News from the TPOL offline fit

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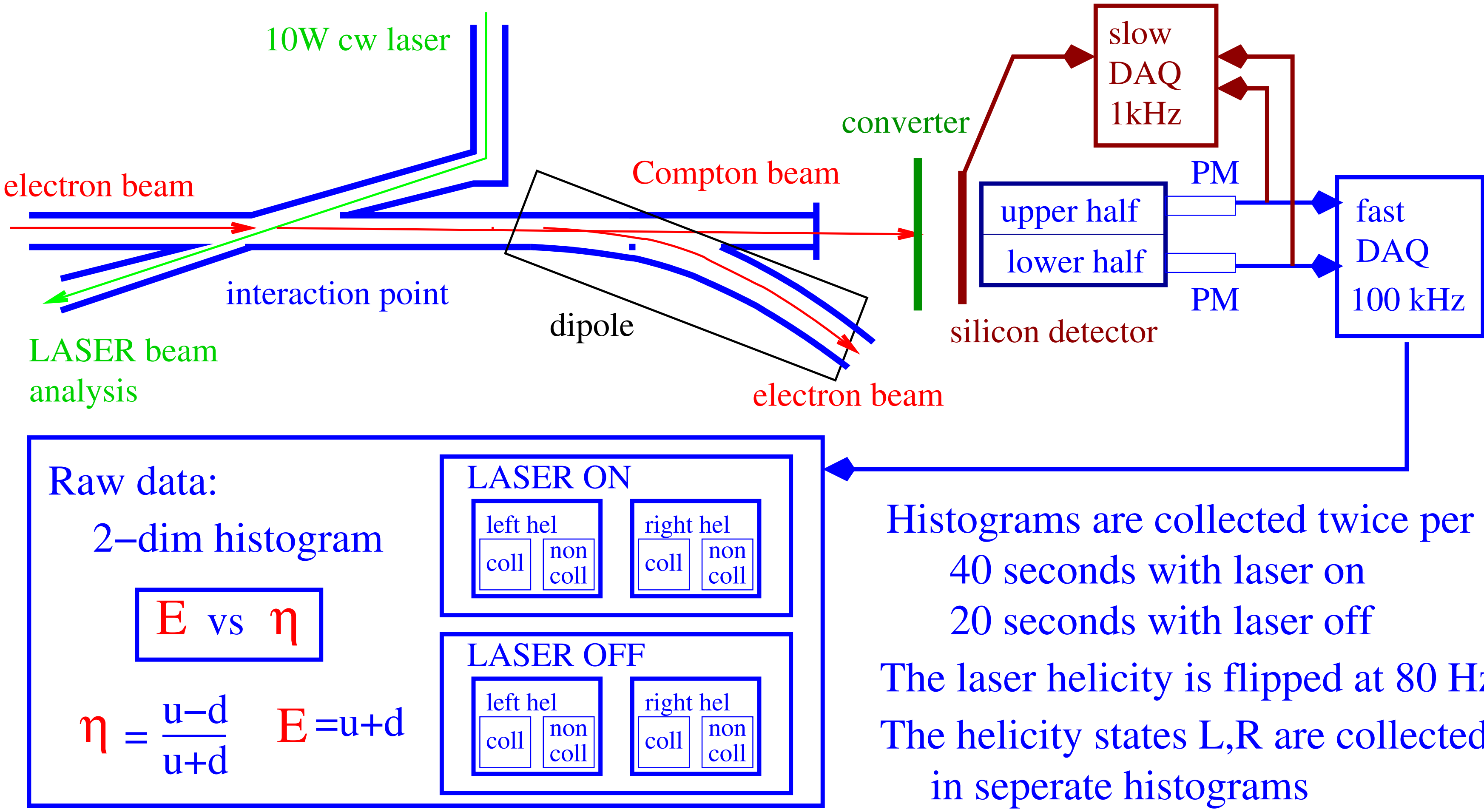
- Offline fit: basic idea
- Lepton beam and TPOL IP
- The calorimeter response function
- Pileup, gain factors, etc
- Numerical evaluation
- First test: HERA I risetime data

The TPOL raw data



Histograms are collected twice per minute
40 seconds with laser on
20 seconds with laser off

The laser helicity is flipped at 80 Hz

The helicity states L,R are collected in seperate histograms

Online Analysis

- Subtract laser-off from laser-on data: pure Compton signal
- Calculate online polarisation $P = \frac{1}{A(f)} \left(\langle\eta\rangle_L - \langle\eta\rangle_R\right)$
- Analyzing power $A(f)$ depends on focus $f \sim \sqrt{\langle\eta^2\rangle}$

Offline fit: basic idea

Basic idea: describe 2-dimensional data histograms $(E,\eta)_{LR}$ by analytical function with many parameters.

Analytical function $\mathcal{F}_{LR}(E,\eta)$: Compton cross-section folded with lepton beam parameters, calorimeter response, pileup, gain factors and pedestals.

Compton cross-section:

$$\mathcal{S}_{L,R}(E_0,\phi) = \frac{d^2\sigma_{L,R}}{dE_0\,d\phi} = \sigma_0(E_0) + S_1^{L,R}\sigma_{1P}(E_0)\cos 2\phi + S_3^{L,R}(P_y\sigma_{2Y}(E_0)\sin\phi + P_z\sigma_{2Z}(E_0))$$

Lepton beam $\mathcal{B}(y,E_0,\phi)$, where $\int dy\,\mathcal{B}(y,\phi) = 1$

Calorimeter Response $\mathcal{C}(E,\eta,E_0,y)$, where $\int dE \int d\eta\,\mathcal{C}(E,\eta,E_0,y) = 1$

Pileup: superposition of two Compton photons in the same calorimeter

Gain factors and pedestals

Determine free parameters from χ^2 fit:

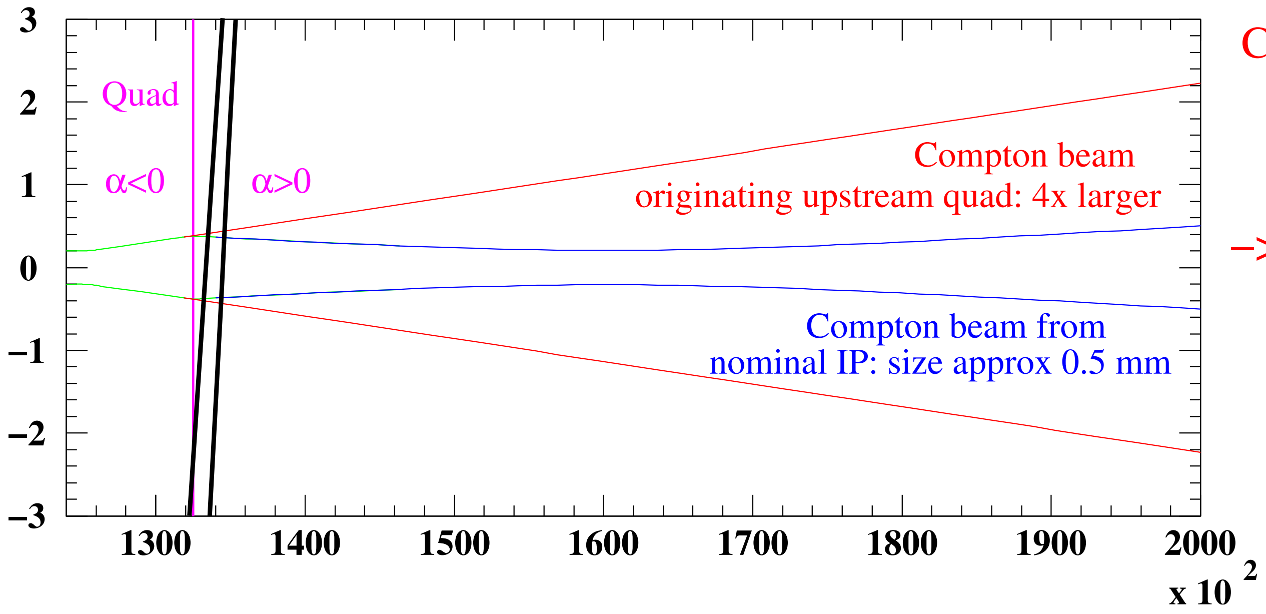
$$\chi^2 = \sum_{i,j,LR} \frac{\left[\mathcal{N}_{LR}\mathcal{F}_{LR}(E_i,\eta_j) - \left(\frac{N^{\mathrm{on}}_{ijLR}}{T_{\mathrm{on},LR}} - \frac{N^{\mathrm{off}}_{ijLR}}{T_{\mathrm{off},LR}}\right)\right]^2}{\frac{N^{\mathrm{on}}_{ijLR}}{T^2_{\mathrm{on},LR}} + \frac{N^{\mathrm{off}}_{ijLR}}{T^2_{\mathrm{off},LR}}}$$

where $\mathcal{F}_{LR}(E,\eta) =$

$$\int dE_0 \int dy\,\mathcal{C}(E,\eta,E_0,y) \int d\phi\,\mathcal{B}(y,E_0,\phi)\mathcal{S}_{LR}(E_0,\phi) \quad + \text{pileup, gain factors, pedestals}$$

Integrals: solve numerically. Minimisation: algorithm similar to MINUIT, but optimized for speed (e.g. analytic derivatives).

Lepton Beam and TPOL IP



Conclusion: Compton beam has contribution from interactions downstream of Quadrupole

-> need double−Gaussian to describe Compton beam at calo

Compton photons travel 65 m towards the calorimeter

Scattering angle is related to the Compton energy $\theta = \theta(E_0)$.

Size of beam is determined by Twiss parameters of the lepton beam,

$$\sigma_y = \sqrt{\epsilon(\beta - 2\alpha D + \gamma D^2)}$$

Nearby Quadrupole → use double-Gaussian.

$$\mathcal{B}(y, E_0, \phi) = \frac{1-f}{\sigma_{y,1}}\mathcal{G}(\frac{y-y_1-D_1\theta(E_0)\sin\phi}{\sigma_{y,1}}) + \frac{f}{\sigma_{y,2}}\mathcal{G}(\frac{y-y_2-D_2\theta(E_0)\sin\phi}{\sigma_{y,2}})$$

Calorimeter response

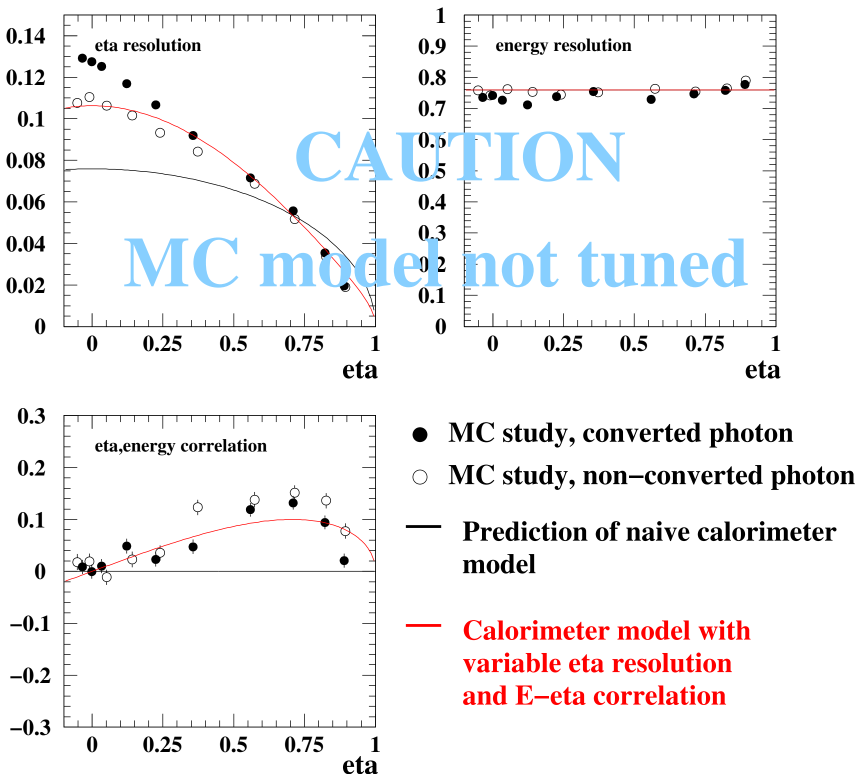
Traditional view: calorimeter consists of two independent halves U,D with equal energy resolution.

Then: $\sigma_E = K\sqrt{E_0}$ and $\sigma_\eta = \frac{K}{\sqrt{E_0}}\sqrt{1-\eta_0(y)^2}$

and the only unknown is K and the transformation $y \rightarrow \eta_0(y)$.

$$\mathcal{C}_{\text{simple}}(E,\eta,E_0,y) = \frac{1}{2\pi K\sqrt{1-\eta_0(y)^2}} \exp\left[-\frac{1}{2}\left(\frac{(E-E_0)^2}{E_0K^2} + \frac{E_0(\eta-\eta_0(y))^2}{K^2(1-\eta_0(y)^2)}\right)\right]$$

But: things are more complicated in reality...



Difference for converted/non-converted photons:

$\mathcal{C}_{\text{calo}}(E,\eta,e_0,y) = (1-f_{\text{conv}})\mathcal{C}_0 + f_{\text{conv}}\mathcal{C}_1$

y-dependent η resolution

$\sigma_\eta \sim \frac{K}{\sqrt{E_0}}\sqrt{1-\eta_0(y)^2}\alpha(\eta_0(y))$

y-dependent correlation term

$$\mathcal{C} \sim \exp[-\frac{1}{2(1-c(\eta_0(y))^2)}(\frac{(E-E_0)^2}{E_0K^2} + \frac{E_0(\eta-\eta_0(y))^2}{K^2(1-\eta_0(y)^2)\alpha(y)^2} + 2\frac{c(\eta_0(y))(E-E_0)(\eta-\eta_0(y))}{K^2\alpha(\eta_0(y))})]$$

U and D resolution may be different for real detector (light collection efficiency)

ηy transformation can be free or fixed from other sources.

Calorimeter response: details

"Sobloher" ηy parametrisation seems to work now, with parameters similar to the silicon analysis: $\eta(y) \sim [\int K_0](y/\lambda)$

η resolution: $\alpha(\eta) = \alpha_0 + \alpha_1 \eta^2$

$\eta - E$ Correlation: $c(\eta) = c\eta\sqrt{1-\eta^2}$

Requires further investigations from MC studies.

Important problem solved recently: correct treatment of correlation term.

Idea: transform from (E_0, y) to independent variables (z, v): $\sigma_z = \sigma_v = 1$ and $c_{vz} = 0$.

$$\int dE_0 \int dy\, \mathcal{C}(E, \eta, E_0, y)[\mathcal{B} \otimes \frac{d^2\sigma}{dE_0\, d\phi}](E_0, y)$$

$$\approx |\frac{\partial(z,v)}{\partial(E,\eta)}| \int dz' \mathcal{G}(z-z') \int dv'\, \mathcal{G}(v-v') |\frac{\partial(E_0,y)}{\partial(z',v')}| [\mathcal{B} \otimes \frac{d^2\sigma}{dE_0\, d\phi}]\,(E_0, y(\eta_0))$$

Choice of (z, v) in not unique. Best results obtained by transforming

$$(E, \eta) \rightarrow (\sqrt{U}, \sqrt{D}) \rightarrow (z, v)$$

$$\sqrt{U} = \sqrt{\frac{E(1+\eta)}{2}}, \quad \sqrt{D} = \sqrt{\frac{E(1-\eta)}{2}}$$

$$z = \frac{\sqrt{E}}{\sqrt{2(1-c_{\mathrm{UD}}(\eta))}} \left(\frac{\sqrt{1+\eta}}{\sigma_{\mathrm{U}}(\eta)} + \frac{\sqrt{1-\eta}}{\sigma_{\mathrm{D}}(\eta)} \right)$$

$$v = \frac{\sqrt{E}}{\sqrt{2(1+c_{\mathrm{UD}}(\eta))}} \left(\frac{\sqrt{1+\eta}}{\sigma_{\mathrm{U}}(\eta)} - \frac{\sqrt{1-\eta}}{\sigma_{\mathrm{D}}(\eta)} \right)$$

Pileup, gain factors, etc

Detector signal for single photon:

$$\mathcal{D}_{1\gamma}(U,D) = |\frac{\partial(E,\eta)}{\partial(U,D)}| \int dE_0 \int dy\, \mathcal{C}(E,\eta,E_0,y) \int\, d\phi\, \mathcal{B}(y,E_0,\phi)\mathcal{S}(E_0,\phi)$$

Pileup: fold detector signal from one photon with itself:

$$\mathcal{D}_{2\gamma}(U,D) = [\mathcal{D}_{1\gamma} \otimes \mathcal{D}_{1\gamma}](U,D) = \frac{1}{\mathcal{N}} \int dU' \int dD'\, \mathcal{D}_{1\gamma}(U-U',D-D')\mathcal{D}_{1\gamma}(U',D')$$

Response including pileup:

$$\mathcal{D}(U,D) = \mathcal{D}_{1\gamma} + f_{\mathrm{pileup}}\mathcal{D}_{2\gamma}$$

Apply gain factors and pedestals:

$$U_{\mathrm{cal}} = f_U U + \delta_U, \quad D_{\mathrm{cal}} = f_D D + \delta_D,$$

Transform to calibrated detector signals

$$\mathcal{F}(E_{\mathrm{cal}},\eta_{\mathrm{cal}}) = |\frac{\partial(U,D)}{\partial(E_{\mathrm{cal}},\eta_{\mathrm{cal}})}|\mathcal{D}(U,D)$$

Summary: numerical evaluation of $\mathcal{F}$

1. calculate cross-section folded with beam shape on aequidistant (z_i, v_j) grid:

   $E_{ij} = E_0(z_i, v_j)$, $y_{ij} = y(z_i, v_j)$

   $(\mathcal{BS})_{ij} = \sum_k \mathcal{S}(E_{ij}, \phi_k)\mathcal{B}(y_{ij}, E_{ij}, \phi_k)\frac{\partial(E_0,y)}{\partial(z_i^0,v_j^0)}\Delta\phi$

2. apply detector response in v:

   $(\mathcal{GBS})_{ij} = \sum_k (\mathcal{BS})_{ik}\mathcal{G}(v_j - v_k^0)\Delta v$

3. apply detector response in z:

   $\mathcal{D}_{1\gamma}^{zv}(z_i, v_j) = \sum_k (\mathcal{GBS})_{kj}\mathcal{G}(z_i - z_k^0)\Delta z$

4. calculate coefficiencts for 2-dim Spline interpolation of $\mathcal{D}_{1\gamma}^{zv}$:

   $\mathcal{D}_{1\gamma}^{zv}(z_i, v_j) \to \mathcal{D}_{1\gamma}^{zv}(z, v)$

5. calculate pileup with reduced grid size (computing time $\mathcal{O}(N^4)$):

   $\mathcal{D}_{ij} = |\frac{\partial(z,v)}{\partial(U_i,D_j)}|\mathcal{D}_{1\gamma}^{zv}(z(U_i, D_j), v(U_i, D_j))$

   $\mathcal{D}_{2\gamma}^{UD}(U_i, D_j) = \sum_{k,l} \mathcal{D}_{k,l}\mathcal{D}_{i-k,j-l}$

6. calculate coefficients for 2-dim Spline interpolation of $\mathcal{D}_{2\gamma}^{UD}$:

   $\mathcal{D}_{2\gamma}^{UD}(U_i, D_j) \to \mathcal{D}_{2\gamma}^{UD}(U, D)$

7. Calculate detector response including gain and pedestal:

   $\mathcal{F}(E_i, \eta_j) = |\frac{\partial(z,v)}{\partial(E_i,\eta_j)}|\mathcal{D}_{1\gamma}^{zv}(z(E_i, \eta_j), v(E_i, \eta_j)) + f_{\text{pileup}}|\frac{\partial(U,D)}{\partial(E_i,\eta_j)}|\mathcal{D}_{2\gamma}^{UD}(U(E_i, \eta_j), D(E_i, \eta_j))$

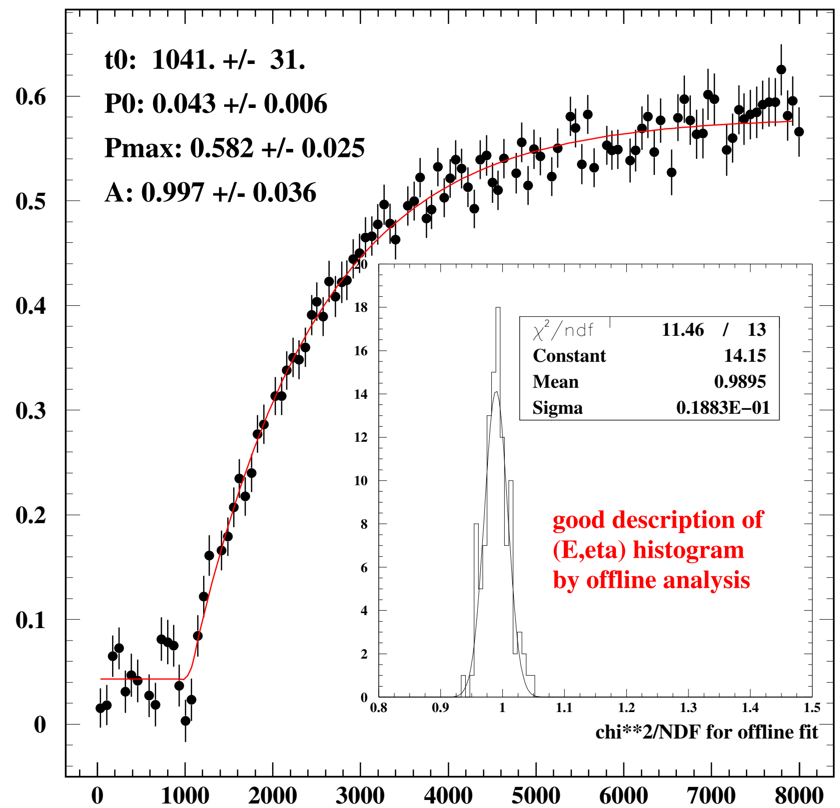
First results: HERA I risetime data

Risetime measurements: time-constant is connected to maximum polarisation

$$P(t) = \begin{cases} A \times P_0 & \text{if } t \leq t_0 \\ A \times P_{\max} \left(1 - \left(1 - \frac{P_0}{P_{\max}}\right) \exp\left[-\frac{(t-t_0)P_{ST}}{\tau_{ST} P_{\max}}\right]\right) & \text{if } t > t_0 \end{cases}$$

Prediction from theory (+1 spin rotator): $P_{ST} = 0.891$, $\tau_{ST} = 2161.5\,\text{s}$, $A = 1$

4-Parameter fit of $[t_0, P_0, P_{\max}, A]$.



Problem: only 10 risetime curves available.

Statistical precision on A of order 3% per curve. Average:

HERMES revisited: $\langle A \rangle = 1.026 \pm 0.006$, $\frac{\chi^2}{N_{DF}} = \frac{1.06}{9}$

This analysis: $\langle A \rangle = 0.991 \pm 0.014$, $\frac{\chi^2}{N_{DF}} = \frac{13.4}{9}$

Suggestion: take 1–2 weeks of risetime curves for polarimeter calibration with flat machine (spin-rotators and H1/ZEUS magnets off) instead of TeV run.

Summary/Outlook

- TPOL offline analysis is not yet final, but well advanced
- Key point is understanding the calorimeter response function $\mathcal{C}(E, \eta, E_0, y)$ Recent progress looks very promising.
- Measuring new risetime curves with HERA II conditions could help significantly in understanding the polarimeters
- Next steps:
  - Finalize functional form of $\mathcal{C}(E, \eta, E_0, y)$: Monte Carlo studies
  - Decide which parameters to take from MC and/or silicon analysis
  - Process "small" amount of data, approx 3 months, where LPOL and/or Cavity are available

    Fitting one minute of data takes several minutes of CPU time! Load H1/ZEUS batch queues?
  - Analysis of LPOL/TPOL(onl/offl) ratio, correlation to operational parameters (mirror position, etc)
- Finally: publish as NIM paper?