Monte Carlo generators for two-hadron analyses, what are the special needs?

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TMD Monte Carlo workshop 2011
7-8 November 2011, INFN-LNF, Frascati, Italy

Outlook

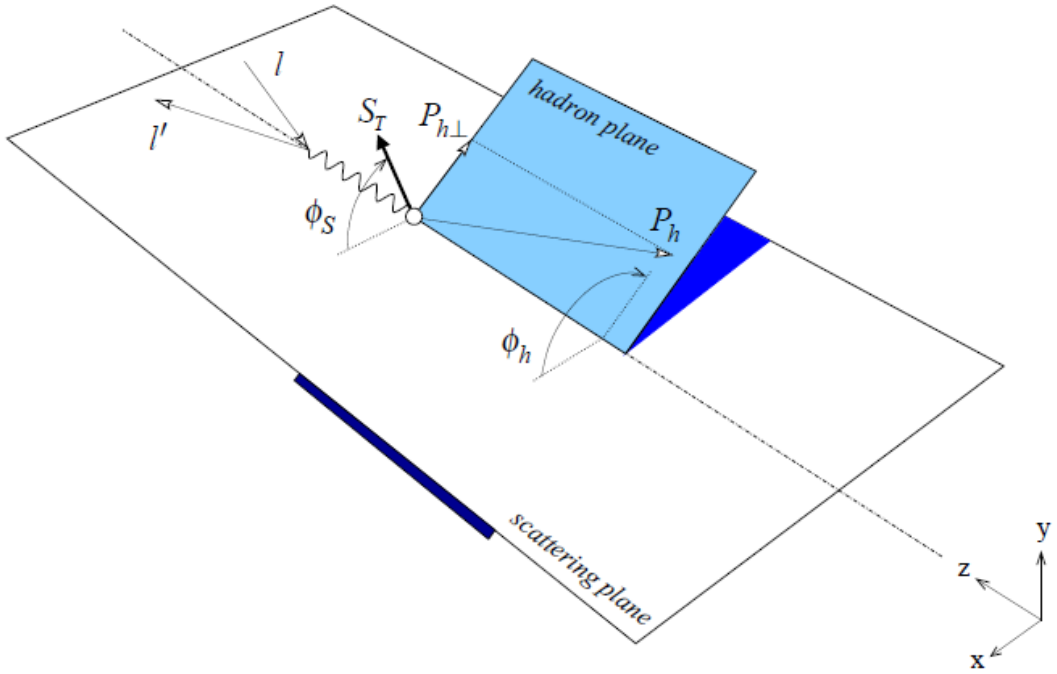
- single- vs. di-hadron case
- single-hadron kinematics
- di-hadron kinematics
  - exemple distributions
- analysis examples
- clasDIS Monte Carlo
  - data x MC comparison of full reconstructed events
- summary

single- vs. di-hadron case

What changes in the di-hadron case?

- new angles are defined;
- the cross section expression is more complex;
- acceptance corrections are more complicated.

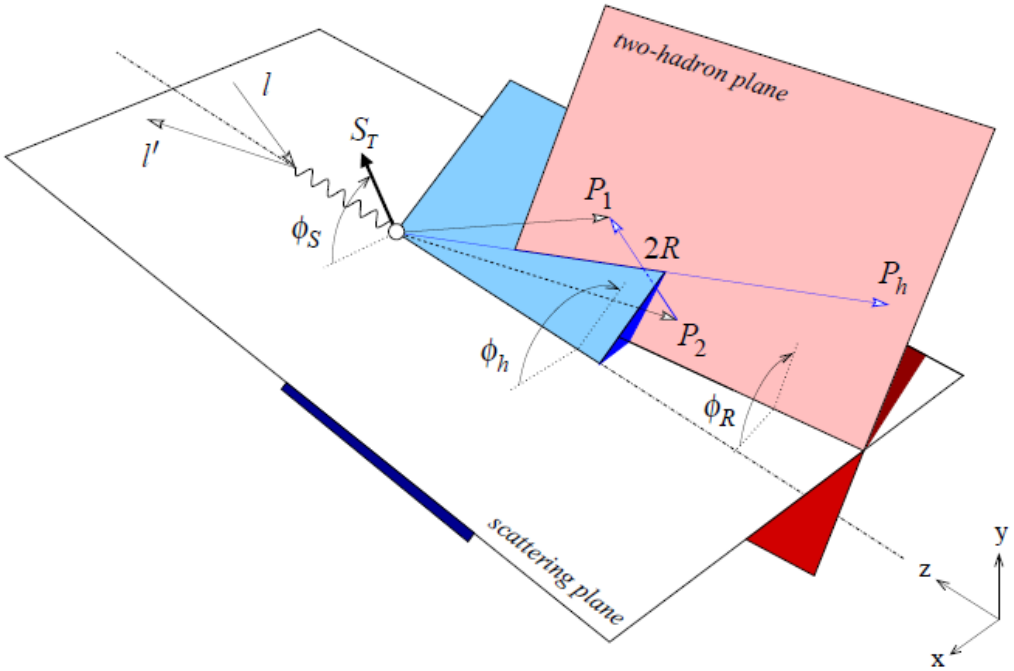
single-hadron kinematics



$$
\begin{aligned}
\nu &= \frac{q \cdot P}{M} = E - E', \\
Q^2 &= -q^2 \approx 4EE' \sin^2(\theta_{e2}/2), \\
W^2 &= (P+q)^2 = M^2 + 2M\nu - Q^2, \\
x &= \frac{Q^2}{2M\nu}, \\
y &= \frac{k \cdot P}{q \cdot P} = \frac{\nu}{E}, \\
z &= \frac{E_h}{\nu},
\end{aligned}
$$

The kinematic SIDIS variables generally used in the cross section are M_h, z *and* $P_{h\perp}$.

di-hadron kinematics

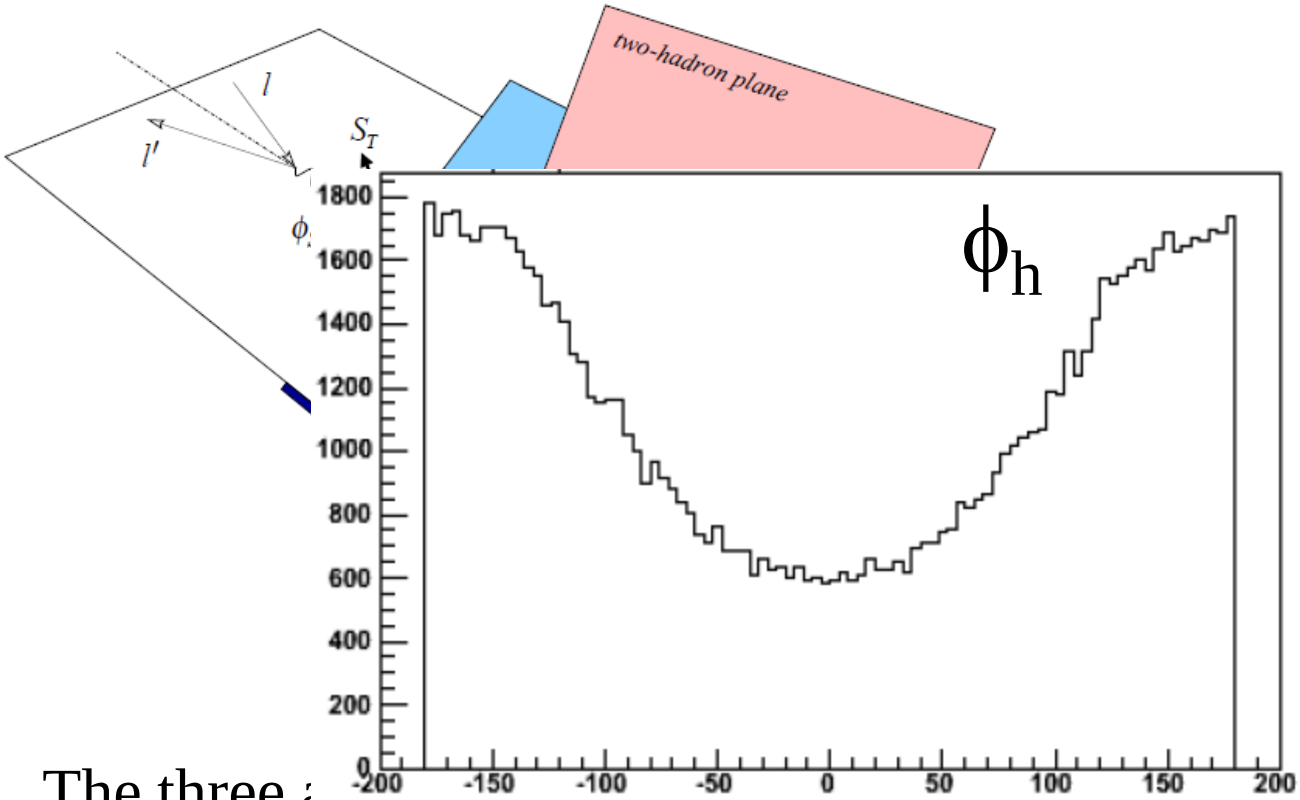


$$P_h = P_1 + P_2$$

$$R = (P_1 - P_2)/2$$

The three additional variables are: the invariant mass of the di-hadron system, M_{hh}, $\cos\theta$ *and* ϕ_R.

di-hadron kinematics



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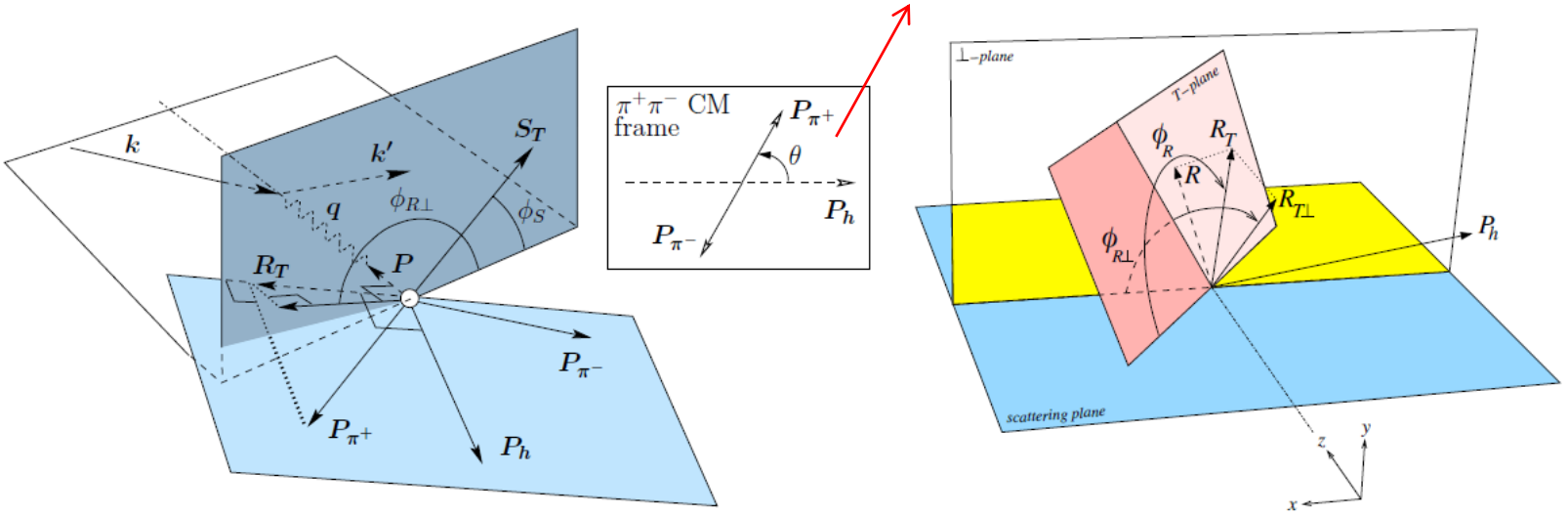
The three additional variables are: the invariant mass of the di-hadron system, M_{hh}, $\cos\theta$ and ϕ_R.

di-hadron kinematics

the angle between the direction of P1 in the $\pi+$ $\pi-$ center-of-mass frame, and the direction of P_h in the photon-target rest frame.



$$\phi_R = \frac{\boldsymbol{q}\times\boldsymbol{k}\cdot\boldsymbol{R}_T}{|\boldsymbol{q}\times\boldsymbol{k}\cdot\boldsymbol{R}_T|}\cos^{-1}\frac{\boldsymbol{q}\times\boldsymbol{k}\cdot\boldsymbol{q}\times\boldsymbol{R}_T}{|\boldsymbol{q}\times\boldsymbol{k}||\boldsymbol{q}\times\boldsymbol{R}_T|}$$

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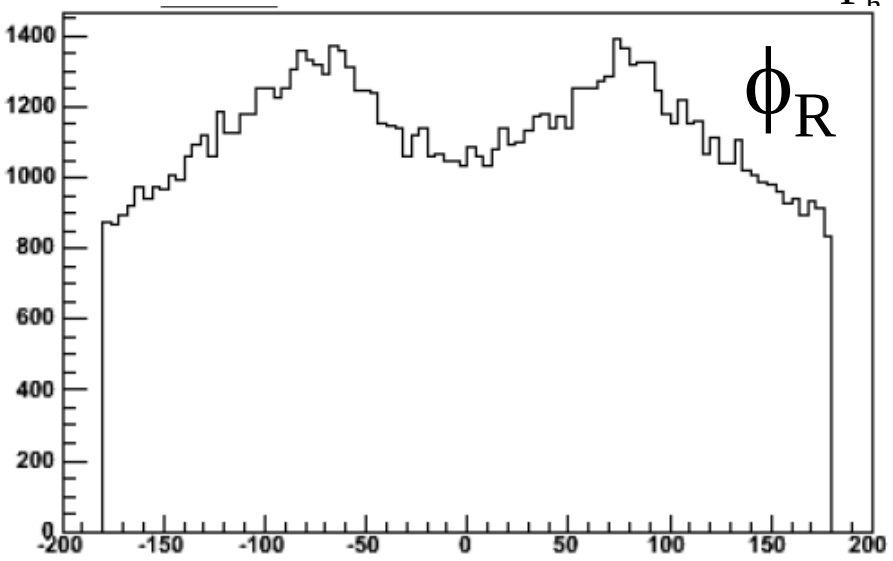

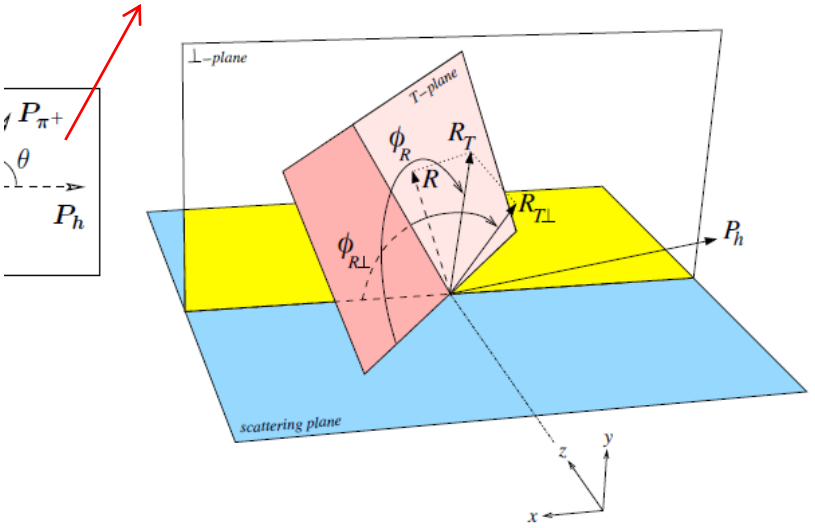

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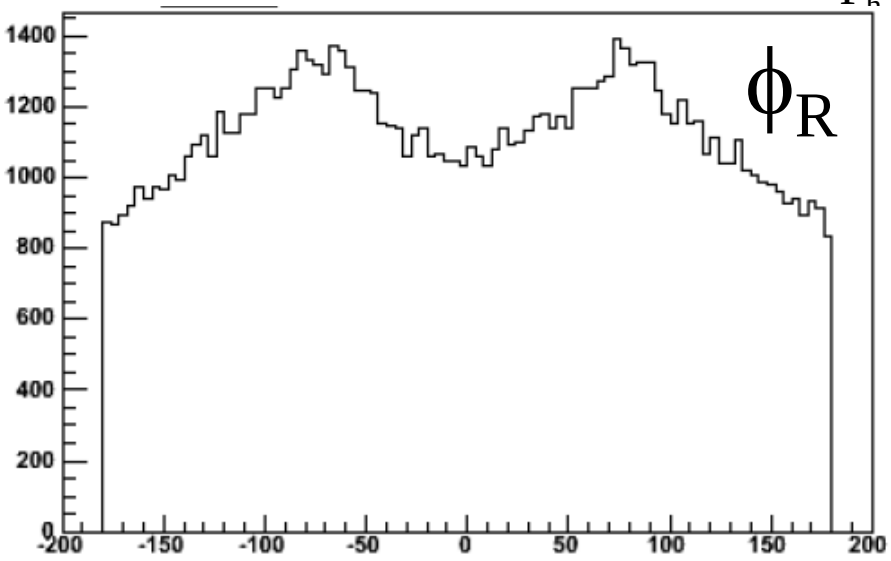

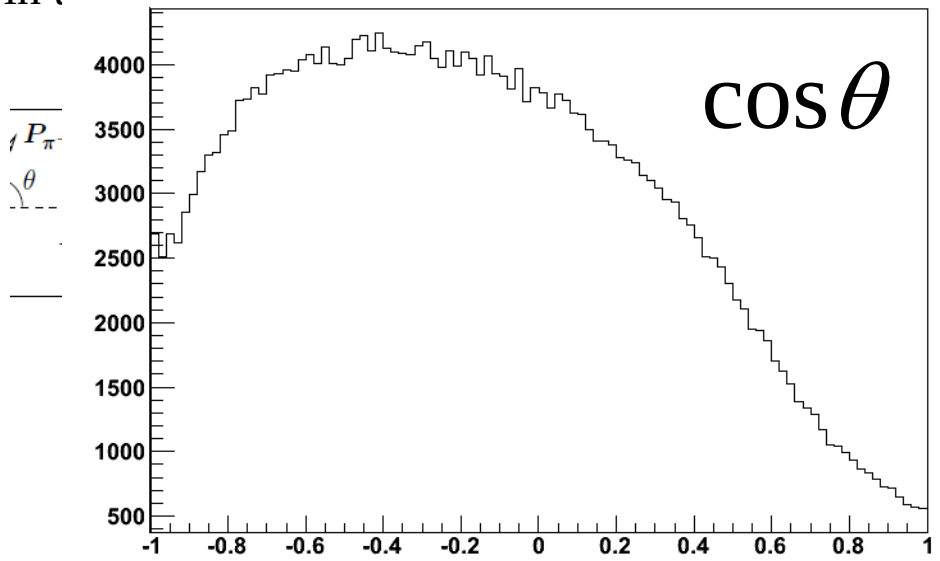

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TMDGen event generator

- No previous Monte Carlo generator has TMD dihadron production with full angular dependence
- Method
  - Integrates cross section per flavor to determine "quark branching ratios"
  - Throw a flavor type according to ratios
  - Throw kinematic/angular variables by evaluating cross section
    - Can use weights or acceptance rejection
  - Full TMD simulation: each event has specific $|\boldsymbol{p}_T|$, ϕ_p, $|\boldsymbol{k}_T|$, ϕ_k values
  - Includes both pseudo-scalar and dihadron SIDIS cross sections
- Guiding plans
  - Extreme flexibility
    - Allow many models for fragmentation and distribution functions
    - Various final states: pseudo-scalars, vector mesons, hadron pairs, etc.
    - Output options & connecting to analysis chains of various experiments
    - Minimize dependencies on other libraries
  - Full flavor and transverse momentum dependence.
- Current C++ package considered stable and allows further expansion
- Can be useful for both experimentalists and theorists.

took from S. Gliske presentation at DiFF2011

TMDGen event generator

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This generator was used for **acceptance systematic studies** (generating data according to the SIDIS di-hadron cross section with the full angular dependence).
http://wwwhermes.desy.de/notes/pub/11-LIB/sgliske.11-003.thesis.pdf

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Paul B. Van der Nat used a different approach to estimate **acceptance effects**. Since the fully differential asymmetry for two-hadron SIDIS scattering depends on 9 kinematic variables (x, y, z, $M_{\pi\pi}$, $P_{h\perp}$, ϕ_R, ϕ_S , ϕ_h *and* θ) it was not possible to determine the amplitudes A_{UT} in all of them, it was introduced a model for A_{UT} into an unpolarized Pythia Monte-Carlo simulation.
http://www.nikhef.nl/pub/services/biblio/theses_pdf/thesis_PB_van_der_Nat.pdf

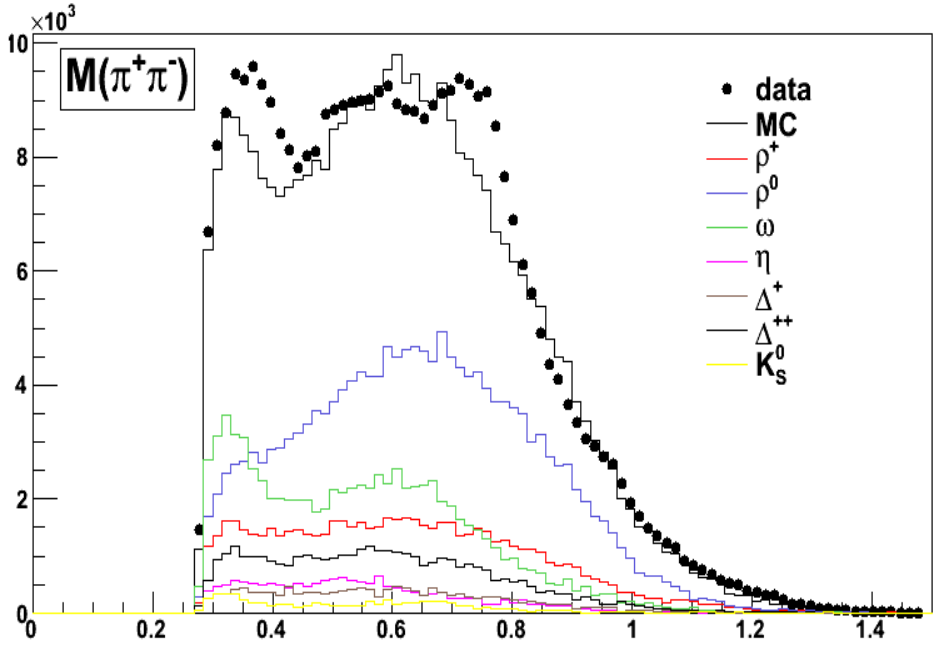
clasDIS event generator

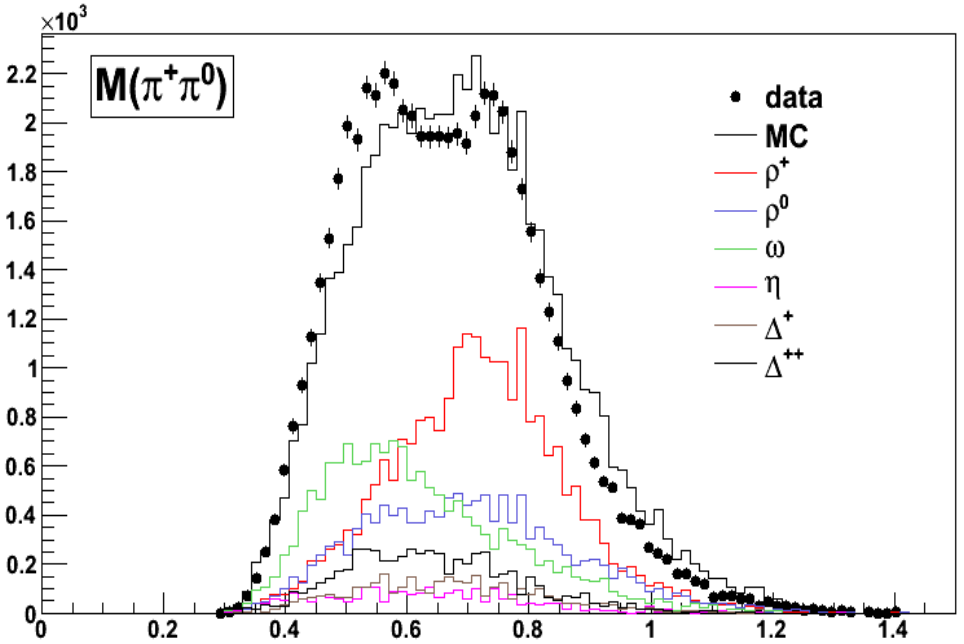
- A simple interface to a polarized target LUND-MC pachage:
  - ❑ **PEPSI (Polarized Electron-Proton Scattering Interactions) or**
  - ❑ **LEPTO (Deep inelastic lepton-nucleon scattering)**
- Detector smearing
- Target magnet effect and fiducial cuts

- The PEPSI /LEPTO generator is used to create large data sets including all hadronic final states produced in Deep Inelastic Scattering (DIS)

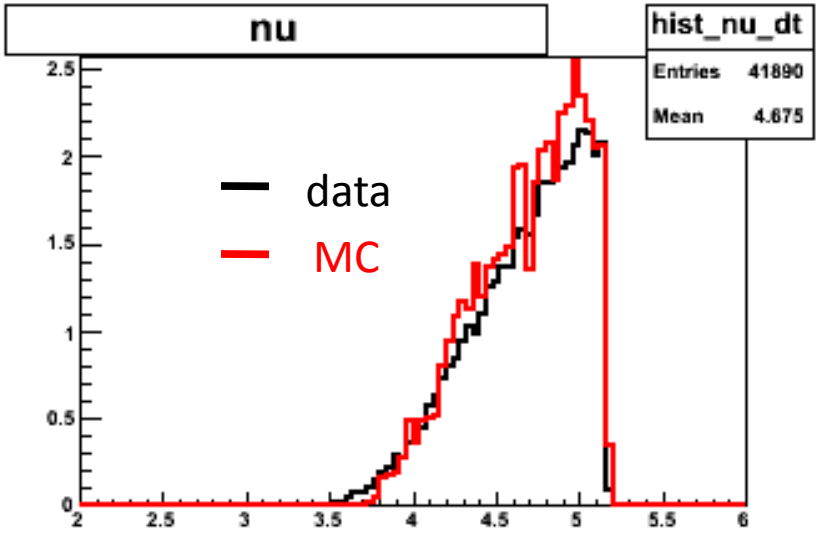
Data x MC comparison

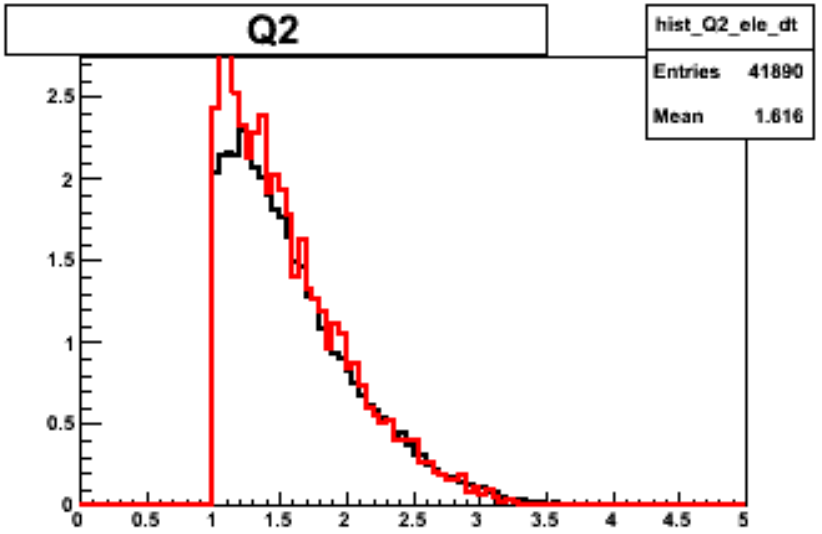
(CLAS data x full CLAS MC)

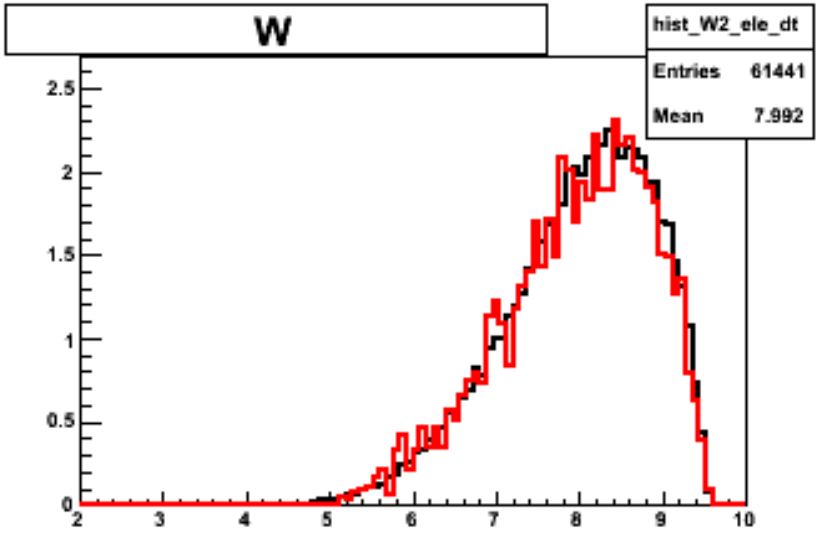


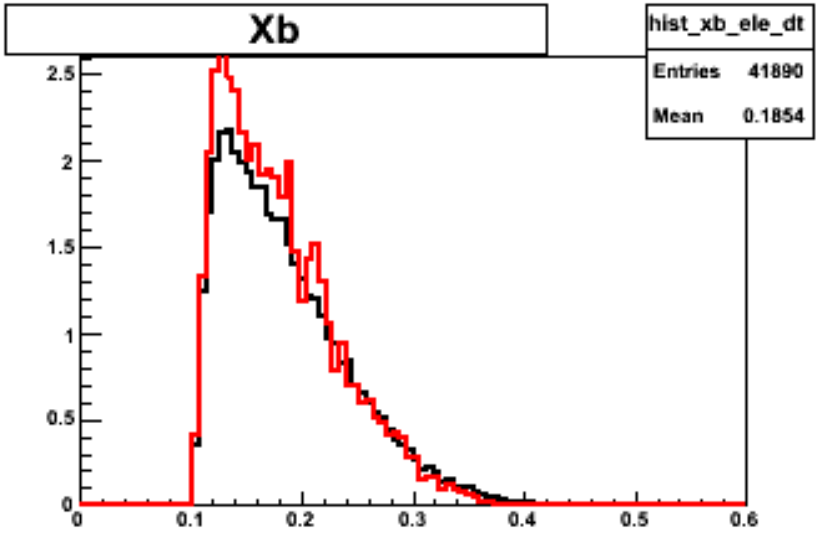


Data x MC comparison - π^+ π^- pairs



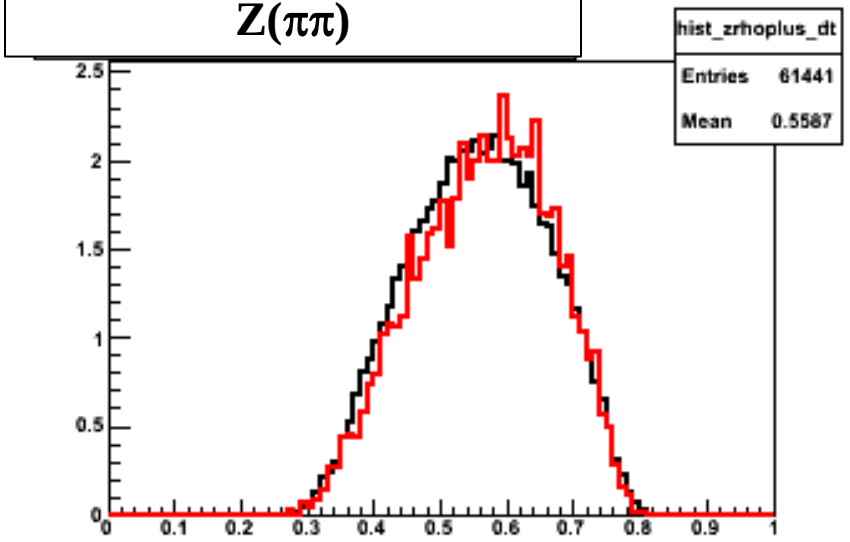




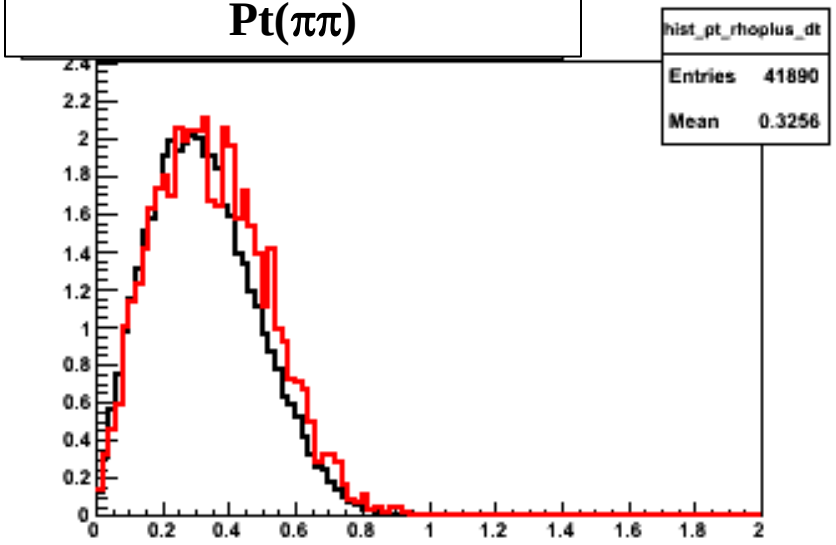


Data x MC comparison - $\pi^+ \pi^-$ pairs

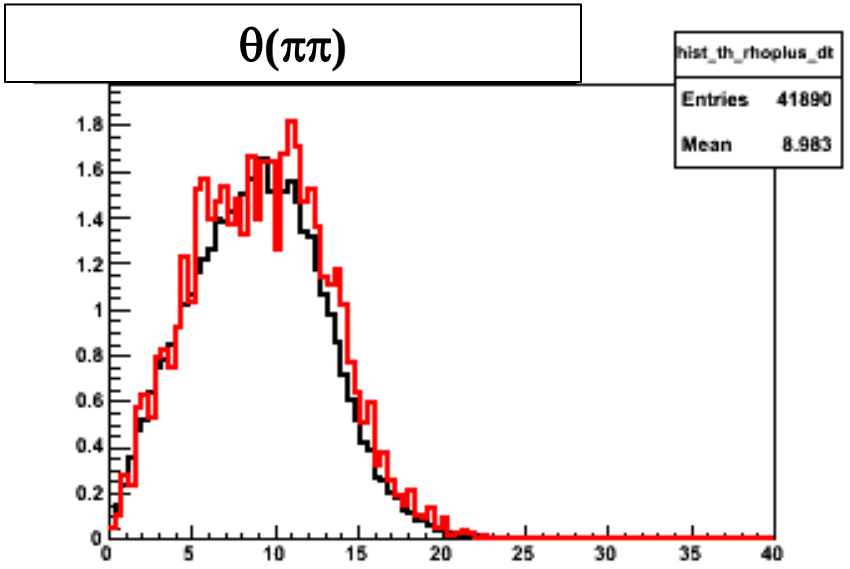
Z(ππ)



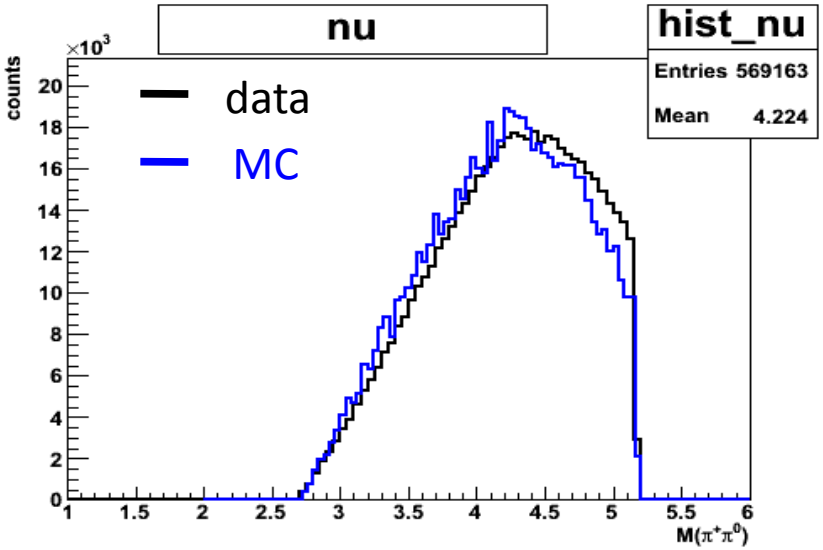
Pt(ππ)

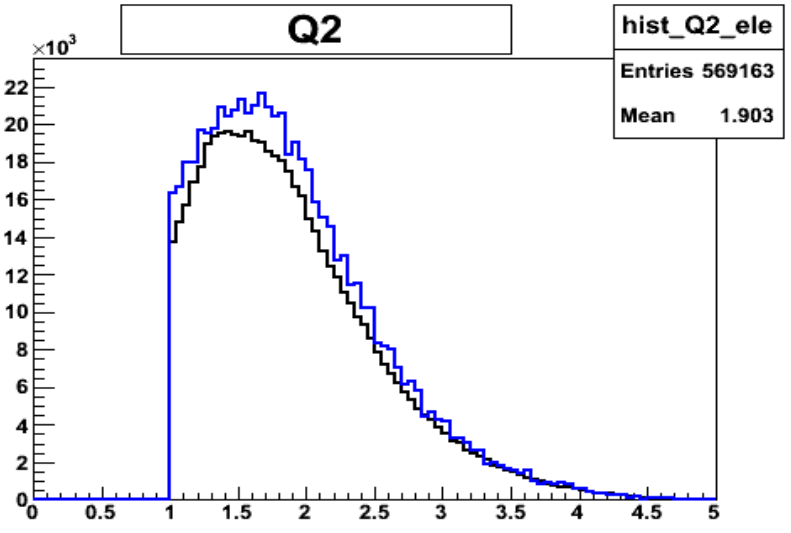


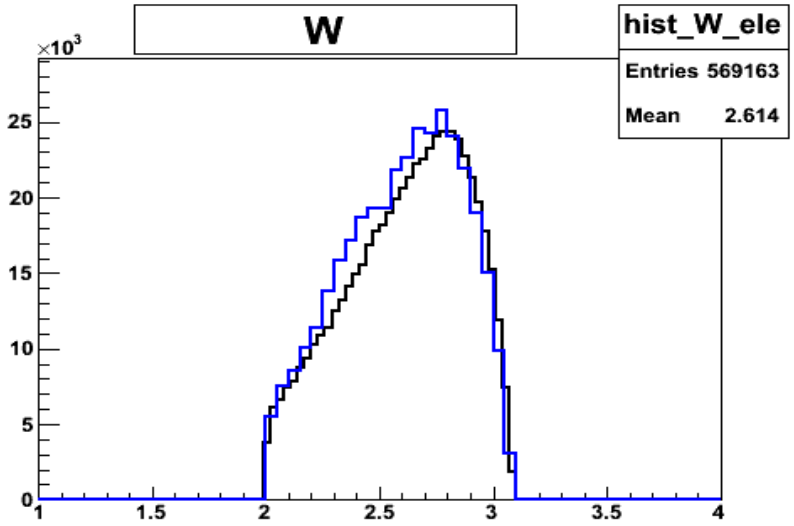
θ(ππ)

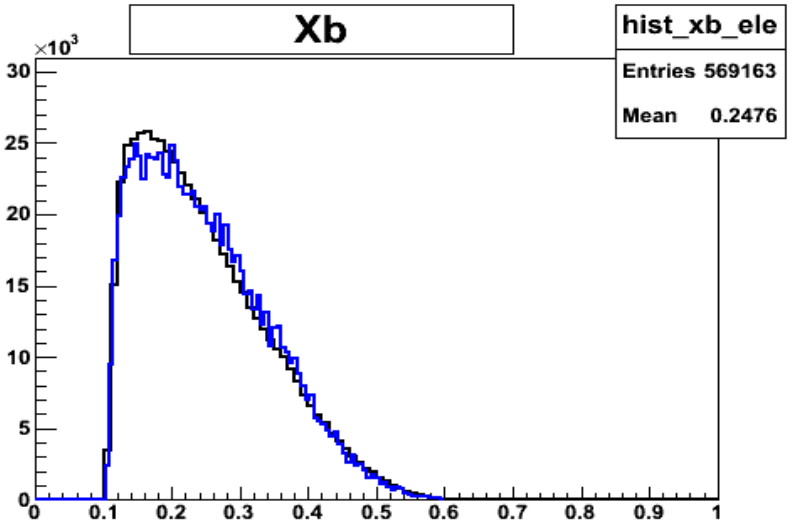


Data x MC comparison - $\pi^+ \pi^0$ pairs









Data x MC comparison - $\pi^+ \pi^0$ pairs

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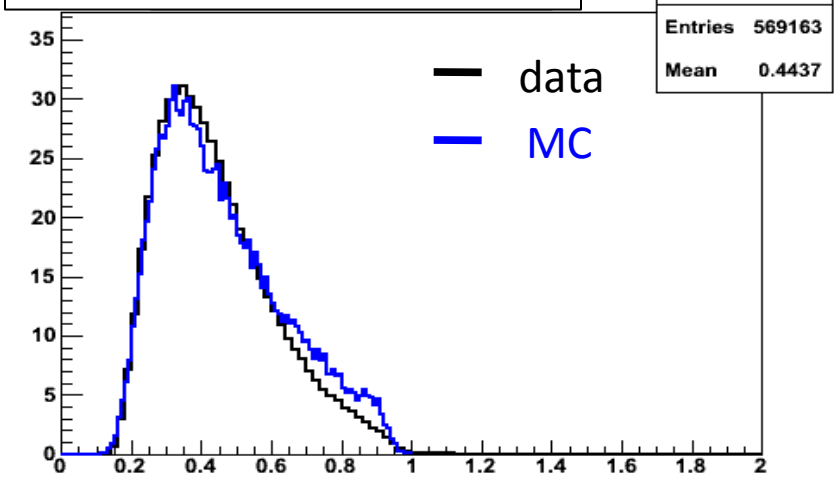
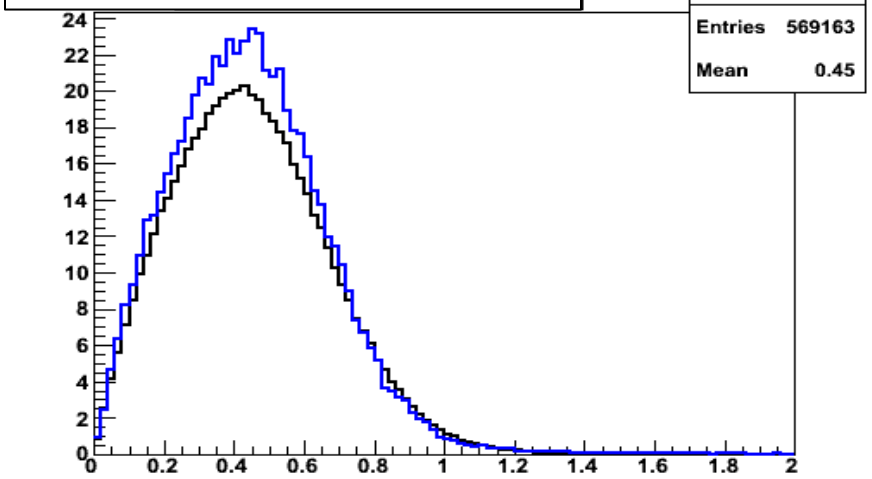
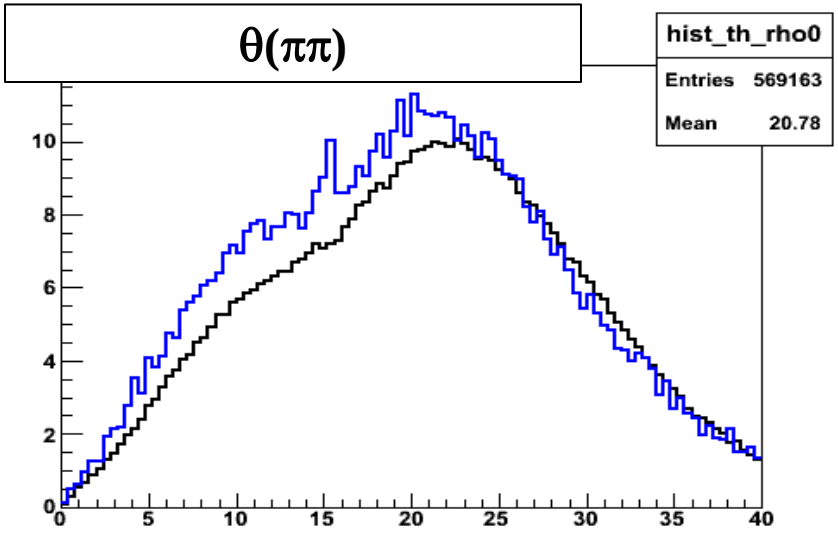


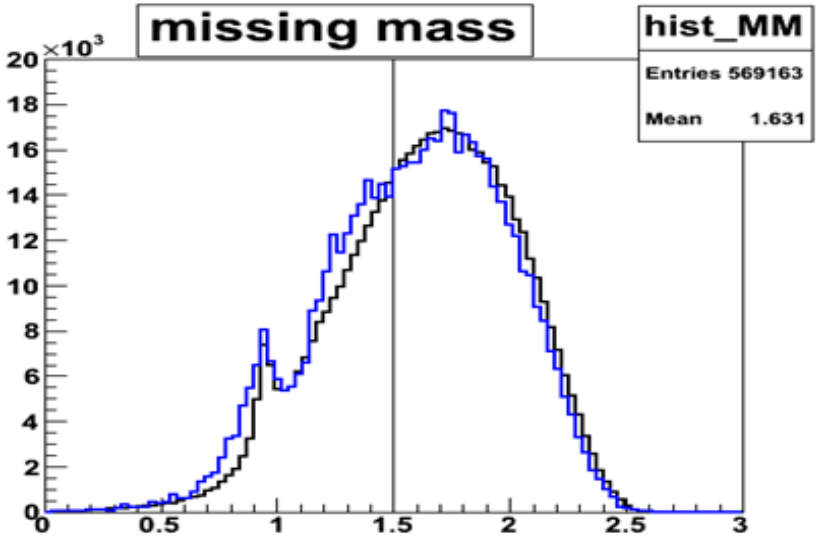
Pt(ππ)



θ(ππ)



missing mass



Summary

- No particular need has been found for a di-hadron event generator MC;
- Present CLAS Monte Carlo reproduces reasonable well the data;
- (**for all cases**) For acceptance calculations is a “polarized” MC needed?
  - at event generator level?
  - a post-generation dependence?