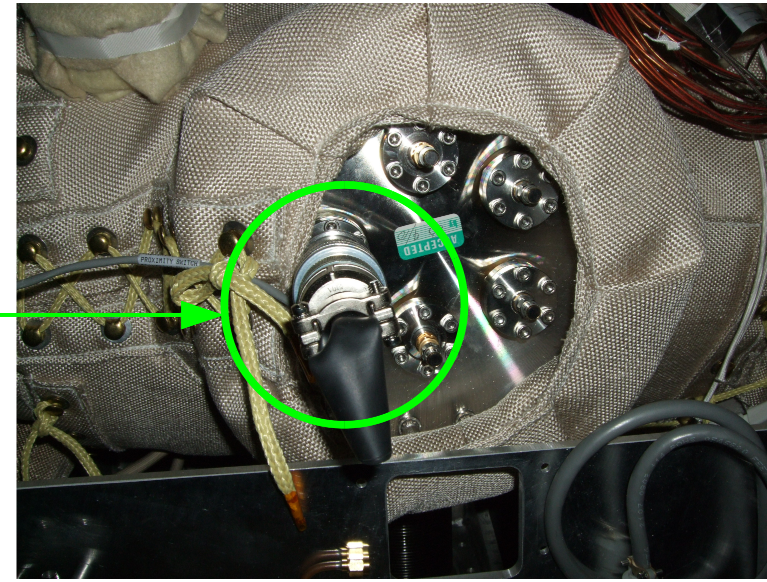
- RMS/mean of ($\langle P \rangle_{fit}/\langle P \rangle_{sweep}$) distributions (extra factor √2 in $\langle P \rangle_{fit}$ here):



- RMS/mean ~ 4.5-6.5% per measurement
- Each fill ~3 measurements × 2 polarimeters
  ⇒ fill-to-fill profile correction uncert. 2.2%
- Again for N fills contributes ∝1/√N, negligible w.r.t. scale uncert.

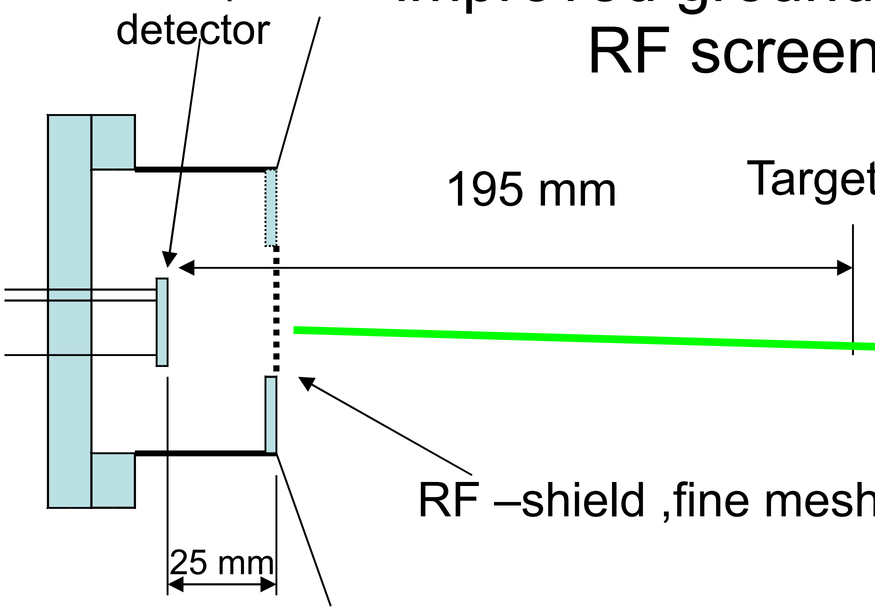
Run13: RF pickup reduction

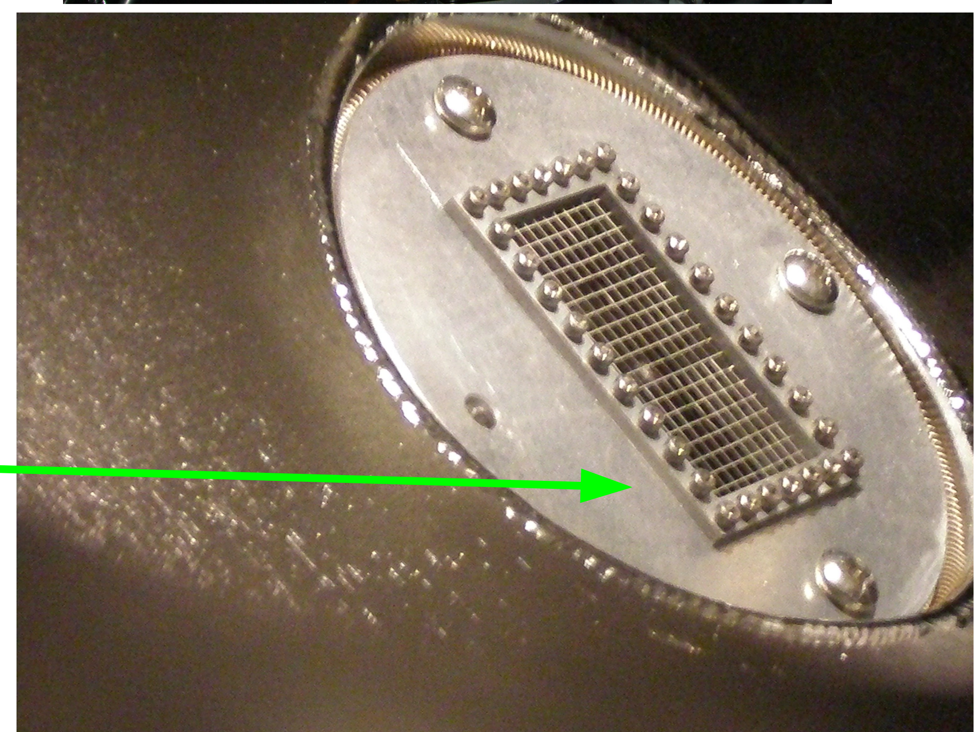
- Run12 big problems with RF pickup noise in pC detectors



- Major external source:
  YEL stochastic cooling pickup
- Steps to reduce:
  - properly terminate feedthroughs
  - upgraded grounding/shielding
    pC preamp boxes on chamber

- Reduce internal RF from in chamber:
  - improved grounding,
    RF screens





Run13: target lifetime improvement

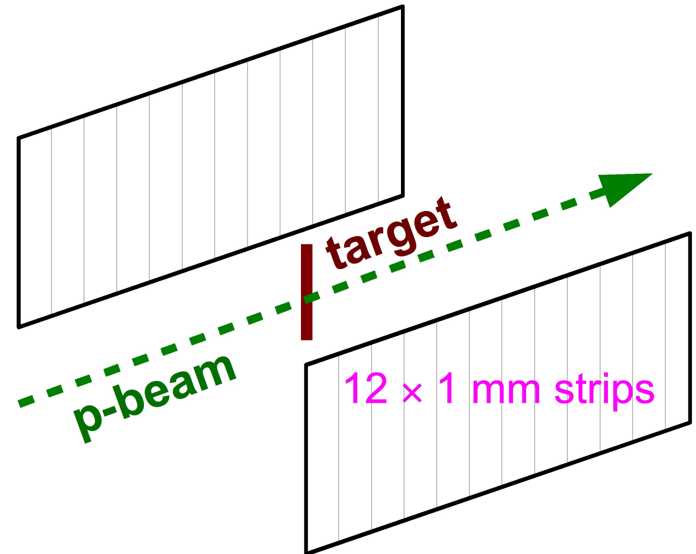
- Run12 had high rate target mortality:
  entire target set replaced twice, entire maintenance days
- Run12 used thinnest possible 25 nm thick carbon targets
- Run13 will use 50 nm thick carbon targets, more robust
  - monitor rates closely, avoid DAQ buffer overflows (target speed)

- Observation: targets are non-conducting before use;
  targets that survive beam exposure are conducting
- Hypothesis: heating in beam changes structure (& conductivity)
- Will install some targets treated to become conductive:
  treated with intense flash lamp; annealed by current heating
- If available: install few graphene targets from outside firm
- Early RHIC operations:
  expose all targets to low current beam, anneal

- Installing video system to monitor
  all targets behavior, viability

Run13: long. segmented det.

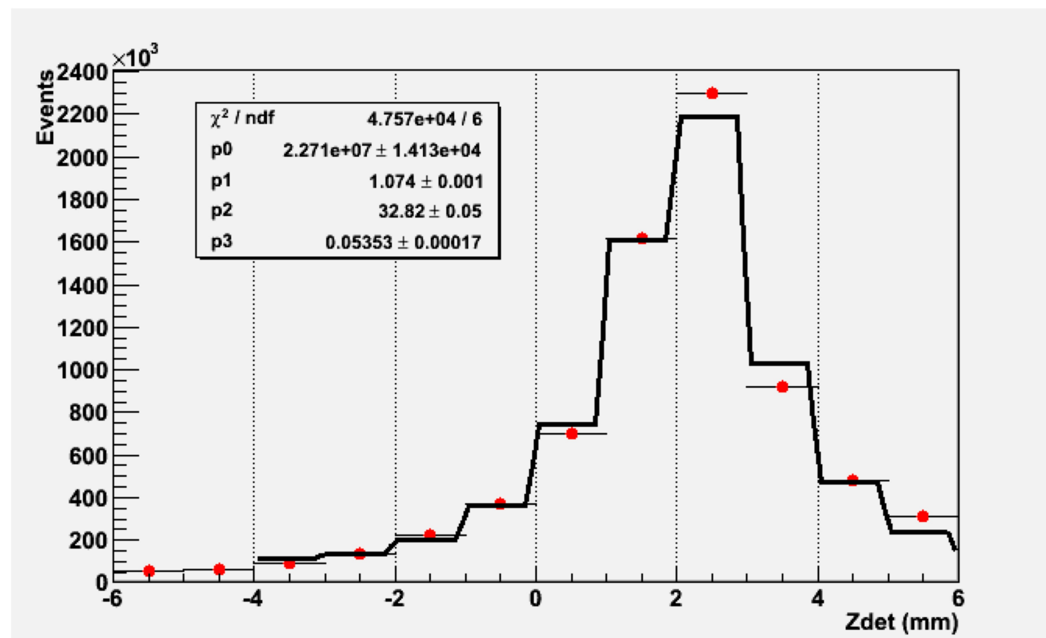
- pC detectors usually segmented azimuthally
- Run13: each polar. pair of detectors segmented longitudinally (along beam):



- One such pair tested in Run12, promising results

<u>Distribution of hits in strips gives info (fit to MC distribution):</u>

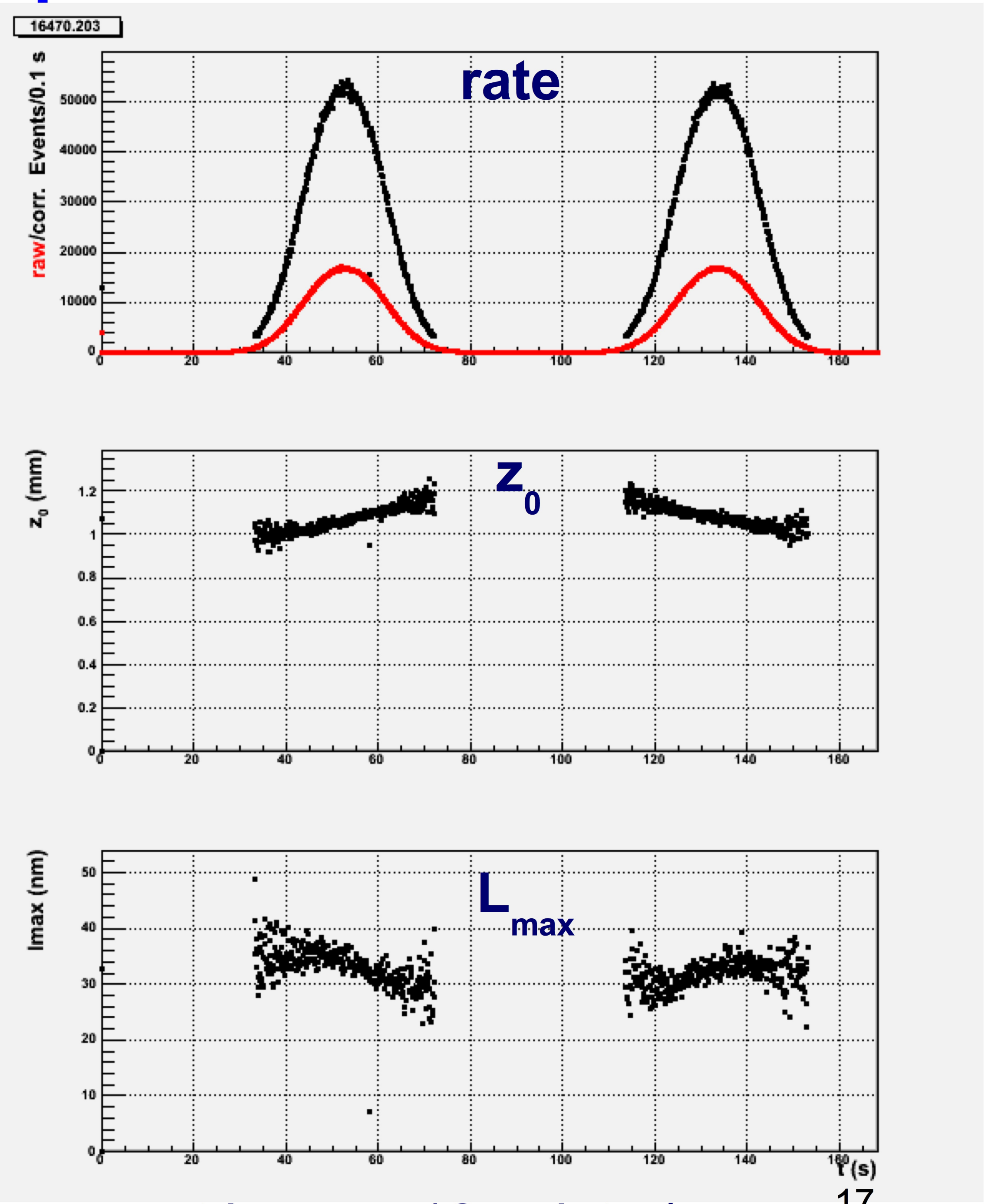
- Centroid $\Rightarrow z_0$
  target position along beam
- Width $\Rightarrow L_{max}$
  amount of target material traversed
  pC scattering→detector
  (width from multiple scattering)



⇒ monitor these parameters through sweep measurements ↘

Run profile

- Fits performed for 0.1 sec. bins
- Rate ~ position across beam:



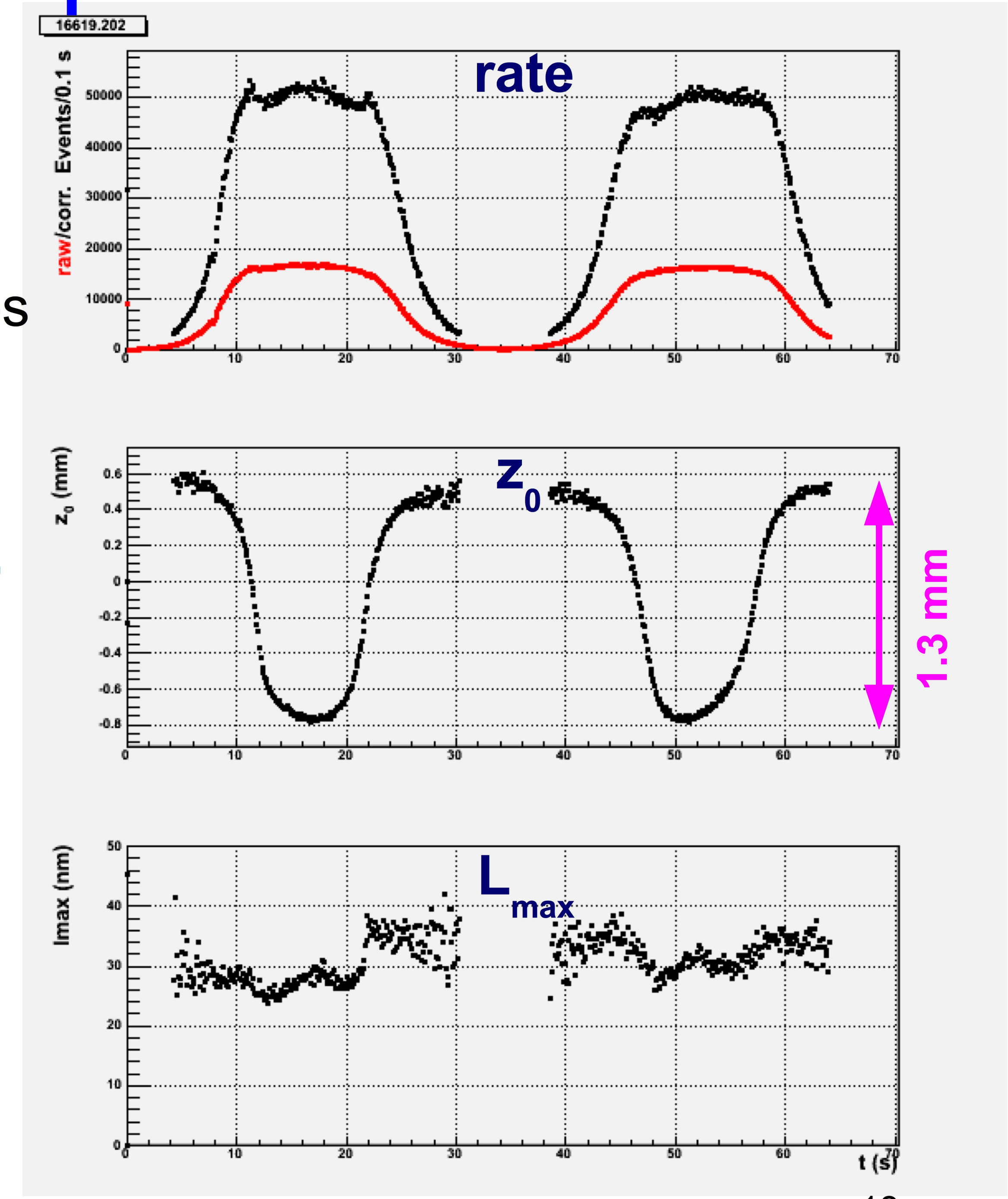
- z_0 varies ~linearly in time
- Target sweep direction not perpendicular to beam axis, crosses beam at an angle
- L_{max} ~ constant

t in sec.; 10 points /

Run profile

<u>Hypothesis:</u>

- Loose target, ~1.2 mm sway
- Attracted radially toward beam
- As it reaches radial center of beam it stays there, rate flat tops



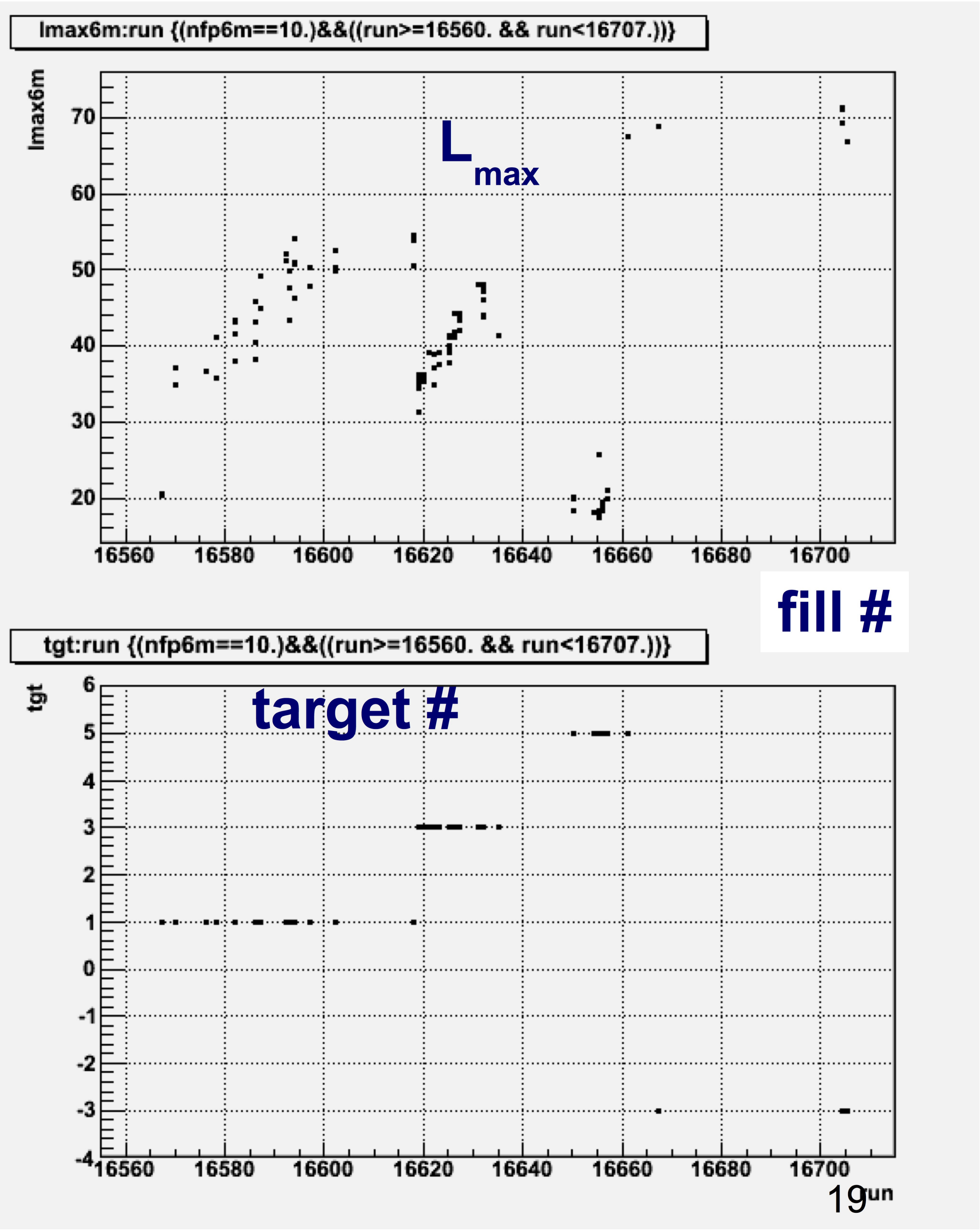
- While at radial center of beam, other forces attract it toward -z, it moves ~1.3 mm along beam
- Reverse process as target drawn out other side of beam
- The long. segmented detectors provide useful info on target looseness, viability...
- Also spectacular when a target breaks...

Long term L_{max} vs. time, target

- L_{max} (material crossed) ~constant in sweep, but evolves over long term (fills):
- Effective thickness L_{max} some targets seems to increase with # exposures

Amount of material crossed can effect P measurement:

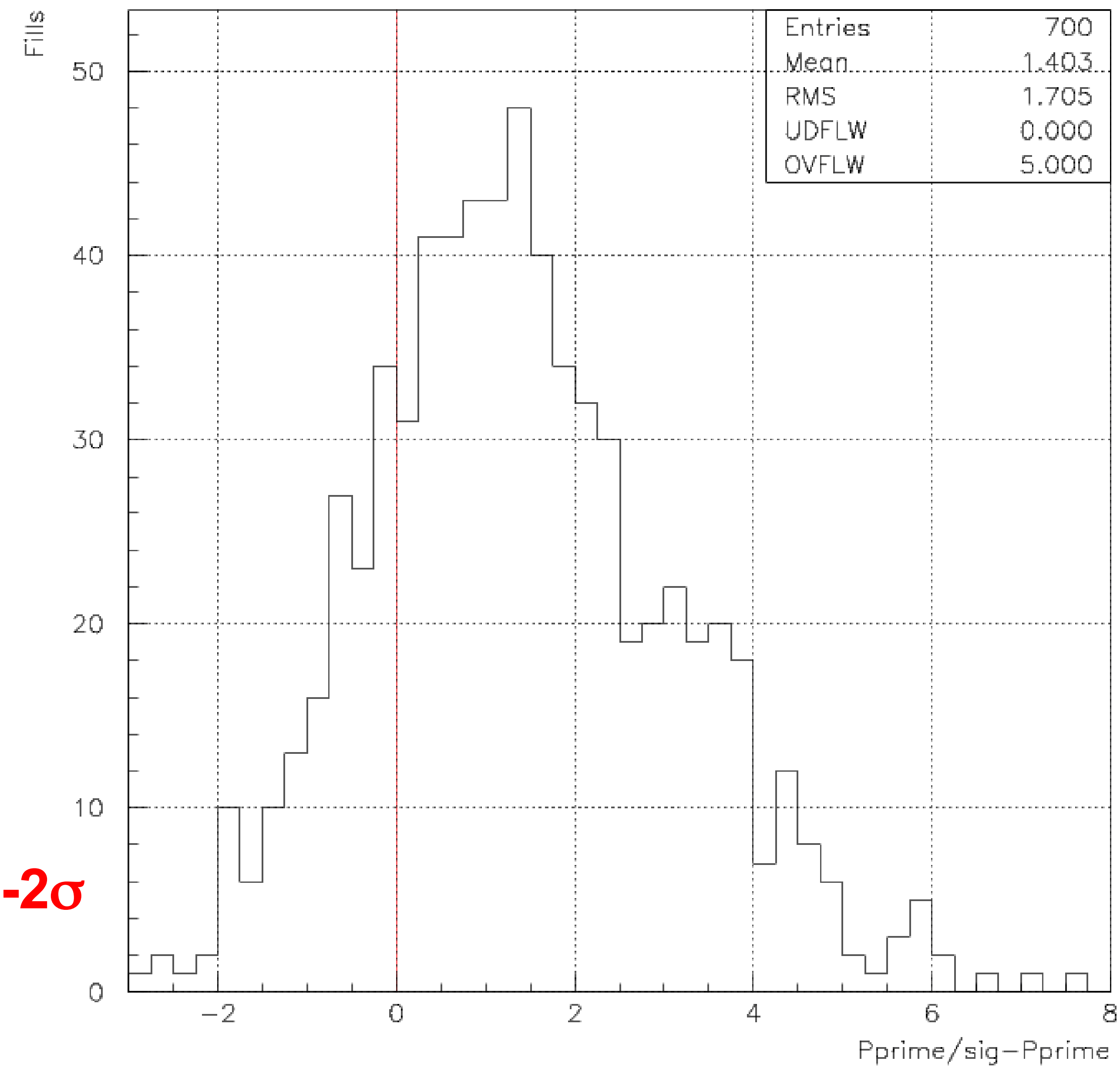
- detect fixed carbon E range
- loss by dE/dx ⇒ shift from scattered→detected carbon E
- changed $A_N(E_{scat})$
- With thicker targets Run13 larger L_{max} variations
- monitor and perhaps correct for



Extras

Significance of P'=-dp/dt

- Histogram P'/σ(P'), all fill Runs 9-12:



no fills <-2σ