Spin tilt @ pC polarimeters

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CAD spin mtg.
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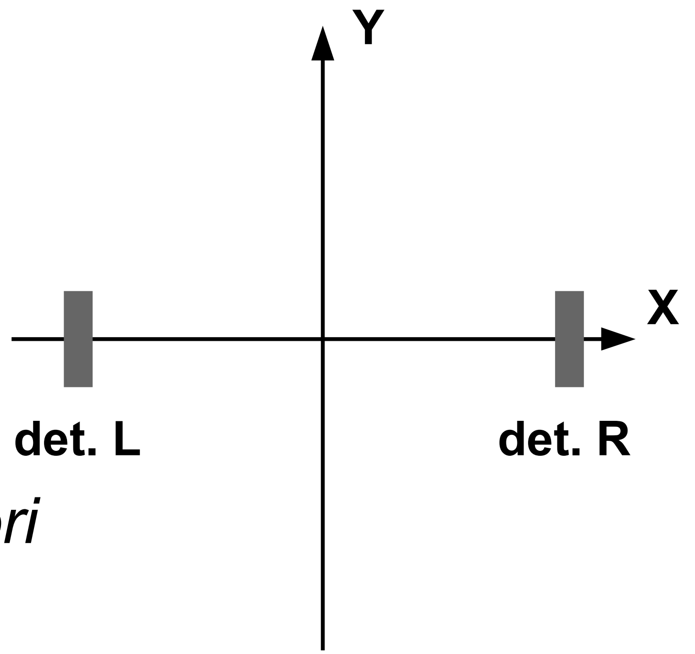
- The instrumentation & measurement:
  - 2 detectors 'Square root formula' → 3 asymmetries:
    +/- beam current, L/R acceptance, $P_{\perp}$ (along axis ⊥ detectors)
  - pC polarimeters, 3 pairs detectors:
    cross checks → systematics negligible
    stat. uncert. dominates
- Spin tilt @ pC polarimeters: Run13 255 GeV
- Question: Spin tilt @ IP12 (H-jet polarimeter) ???

Square root (cross ratio) formula

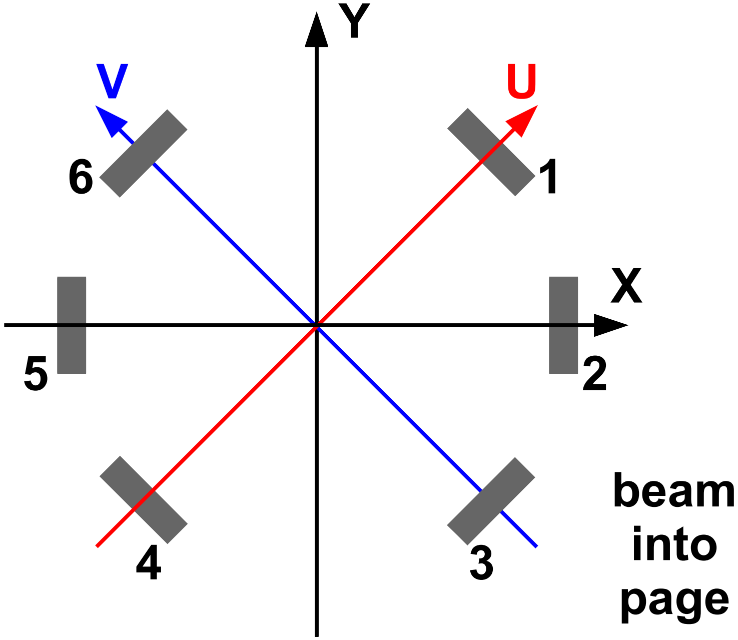


- Pair of detectors (L,R), 180° apart:
  different detector acceptances a_L, a_R
- Exposed to up/down beam spins +,-:
  different up/down luminosities L_+, L_-
- Beam polarization along Y-axis P_Y:
  physics asymmetry $\epsilon = A_N P_Y$
  proportionality const. A_N not known *a priori*
- Measure 4 event counts:
  beam up: $N_{R+} = a_R L_+ (1+\epsilon)$ $N_{L+} = a_L L_+ (1-\epsilon)$
  beam down: $N_{R-} = a_R L_- (1-\epsilon)$ $N_{L-} = a_L L_- (1+\epsilon)$
- Extract 3 asymmetries (& statistical uncertainties):
  - physics asym. $\epsilon = A_N P_Y$ e.g. $\epsilon = (\sqrt{N_{R+} N_{L-}} - \sqrt{N_{L+} N_{R-}})/(\sqrt{N_{R+} N_{L-}} + \sqrt{N_{L+} N_{R-}})$
  - luminosity (beam current) asym. $\lambda \equiv (L_+ - L_-)/(L_+ + L_-)$
  - acceptance asym. $\alpha \equiv (a_R - a_L)/(a_R + a_L)$

pC polarim.: 3 detector pairs

- 3 180° detector pairs, det.1+4, 2+5, 3+6:
- Measure 3 sets of asymmetries:

$$\epsilon_{25} = A_N P_Y \,,\ \lambda_{25}\,,\ \alpha_{25}$$
$$\epsilon_{14} = A_N P_V \,,\ \lambda_{14}\,,\ \alpha_{14}$$
$$\epsilon_{36} = A_N P_U \,,\ \lambda_{36}\,,\ \alpha_{36}$$

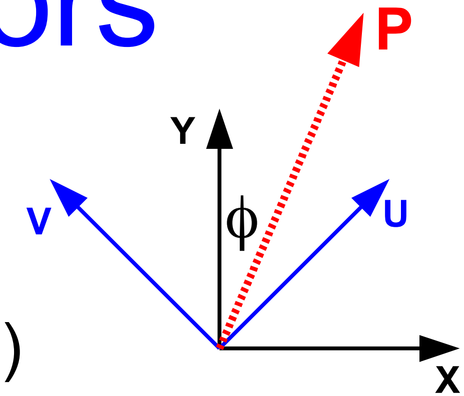


Cross checks:

- All detector pairs measure same beam, lumi asym. λ
  compare λ_{14}, λ_{25}, λ_{36} : agree within stat. uncert. (↘ extra slide)
- All detector pairs measure same beam, polarization vector P
  two measures of $\epsilon_Y = A_N P_Y$, using $P_Y = 1/\sqrt{2}(P_V+P_U)$
  - from 90° det. 2+5: $\epsilon_{Y90} = \epsilon_{25}$ (vertical targets only)
  - from 45° det. 1+4, 3+6: $\epsilon_{Y45} = 1/\sqrt{2}(\epsilon_{14}+\epsilon_{36})$
  - compare ϵ_{Y90}, ϵ_{Y45}: agree within stat. uncert. (↘ extra slide)

Also: A_N ~same all detector pairs

tanϕ from 45° detectors



- Using 45° detectors (simpler) measure P_X, P_Y and spin tilt from vertical ϕ:

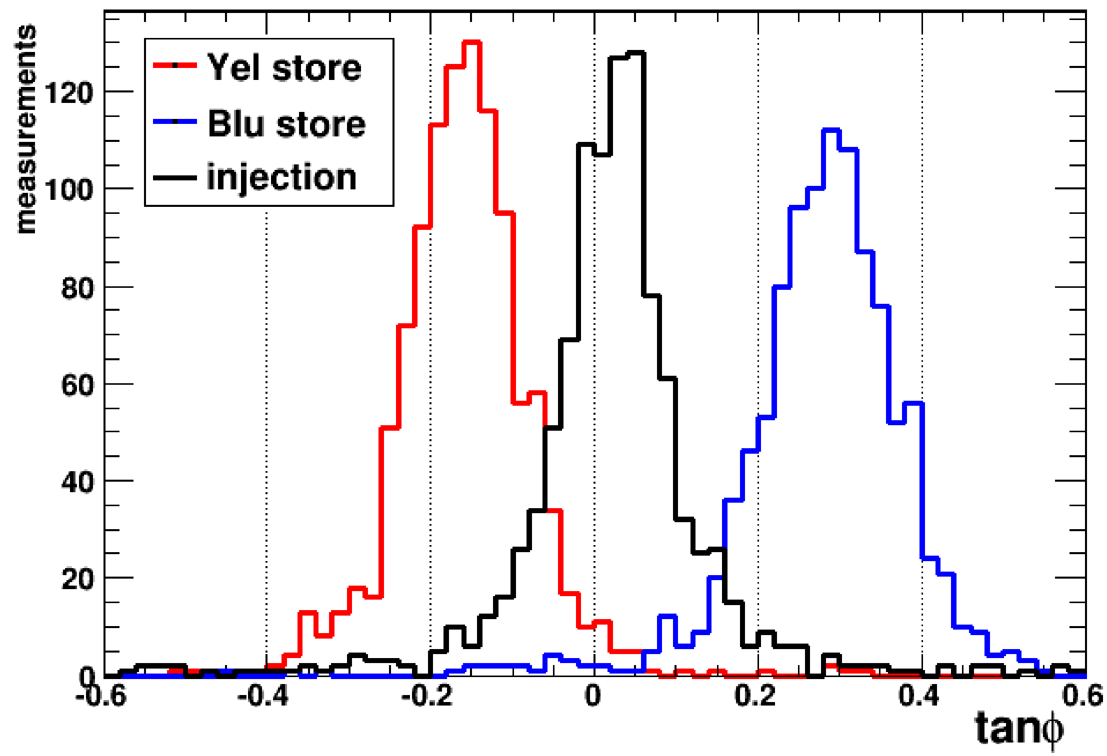
$$\tan\phi = P_X/P_Y = (P_U - P_V)/(P_U + P_V) = (\epsilon_{36} - \epsilon_{14})/(\epsilon_{36} + \epsilon_{14})$$

independent of scale of A_N

<u>Run13 255 GeV:</u>

- ~1100 measurements each:
  - Blu/Yel @ injection
  - Blu @ store
  - Yel @ store

Results:

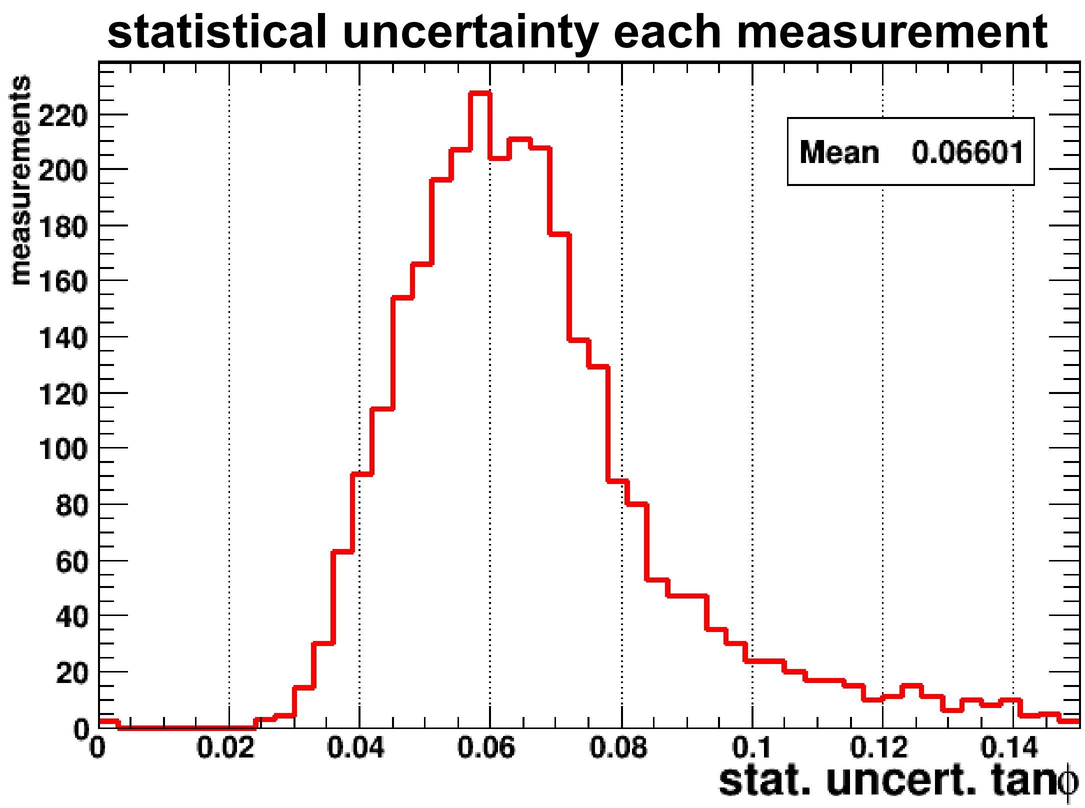


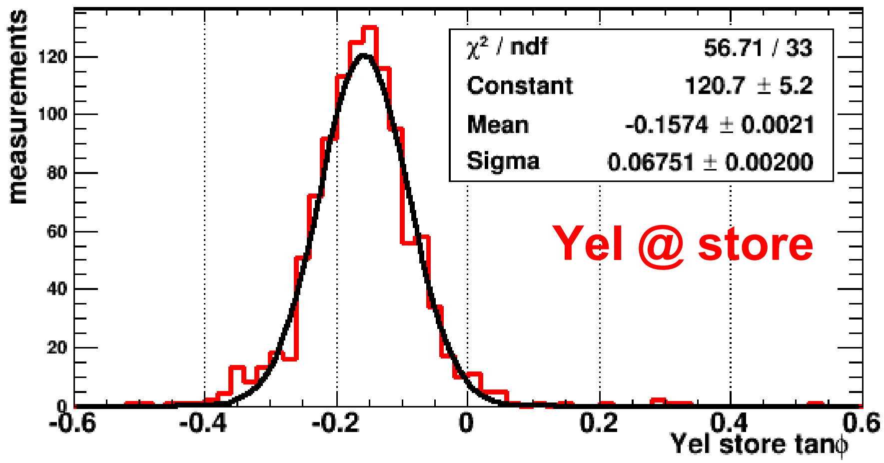
- Very clear:
  - @ injection tanϕ~0
  - @ store tanϕ>0 (Blu)
  - tanϕ<0 (Yel)

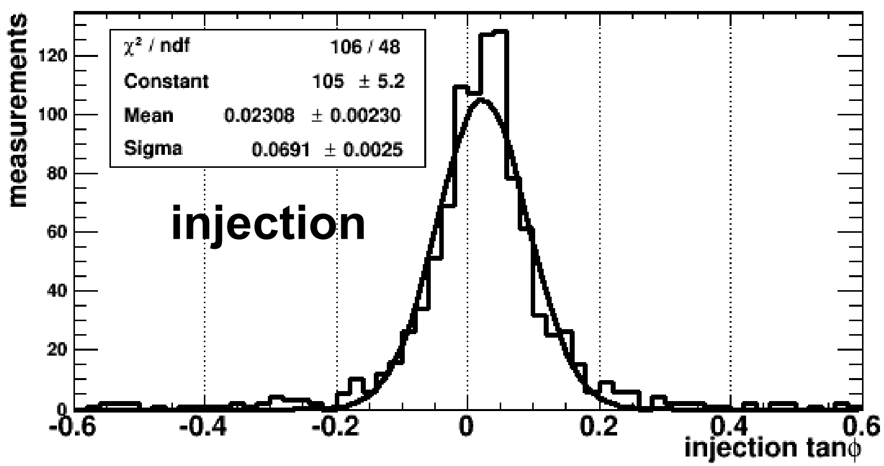
tanϕ fits

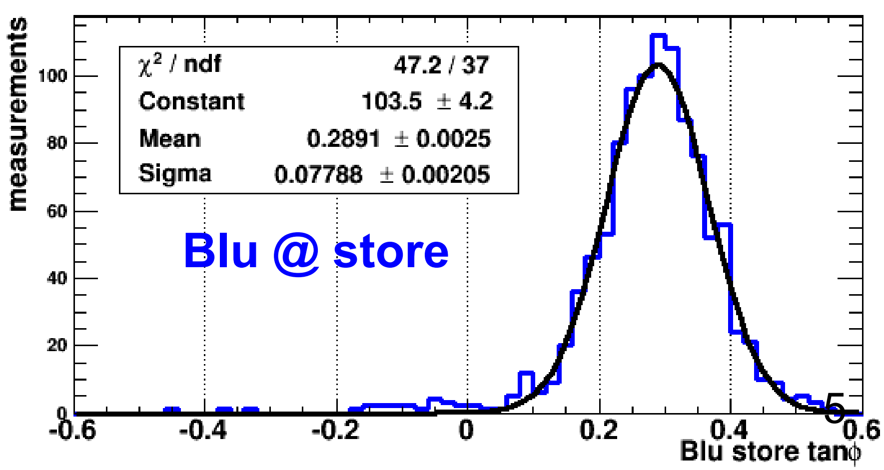
- Fit tanϕ distributions to gaussians
- RMS fit ~0.07
- Statistical uncertainty each measurement ~0.07

⇒ **Widths of tanϕ distributions due to statistical fluctuations**

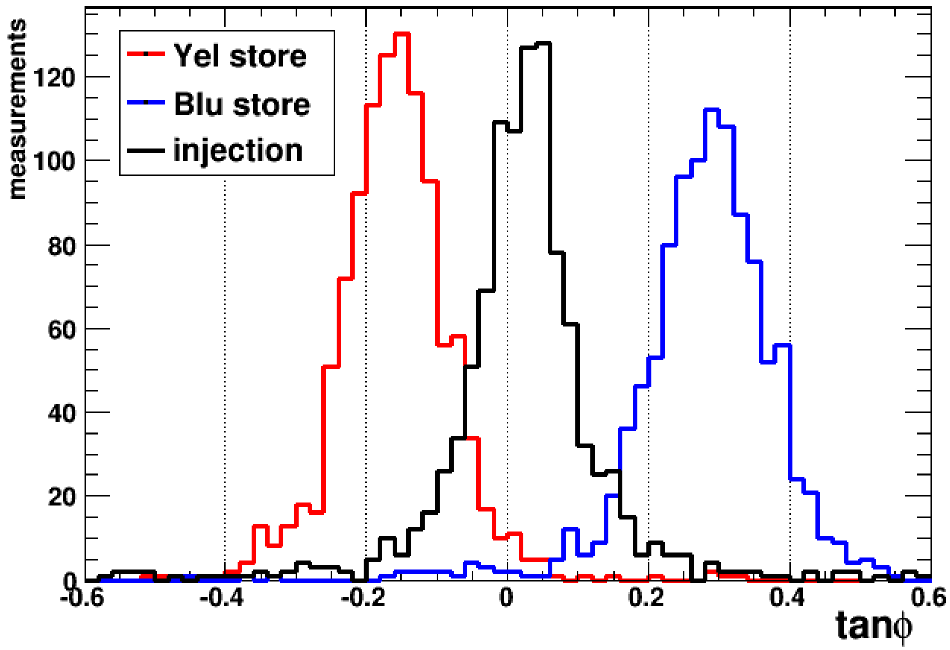








tanϕ @ pC polarimeter



- Widths due to stat. fluctuations,
  take central values:

  - injection: $\tan\phi = 0.02$ $\phi = +1°$
  - Blu @ store: $\tan\phi = 0.29$ $\phi = +16°$
  - Yel @ store: $\tan\phi = -0.16$ $\phi = -9°$

- In geographical coordinates:
  @ pC polarimeter
  @ store both Blu and Yel spin vectors
  tilted toward RHIC ring center

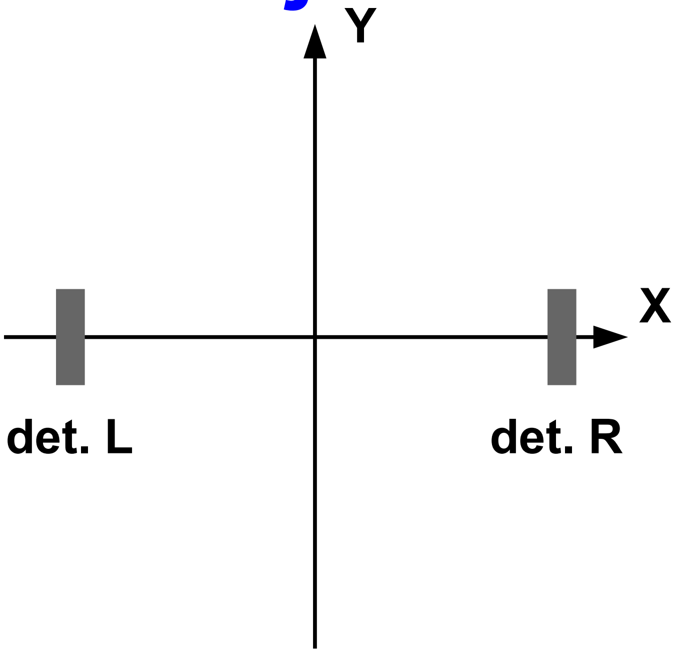
<u>Recall:</u>

- pC polarimeter ~100m clockwise from IP12
  Blu beam heading out from IP12, Yel beam heading in to IP12

<u>Question (not academic):</u>

- What is spin tilt @ IP12???

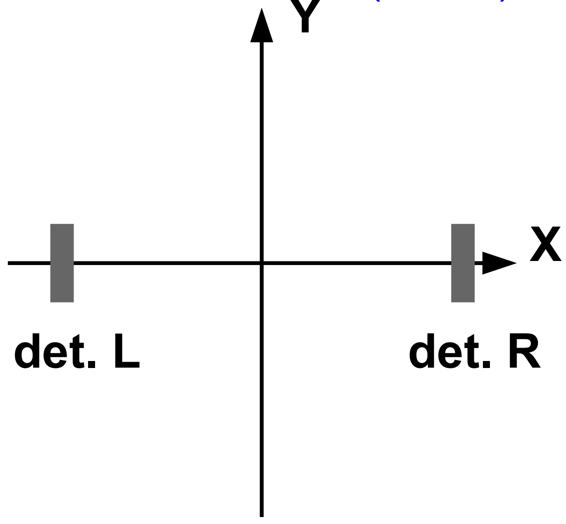
Spin vector tilt @ IP12 = H-jet?



- H-jet polarimeter is at IP12:
  has only 90° horizontal detectors,
  measures $\epsilon_Y \propto P_Y$
- The H-jet measurements normalize scale of pC measurements (determine pC A_N)
- To date we have assumed H-jet measures polarization magnitude |P|
- If there is a spin tilt $\phi \neq 0$ @ IP12 we have a |P| scale shift of $\cos\phi$
  e.g. Yel @ store: ϕ = -9° $\cos\phi$ = 0.99   1% scale shift
  Blu @ store: ϕ = +16° $\cos\phi$ = 0.96   **4% scale shift**
- A 4% shift is significant, need to account for in polarization measurements...

Extras

Square root (cross ratio) formula (contd.)



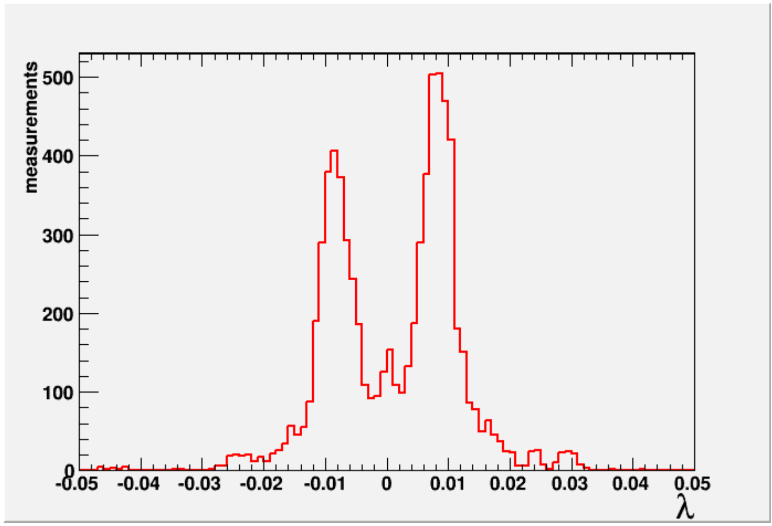
- 4 event counts: $N_{R+} = a_R L_+(1+\epsilon)$ $N_{L+} = a_L L_+(1-\epsilon)$
  $N_{R-} = a_R L_-(1-\epsilon)$ $N_{L-} = a_L L_-(1+\epsilon)$
- Cross ratio asymmetries:
  e.g. $\epsilon = (\sqrt{N_{R+}N_{L-}} - \sqrt{N_{L+}N_{R-}})/(\sqrt{N_{R+}N_{L-}} + \sqrt{N_{L+}N_{R-}})$
  are exact under some assumptions about N_{R+}, N_{L+} etc.

<u>Assumptions:</u>

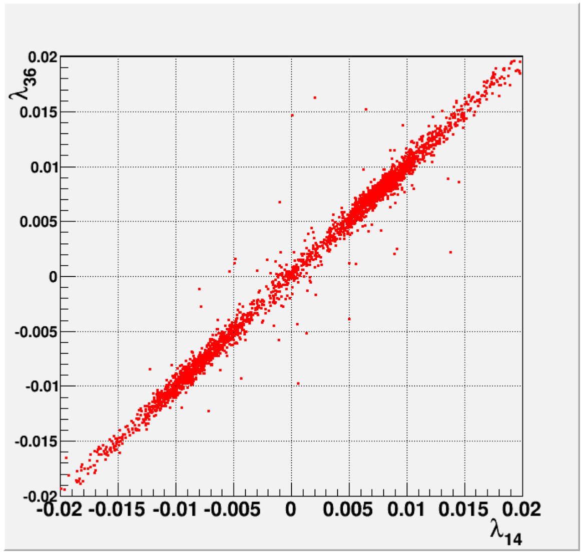
- Detector acceptances a_L, a_R are same for +/- beam spin states;
  - detector geometry (θ,ϕ) ~fixed
  - +/- spin bunches separated by 100's nanoseconds; fair assumption
- Detectors are 180° apart; ~fixed by scattering chamber design
- +/- bunches same magnitude polarization: $|P_+| = |P_-|$
  - to 1st order: $\epsilon = ½(|P_+|+|P_-|) A_N$ (mean of P magnitudes)
- Detectors have same analyzing power A_N
  - varying calibrations, target ⇒ varying E_{carbon} ranges ⇒ varying A_N
  - to 1st order: $\epsilon = ½(A_{NR}+A_{NL})P$ (mean of detector A_N's)
  - luminosity asym. λ unchanged to 1st order
  - **least certain assumption, test $A_N \propto \epsilon$ with cross checks**

Luminosity asymmetries λ

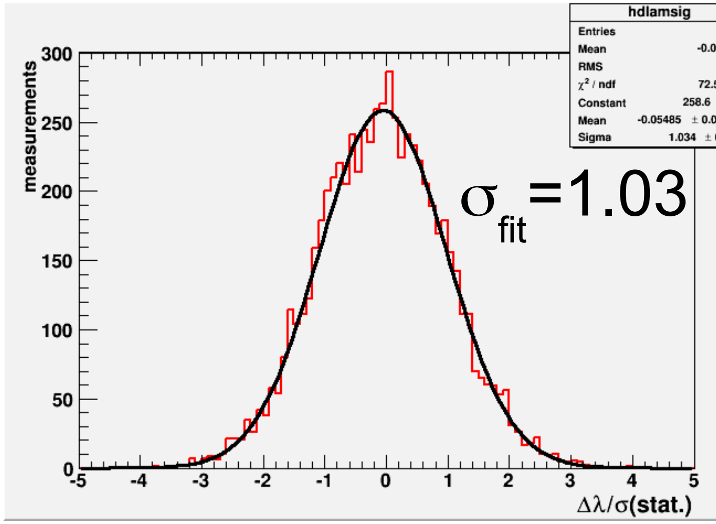
- Lumi asyms. λ ~ +/- 1% typically 111 bunches, one extra +/- bunch



- λ from different detector pairs track each other, here e.g. λ_{36} vs. λ_{14}:

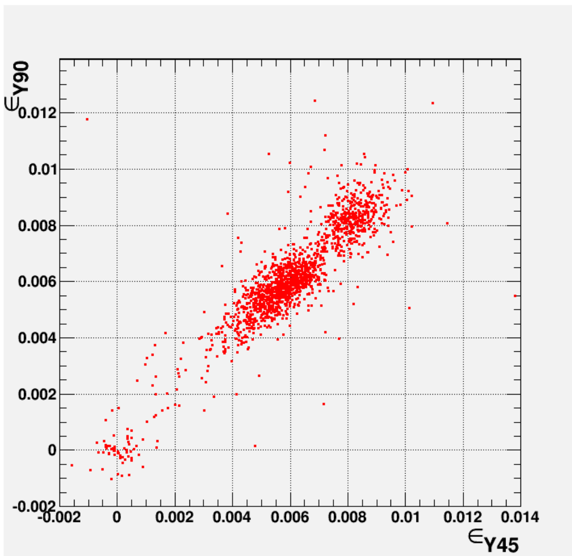


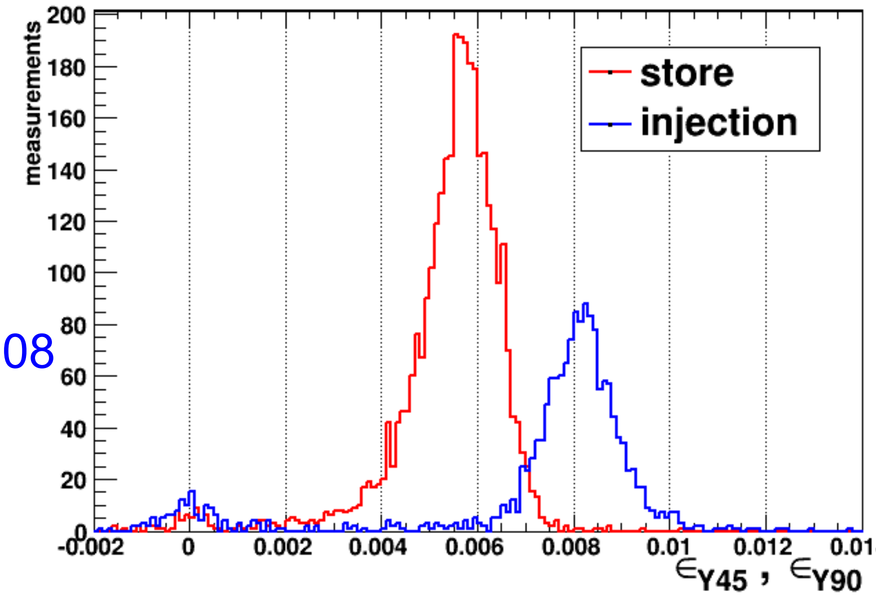
- Plot $(\lambda_A - \lambda_B)/\sigma(\text{stat})$
- Unit gaussian: no significant systematic, square root formula works
- Good measure of λ for experiments?



ϵ_Y from 90°, 45° detectors

- Independently measure ϵ_Y with 90°,45° detectors (vertical targets only):
- ϵ_{Y90}, ϵ_{Y45} nicely correlated:

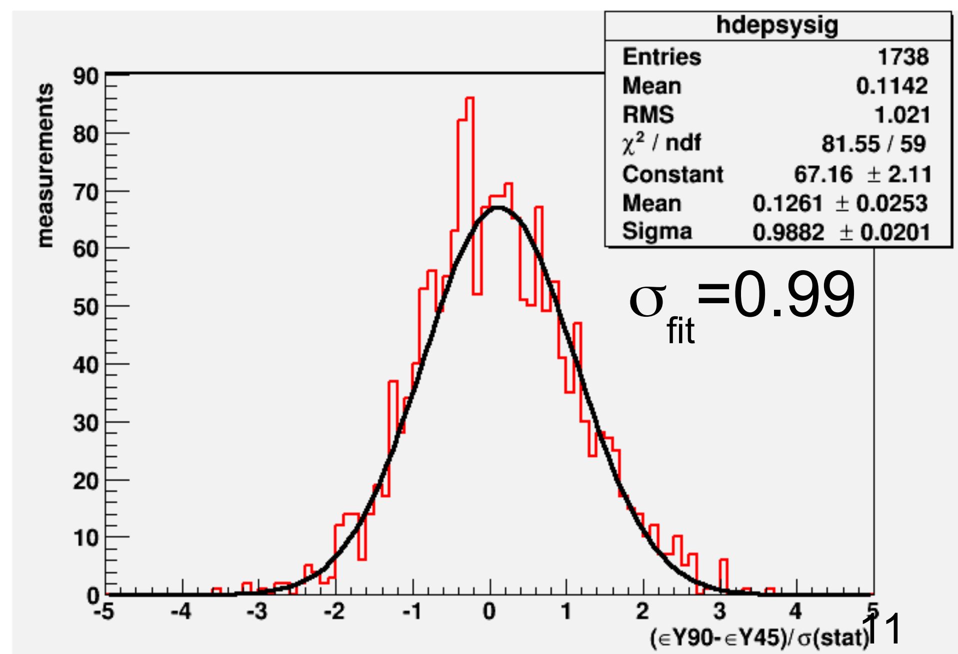




store ϵ_Y~0.006

injection ϵ_Y~0.008

- Distribution $(\epsilon_{Y90}-\epsilon_{Y45})/\sigma(\text{stat})$, unit gaussian:
- $\sigma_{fit} = (1 \oplus \sigma_{syst}/\sigma_{stat})$, $\sigma_{syst}(\epsilon_Y) \ll \sigma_{stat}(\epsilon_Y)$
- The variations we see in ϵ_{Y90}, ϵ_{Y45} are statistical, no indication systematic variations



σ_{fit}=0.99