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Systematic errors in HJET measurements

Corrections to the "square root formula"

$$P\delta A_N = P\frac{\delta A_N^{(L)} + \delta A_N^{(R)}}{2} + \frac{\delta\epsilon_L - \delta\epsilon_R}{2}$$

$$\delta\lambda = P\frac{\delta A_N^{(L)} - \delta A_N^{(R)}}{2} + \frac{\delta\epsilon_L + \delta\epsilon_R}{2}$$

$$\delta\epsilon = \delta P A_N$$

- λ and ϵ are luminosity and acceptance asymmetries, respectively
- $P = \frac{P^+ + P^-}{2}, \quad \delta P = \frac{P^+ - P^-}{2}$

At this, first order, approximation the only sources of systematic errors are uncontrollable variations of analyzing power (due to background and systematic error in energy calibration)

$$\delta A_N^{(L,R)} = \left\langle A_N^{(\mathrm{eff})} - A_N \right\rangle_T = \left\langle \frac{b}{1+b}\left(A_N^{(\mathrm{bgr})} - A_N\right) - 2m_p \frac{dA_N(t)}{dt}\delta T \right\rangle_T \qquad t = -2m_p T$$

and acceptance Ω dependence on polarization (for the Jet asymmetry only)

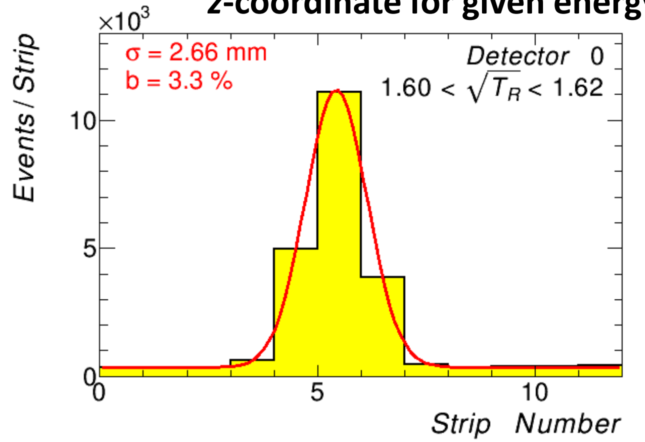
$$\delta\epsilon_{L,R} = \frac{2\left(\Omega_{L,R}^+ - \Omega_{L,R}^-\right)}{\Omega_L^+ + \Omega_L^- + \Omega_R^+ + \Omega_R^-}$$

The measured luminosity asymmetry λ has to be independent on recoil proton energy T. In some cases, the inspection of $\lambda(T)$ allows us to evaluate systematic error in physics asymmetry $PA_N(T)$ measurement. If only one of 4 perturbations $\delta A_N^{(L,R)}$, $\delta\epsilon_{L,R}$ is non-zero then there is strict correlation between systematic errors $P\delta A_N = \pm\delta\epsilon$.

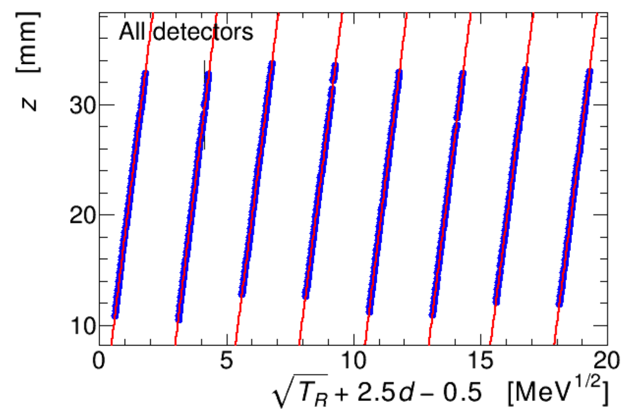
Verification of the calibration using recoil protons from elastic scattering:

$$\langle z_{det} - z_{jet} \rangle = \kappa\sqrt{T_R}, \qquad \kappa = 18\ \mathrm{mm}/MeV^{1/2}$$

z-coordinate for given energy



z-coordinate dependence on energy



A discrepancy is being observed:

$$\delta\sqrt{T_R} \approx 0.035 + 0.009\sqrt{T_R} \quad \Rightarrow \quad \langle \Delta T/T \rangle \approx 3\% \quad \text{and} \quad \langle \Delta T \rangle = 180\ \mathrm{keV}$$

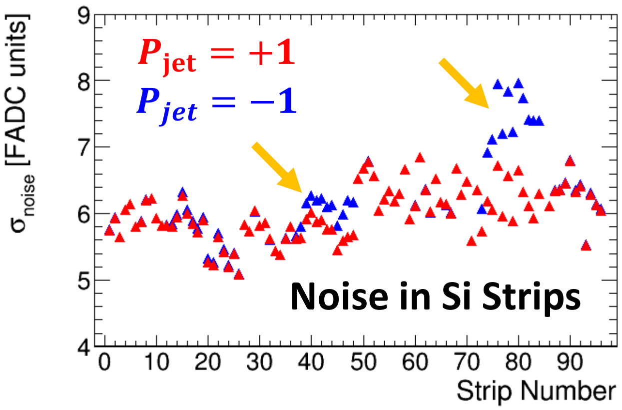
After corrections: $\langle \sigma_T^{syst}/T \rangle \approx 0.9\%$ and $\langle \sigma_T^{syst} \rangle \approx 20\ \mathrm{keV}$

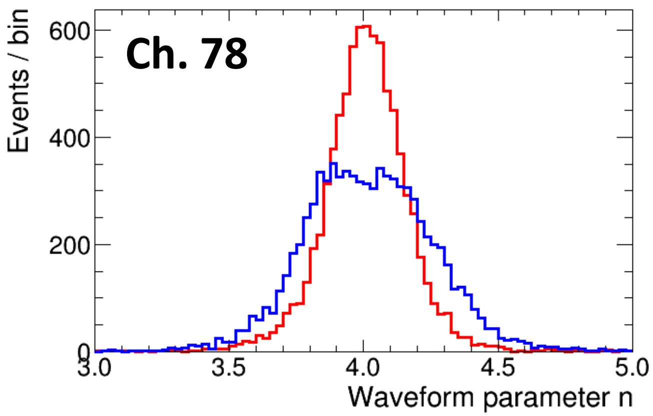
- **Since the source of discrepancy (calibration?, geometry?, magnetic field corrections?, …?) is not proved yet, the corrections are not validated. The study is being continued.**
- **Proton beam polarization measurements is not sensitive to these error in calibration**

Detector acceptance correlation with the Jet polarity

<u>The Jet RF transition cavity can induce noise in the Jet Si detectors:</u>

pp Run 2015

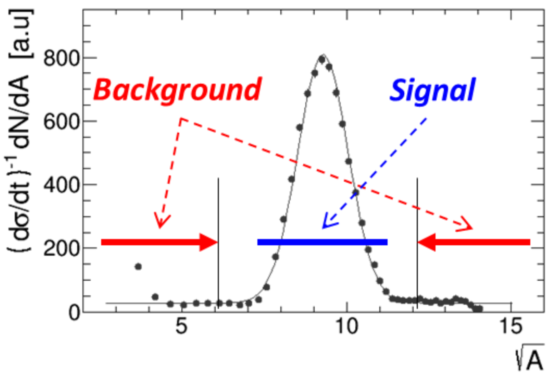




- **For a tight cut the acceptance may be changed by up to a factor 2, which strongly affect the polarization measurement**
  $P\delta A_N = \delta\epsilon_L/2 \approx -0.15$
- **For a loose cut, e.g 4±0.7, the problem is strongly suppressed.**

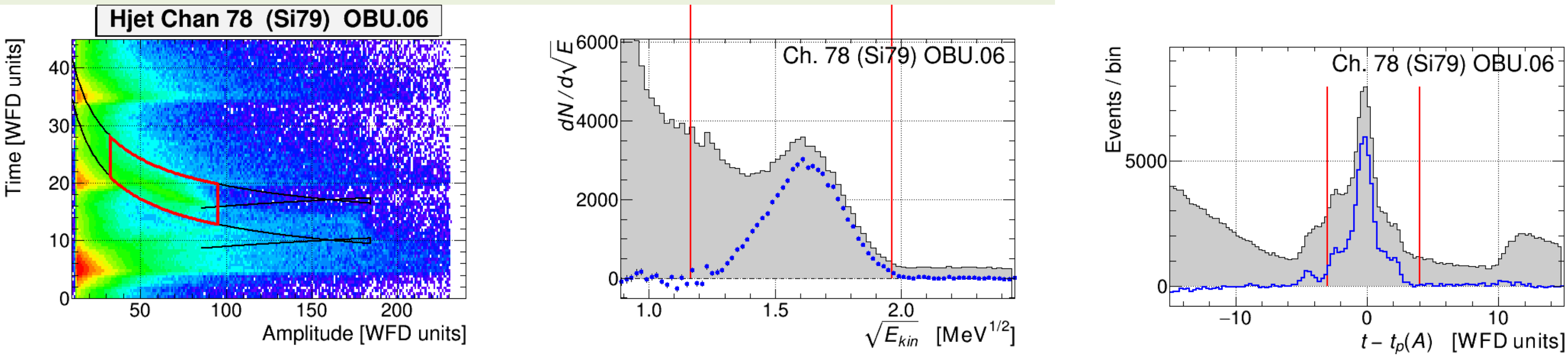
- Only one detector (OBU) is strongly affected by these noise.
- We may expect strong correlation in systematic errors (mostly at low energies) $P\delta A_N = \delta\lambda$.
- This is expected to be a dominant source of systematic errors (excluding molecular hydrogen)

Background subtraction



- Background subtraction is based on assumption that for given recoil proton energy the background is the same for all strips in the detector.
- The background may be subtracted independently for any combination of beam/jet polarizations. Thus, spin correlated asymmetries are properly accounted.
- Currently, the background subtraction is a routine, in-flight, procedure in the data analysis.

The example is given for blue detector in 100 GeV $d\mathrm{Au}$ Run (*The worse background/signal ratio*)

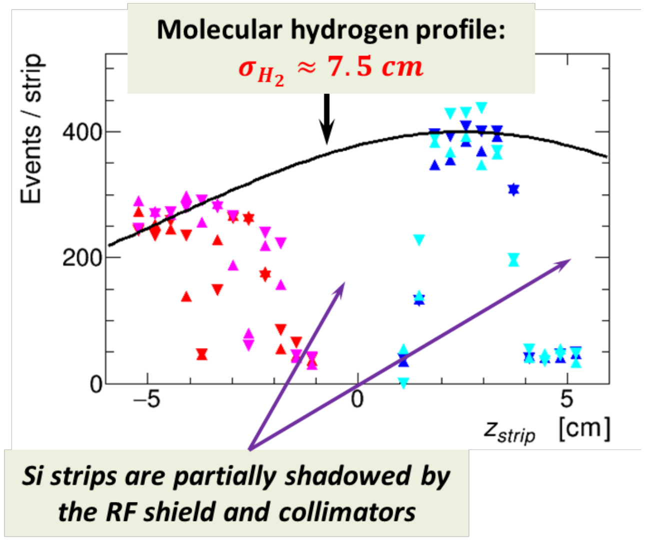


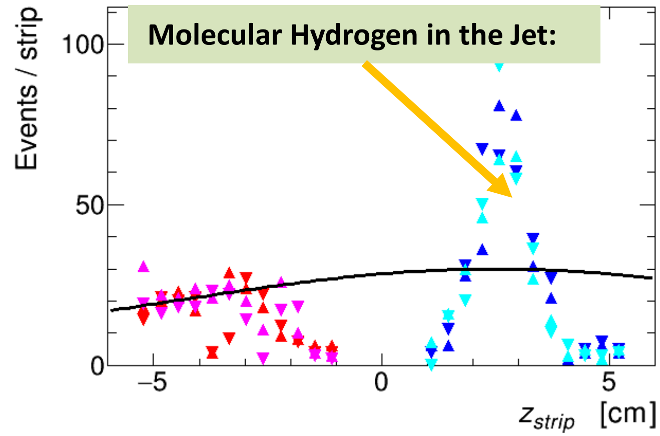
- The method works reasonably well even in this extremal case
- Usually, the accuracy of background subtraction is $\lesssim 10\%$.
- If the background level $< 10\%$ the background related systematic errors might be $< 1\%$.

Molecular Hydrogen Background

Experimental evaluation using 9.8 GeV blue Au beam and injected hydrogen to chambers 7 and 5

$$\sqrt{E_R} = 1.4 \pm 0.1\ \text{MeV}^{1/2}$$





Estimated fraction of hydrogen atoms bounded in molecules:

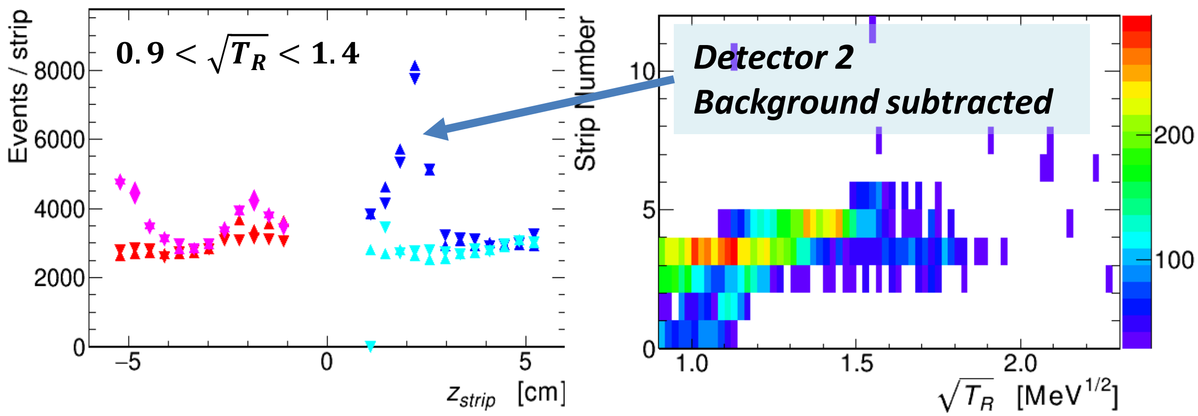
	Peak fraction	Integral fraction	Subtracted
Flat bgr.	0.4 ± 0.1 %	0.9 ± 0.3 %	$\mathbf{0.3 \pm 0.1}$ %
Jet bgr.	0.3 ± 0.1 %	0.4 ± 0.2 %	–
Total:	0.7 ± 0.2 %	1.3 ± 0.4 %	$\mathbf{1.5 \pm 0.1}$ %

Evaluation from pp data
$\mathbf{0.75 < T_R < 7.0\ \text{MeV}}$

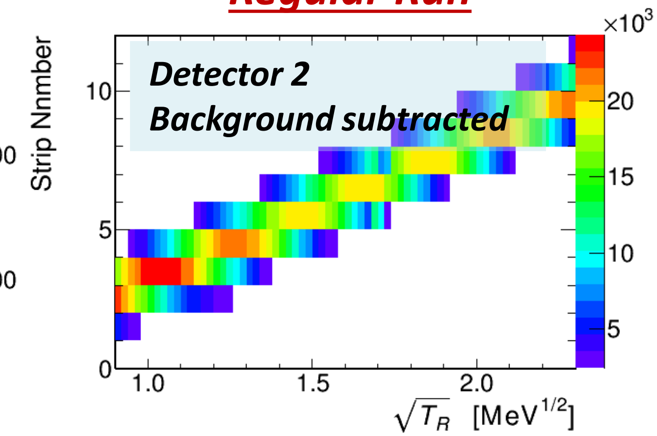
- **The molecular hydrogen background subtraction is not efficient due to shadowing detectors by collimators**
- **There is a significant beam polarization correlated asymmetry for *non*-molecular hydrogen background**
- **The effective Jet polarization may be evaluated as $P_{jet}^{(\text{eff})} = 95.0 \pm 0.5$ %**

Non-uniformity of inelastic background

dAu 9.8 GeV, Empty Target (no Jet) Run



Regular Run



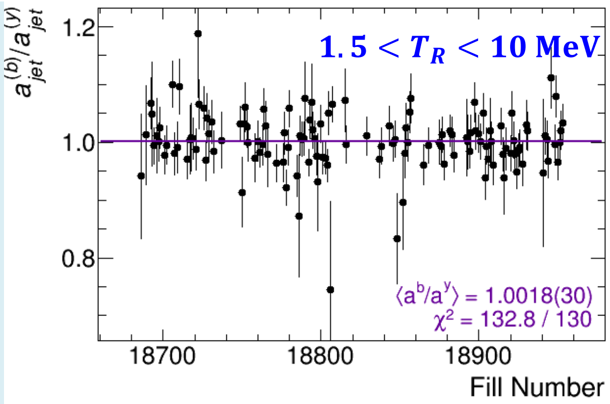
- Flat distributions were expected in empty target (Jet off) runs.
- Strong non-flatness is seen in **inner blue** and **outer yellow** detectors at $0.9 < \sqrt{T_R} < 1.9$
- For inner (right) blue detectors the background is not properly subtracted. The remaining background is well overlapped with the elastic signal.
- As result, for blue beam $\delta A_N^{(R)} < 0$ if $T_R \lesssim 3$ MeV.
- If this is the only systematic error then the measured analyzing power $A_N^{(m)}(t)$ may be corrected using the deviation in the intensity asymmetry measurement $\boldsymbol{\delta A_N^{(m)}(t) = \delta\lambda^{(m)}(t)}$

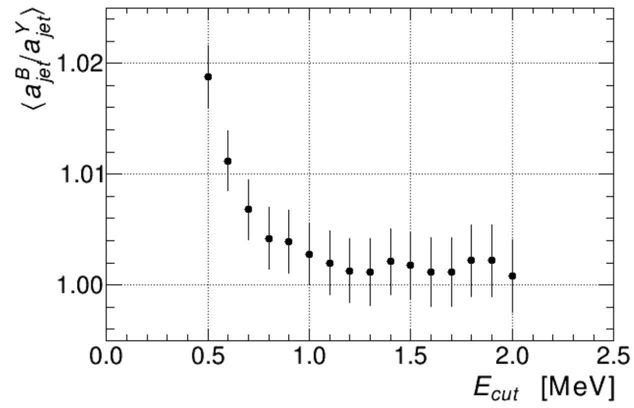
The effect is strongly suppressed in *pp* Run.

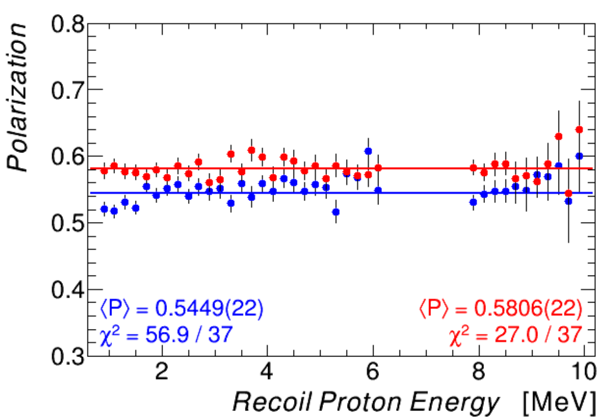
(However, no detailed study was done yet)

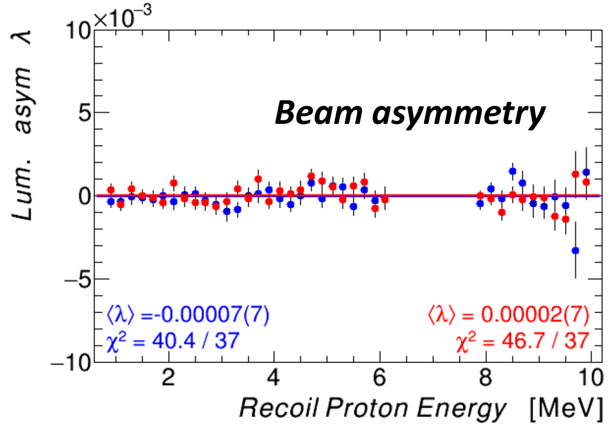
Beam polarization measurement

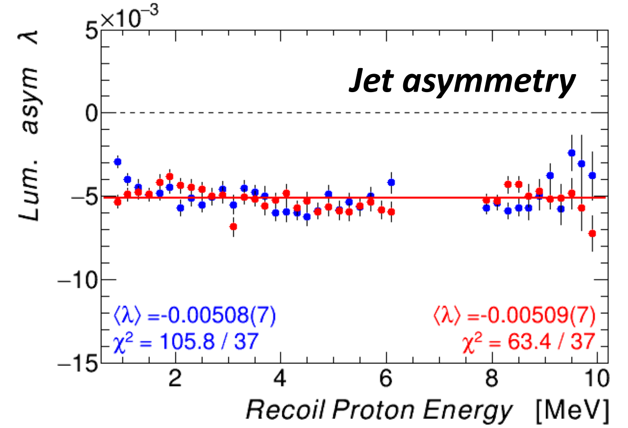
- For recoil proton energy >1.0-1.5 MeV, the measured Jet asymmetry is in a perfect agreement for blue and yellow beams.
- Energy cut may be reduced to ~0.7 MeV if Inner Upper Blue detectors will be excluded from consideration (polarization dependent noise)
- The measured polarization and luminosity asymmetries are recoil proton energy independent.











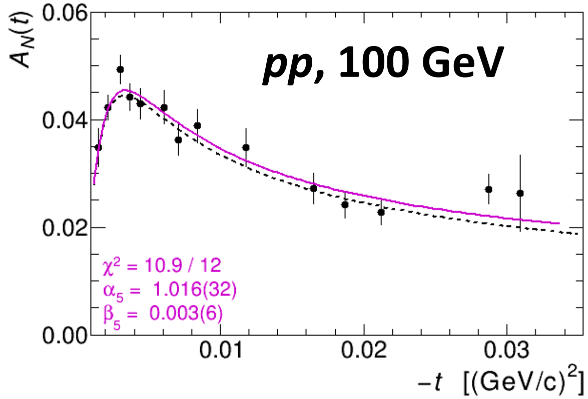
No evidence of possible systematic errors above $\delta P / P \sim 1\%$ (including molecular hydrogen) were found*.

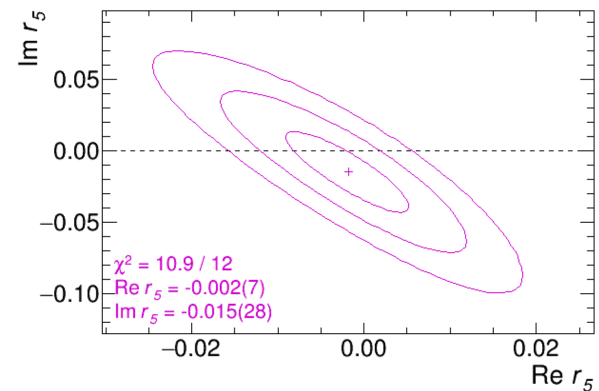
(*Long term stability of molecular hydrogen background was not tested)

Analyzing power

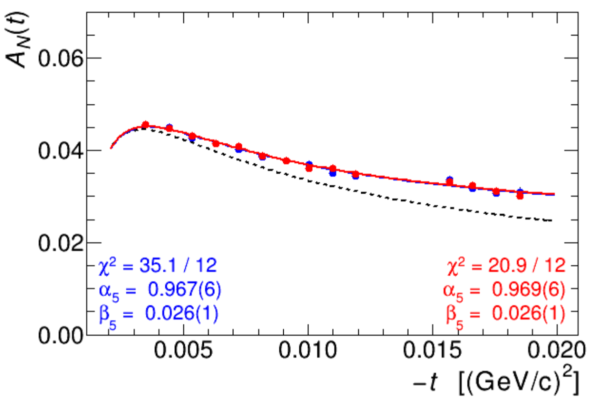
$$A_N(t) = A_N^{\mathrm{QED}}(t)\ \times \alpha_5(1+\beta_5\, t/t_c), \qquad \alpha_5 \sim 1 - \mathrm{Im}\, r_5\,,\ \ \beta_5 \sim -\mathrm{Re}\, r_5\,, \qquad t_c = -8\pi\alpha/\sigma_{tot}^2$$

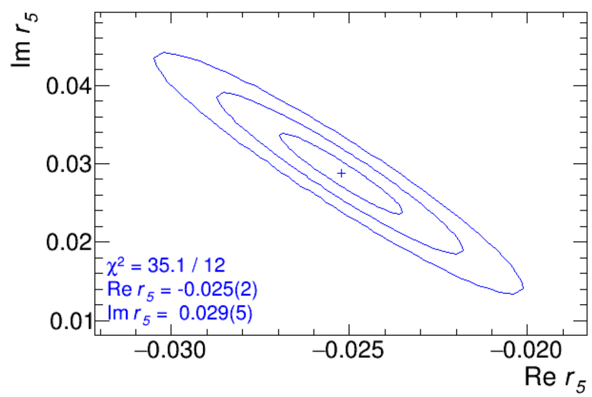
Published HJET results:
Phys. Lett. B638 (2006) 450
$\mathrm{Re}\, r_5 = -0.0008 \pm 0.0091$
$\mathrm{Im}\, r_5 = -0.015 \pm 0.029$
$(\rho = -0.08, \delta_C = 0.02)$

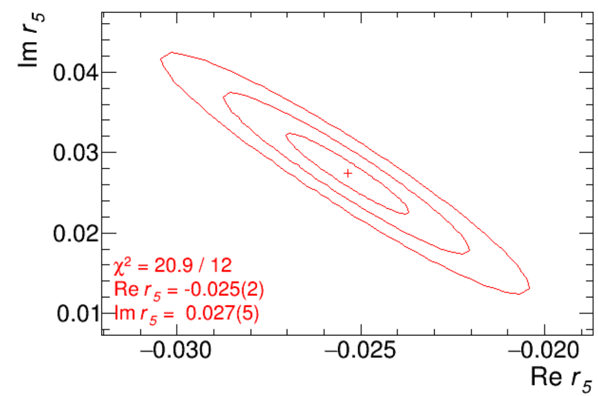




2015 data, preliminary:







Some systematic errors:

$\Delta\, \mathrm{Im}\, r_5 = 0.009\ \ \Delta P_{\mathrm{jet}}/0.01, \quad \Delta\, \mathrm{Re}\, r_5 = -0.001\ \ \Delta P_{\mathrm{jet}}/0.01$

$\Delta\, \mathrm{Im}\, r_5 = 0.008\ \ \Delta\rho\ \ \ /0.01, \quad \Delta\, \mathrm{Re}\, r_5 = -0.001\ \ \Delta\rho\ \ \ /0.01$

There is a significant discrepancy with old (published) data. The issue must be resolved.