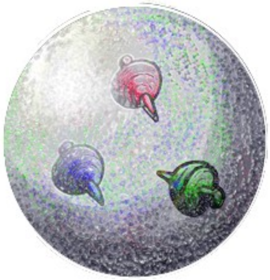
Hadron production from μ-d scattering at $\sqrt{s}$ =17GeV at Compass

$\mu^+ d \longrightarrow \mu^+ h^\pm X$

Astrid Morréale. Hadron Structure 2011 27 June 2011

The QCD Proton Picture



That nucleon has a large anomalous magnetic moment proves that this is not ***fundamental*** spin1/2 Dirac particle.

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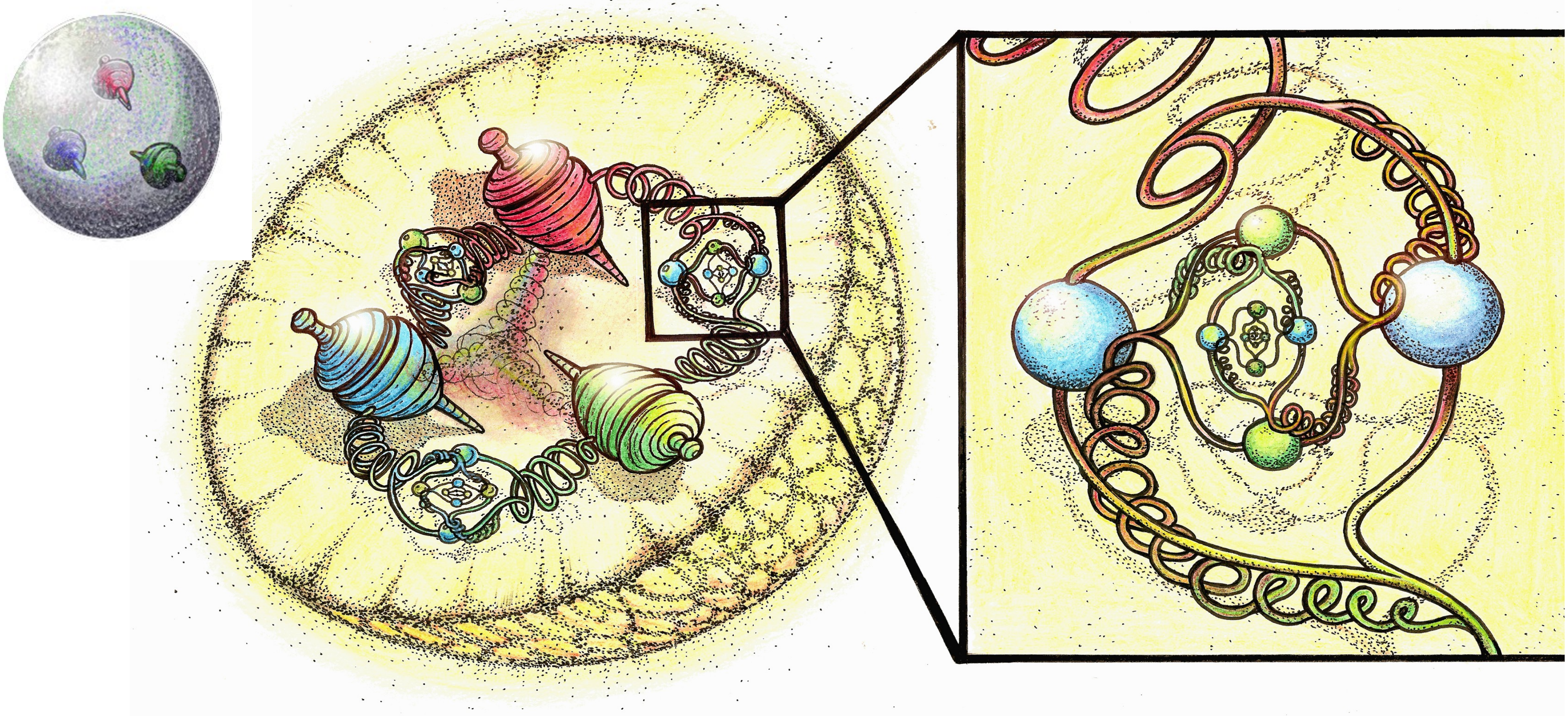

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Nucleon Spin is Subtle: Quarks, gluons and their angular momentum caused by their high speed motion within the nucleon are contributors to the Nucleon's spin.

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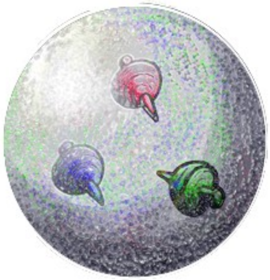

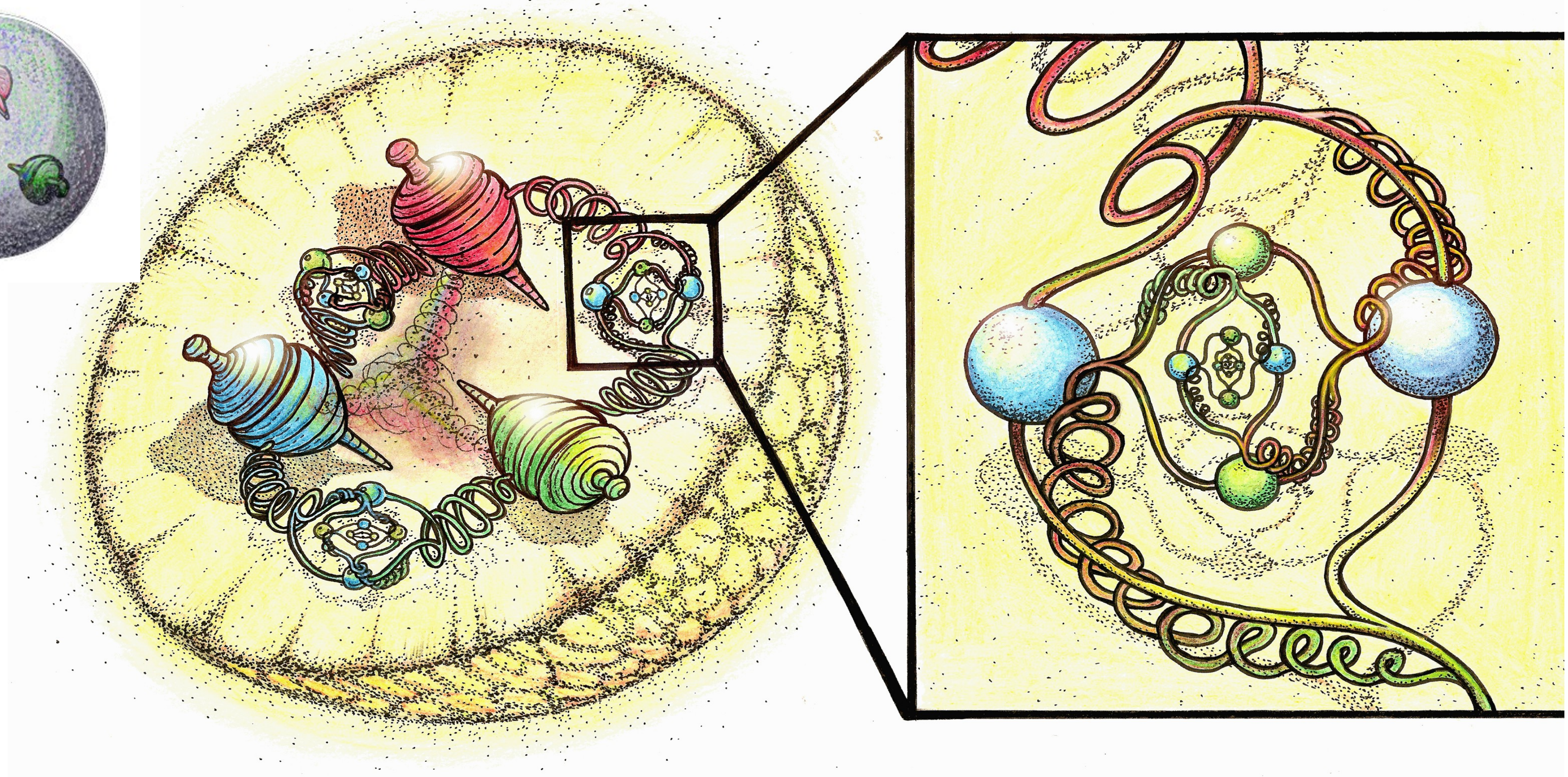

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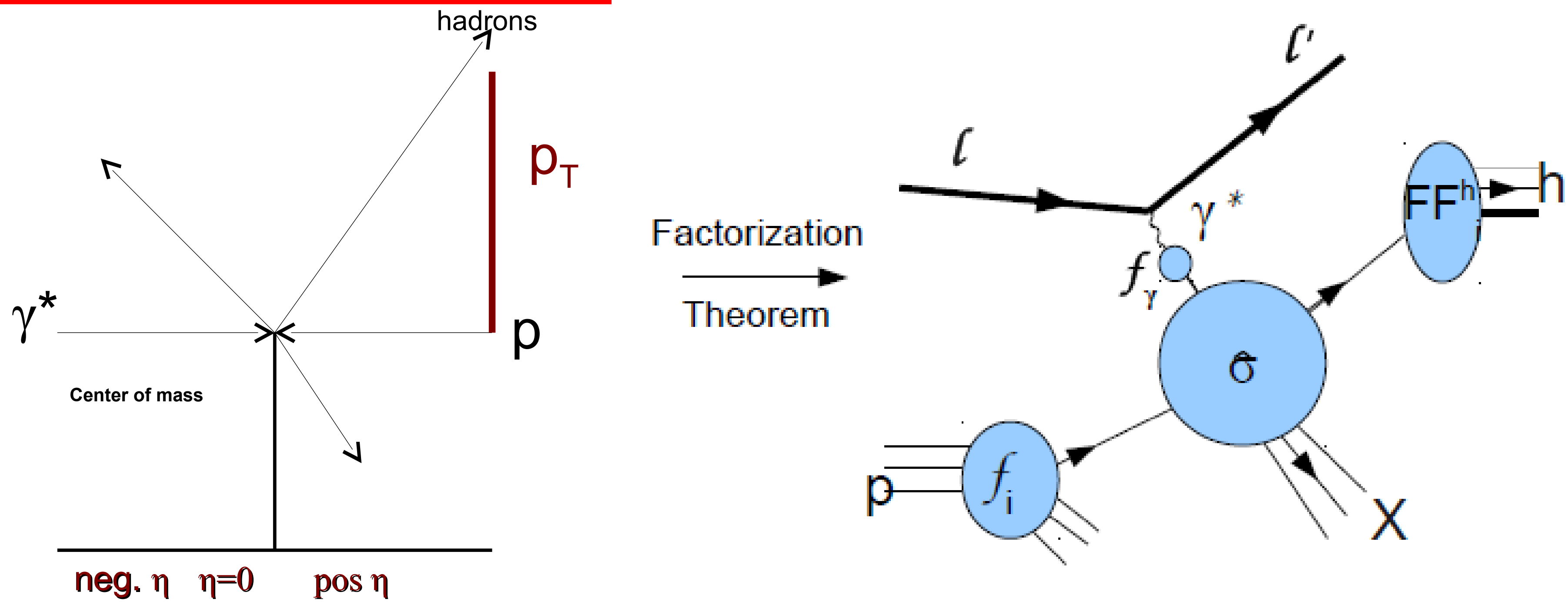
Nucleon Spin is Subtle: Quarks, gluons and their angular momentum caused by their high speed motion within the nucleon are contributors to the Nucleon's spin.

Spin physics has open a box full of questions about matter, and it has also laid the groundwork to a plethora of scientific advancements: from the medical field, to astronomy research.

How can we access polarized parton information?



$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{\sum\limits_{i=\mathrm{q},\bar{\mathrm{q}},\mathrm{g}} \Delta f_\gamma \otimes \Delta f_i \otimes \Delta\hat{\sigma} \otimes FF_{h/i}}{\sum\limits_{i=\mathrm{q},\bar{\mathrm{q}},\mathrm{g}} f_\gamma \otimes f_i \otimes \hat{\sigma} \otimes FF_{h/i}}$$

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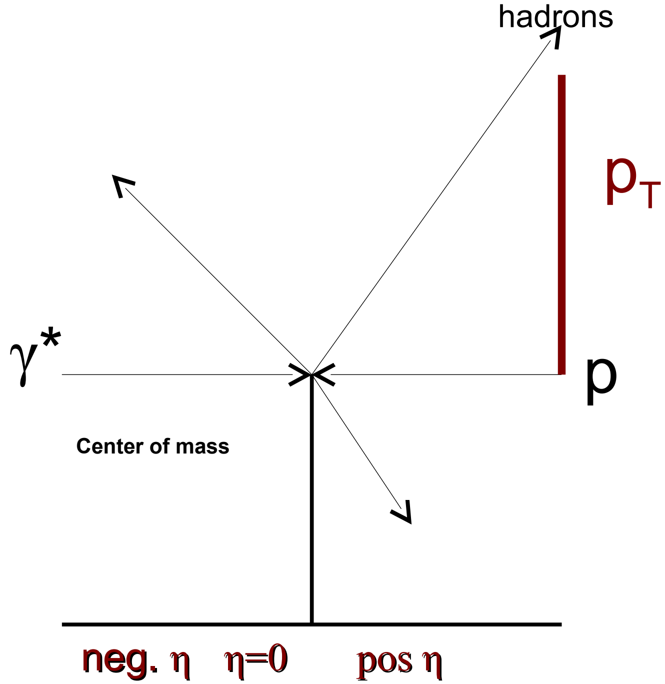

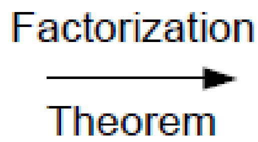

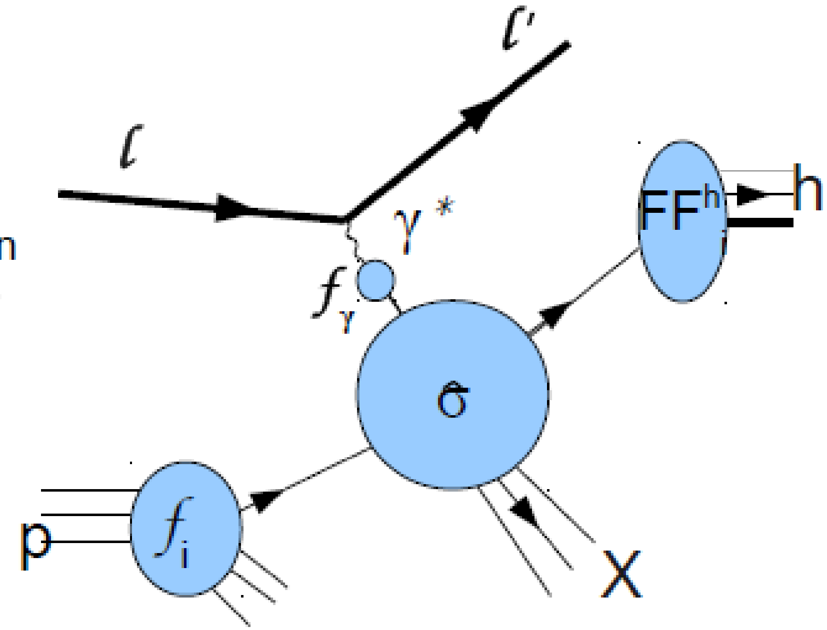

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↓

$$A_{LL} = \frac{1}{\mathcal{F} P_{beam} P_{target}} \frac{N_{++} - N_{+-}}{N_{++} + N_{+-}}$$

(N) Number of events
(F) Dilution Factor
(P) Polarization in beam or target

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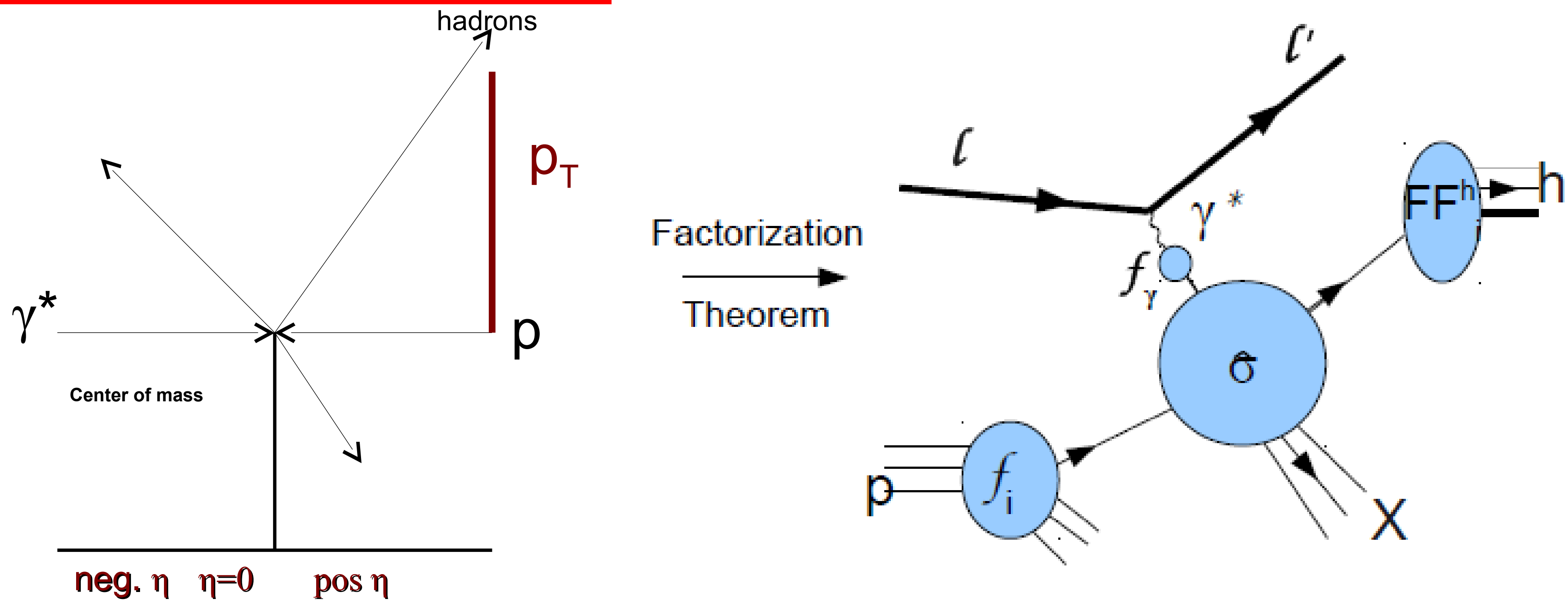

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Spin Asymmetries give us access to polarized parton distribution functions

What motivates the Measurement of an Unpolarized Cross-section?

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{\sum\limits_{i=\mathrm{q},\bar{\mathrm{q}},\mathrm{g}} \Delta f_\gamma \otimes \Delta f_i \otimes \Delta\hat{\sigma} \otimes FF_{h/i}}{\sum\limits_{i=\mathrm{q},\bar{\mathrm{q}},\mathrm{g}} f_\gamma \otimes f_i \otimes \hat{\sigma} \otimes FF_{h/i}}$$

1. Measure the unpolarized differential Cross Section to confirm that the pQCD framework is applicable to data.

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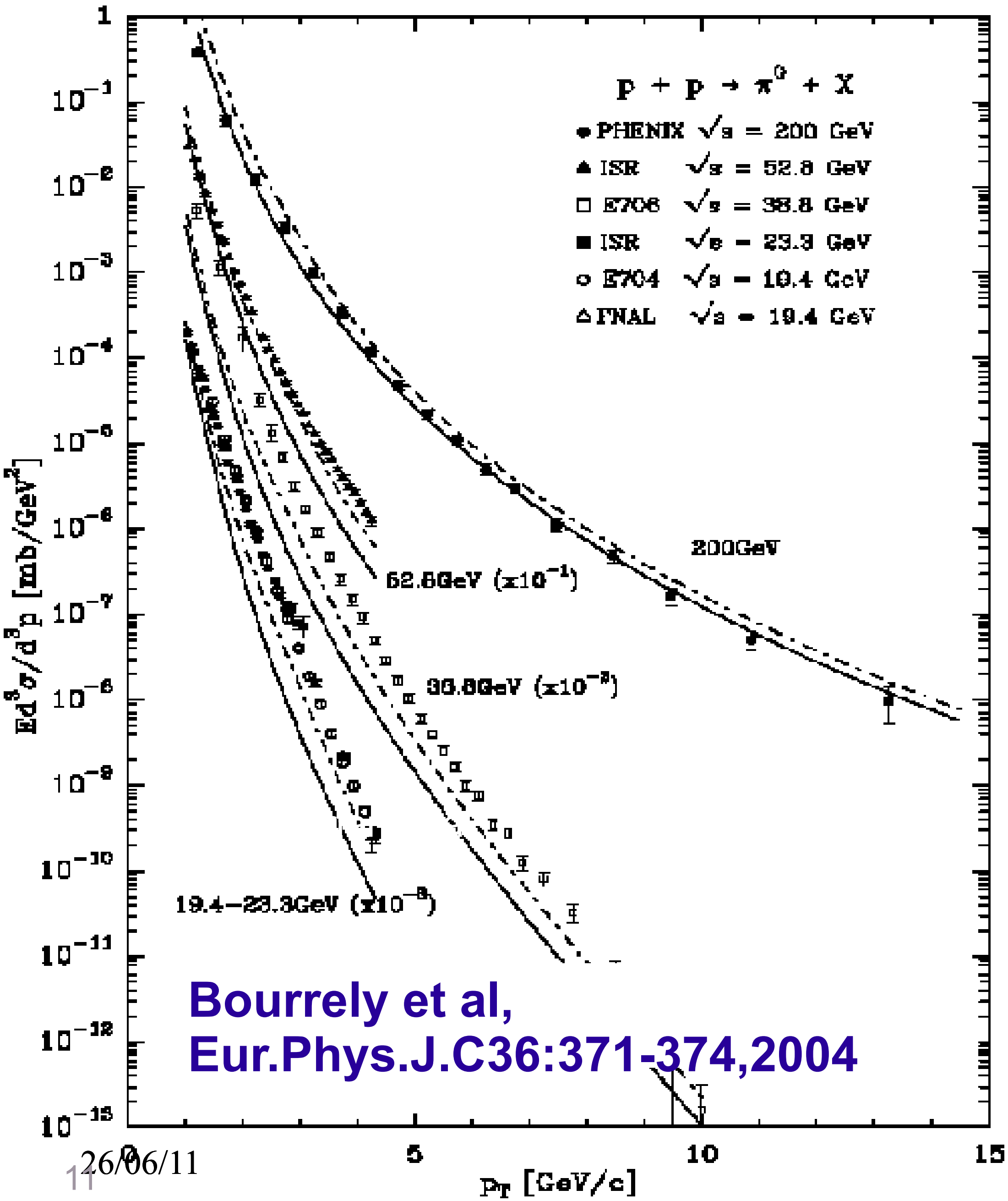
→ **The pQCD unpolarized cross section**

Pion Cross-Sections compared to pQCD: The p+p case



Bourrely et al,
Eur.Phys.J.C36:371-374,2004

π^0 Cross-Sections at $\eta_{cm} = 0$
Experiment vs Theory in p+p

- √s=200 GeV (RHIC) Agreementgies?

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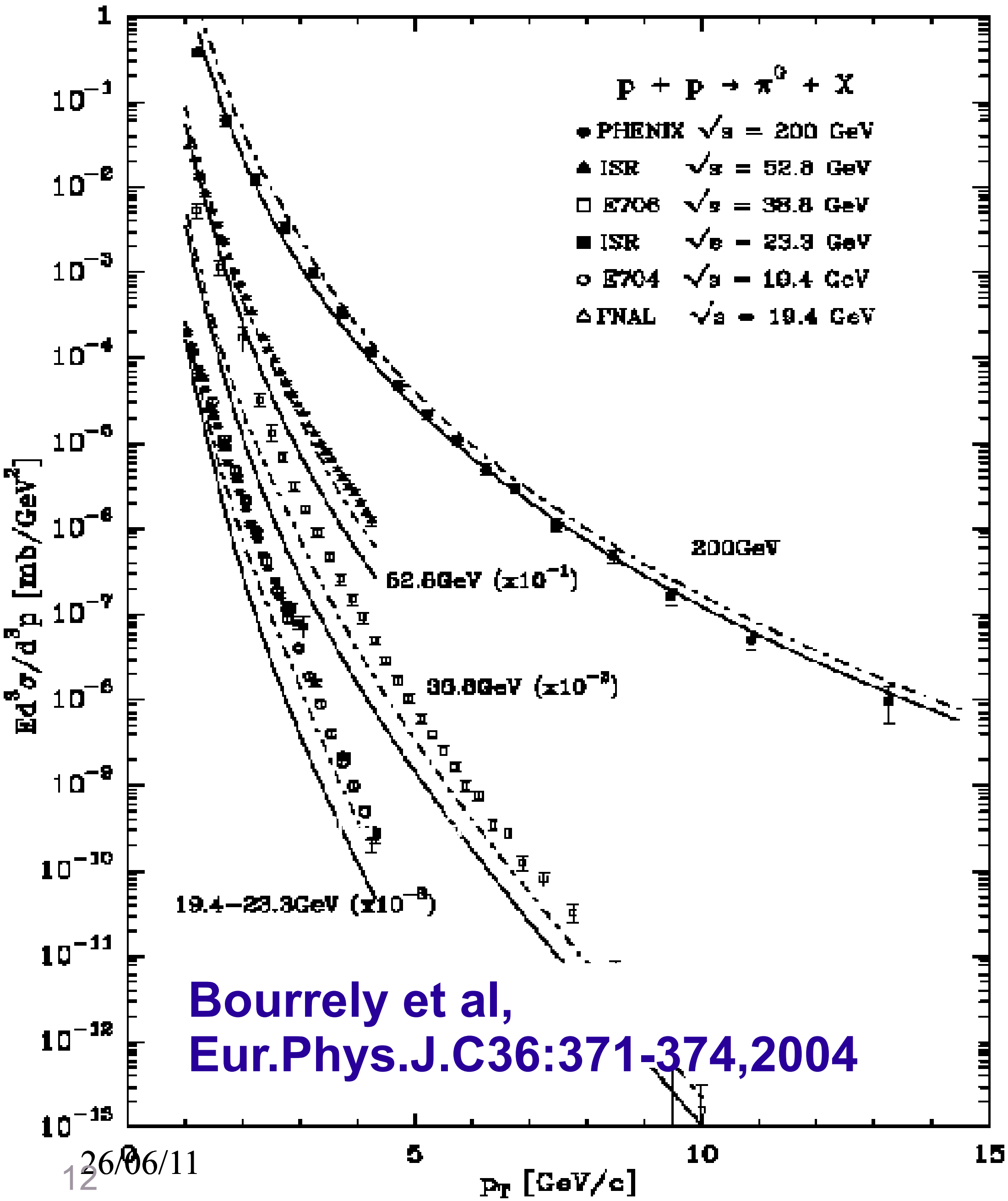

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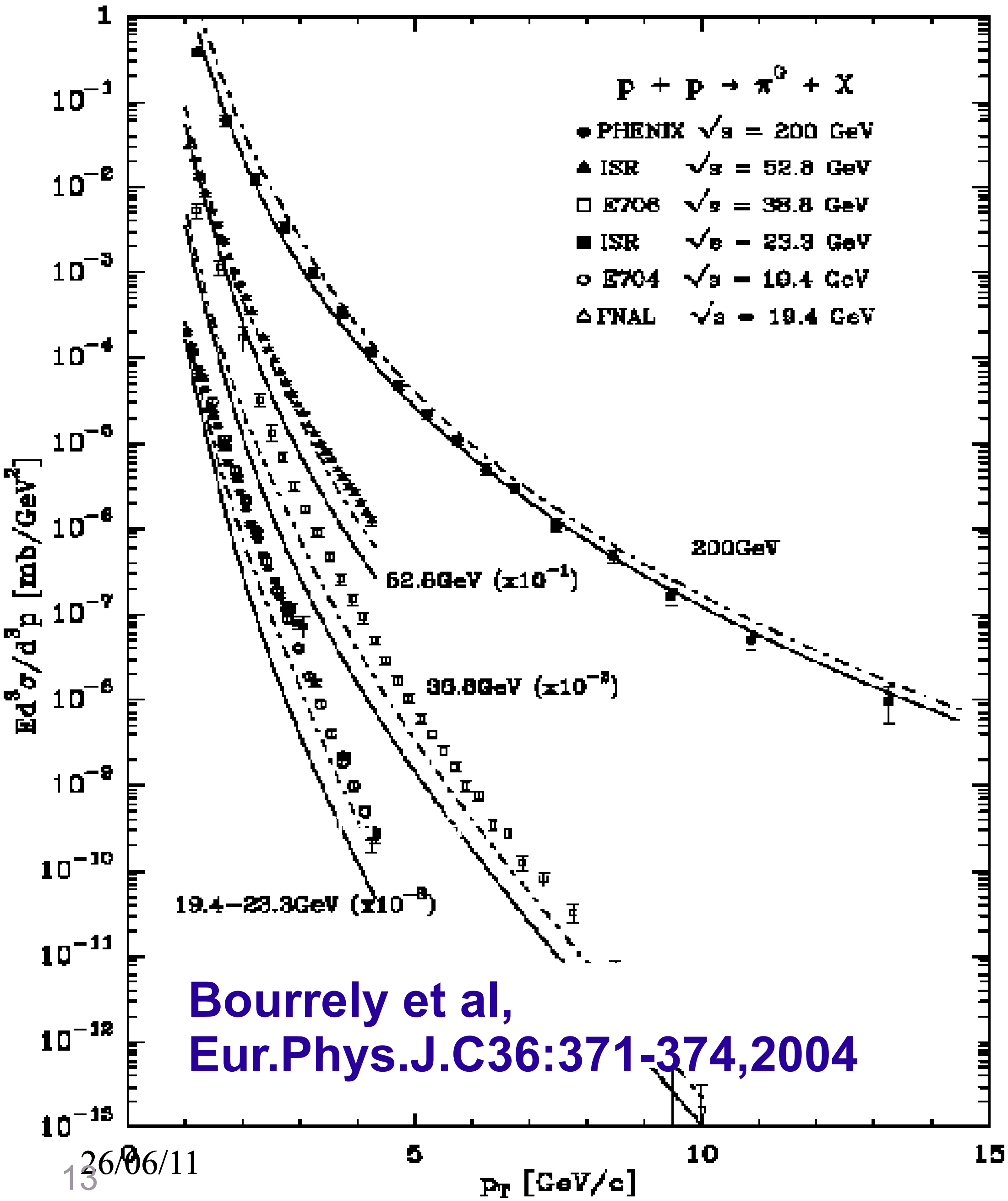

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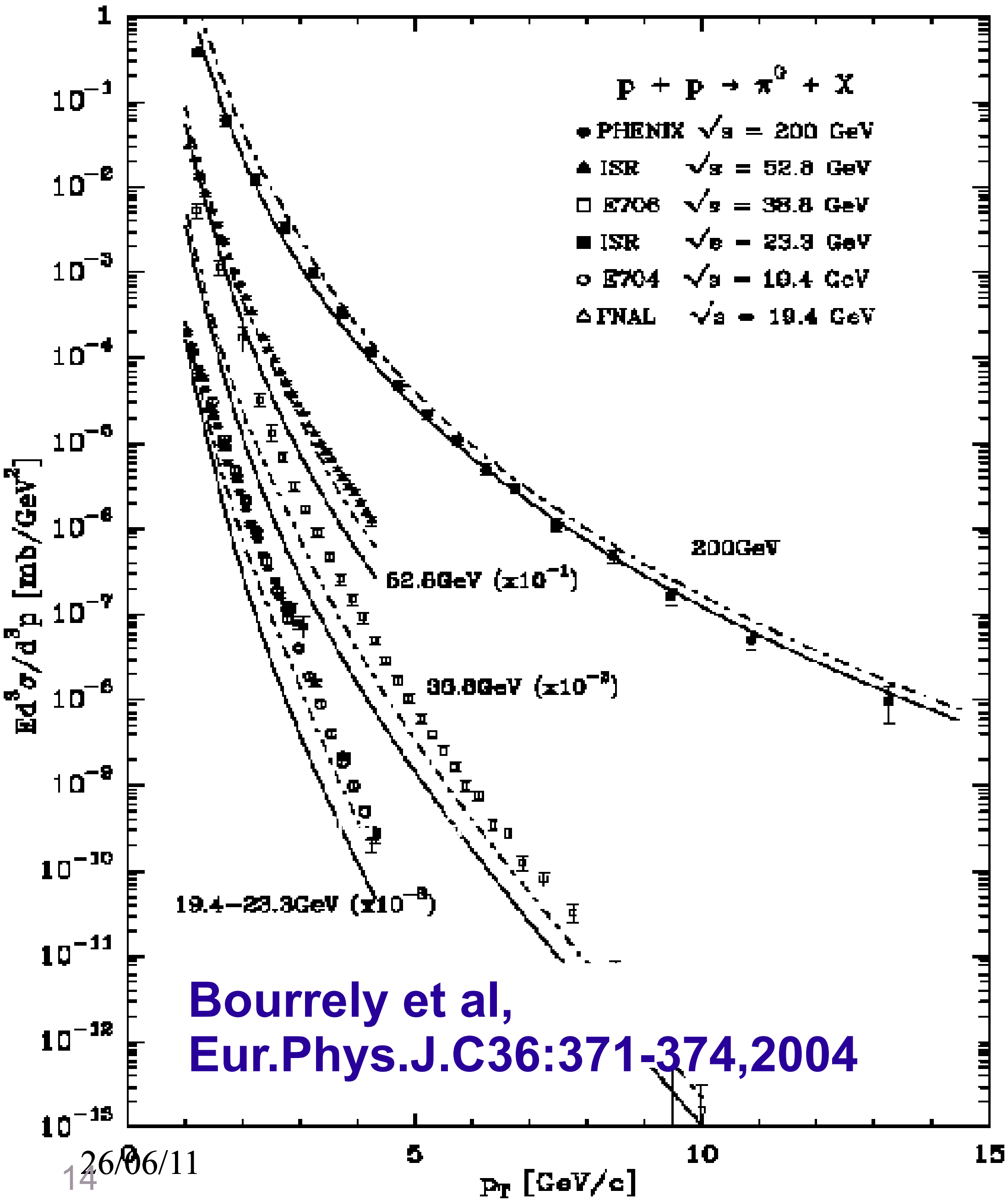

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Disagreement at lower center of mass energies observed in p+p data

Work needed to understand lower energies?

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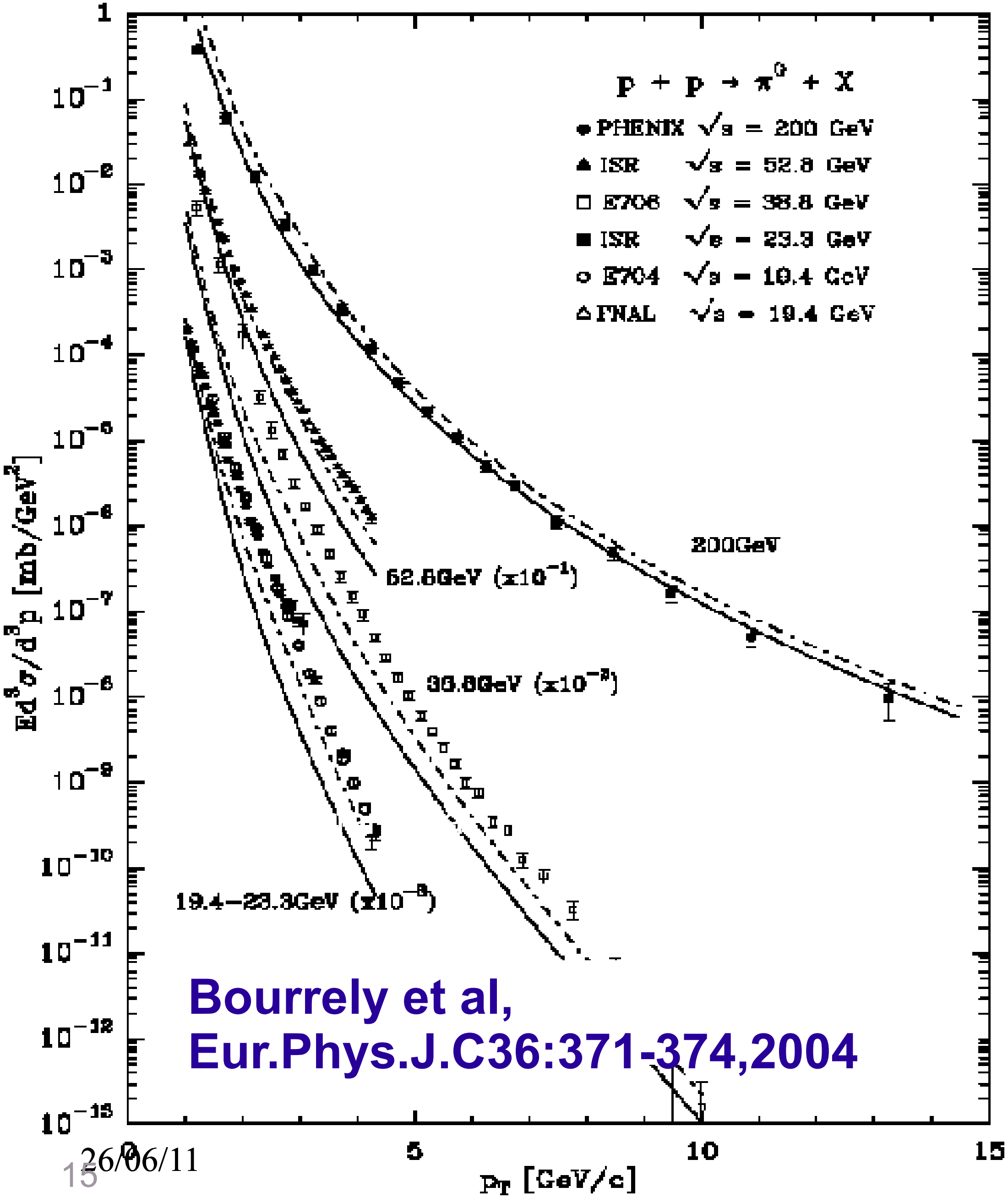

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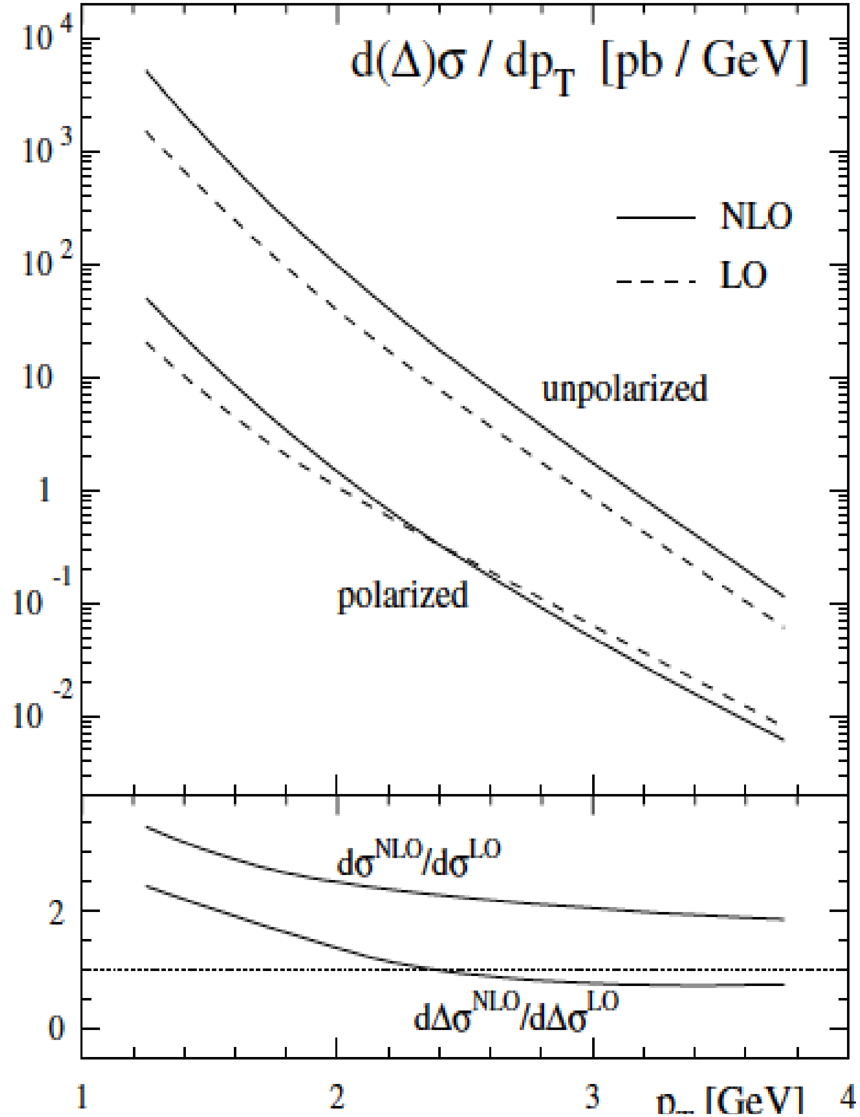
What about μ+d → μ'hX?
→ Quasi-real Photo Production

The quasi-real photo production case: **NLO pQCD.**

Eur. Phys. J. C 36, 371–374 (2004)

→ π^0 production prediction: difficult to compare at the time.

→ The updated calculations for charged hadron production at **Compass' full kinematics** have been performed by **V. Wogelsang**



Unpolarized and polarized cross-sections at LO and NLO

B. Jaeger, M. Stratmann, V. Wogelsang

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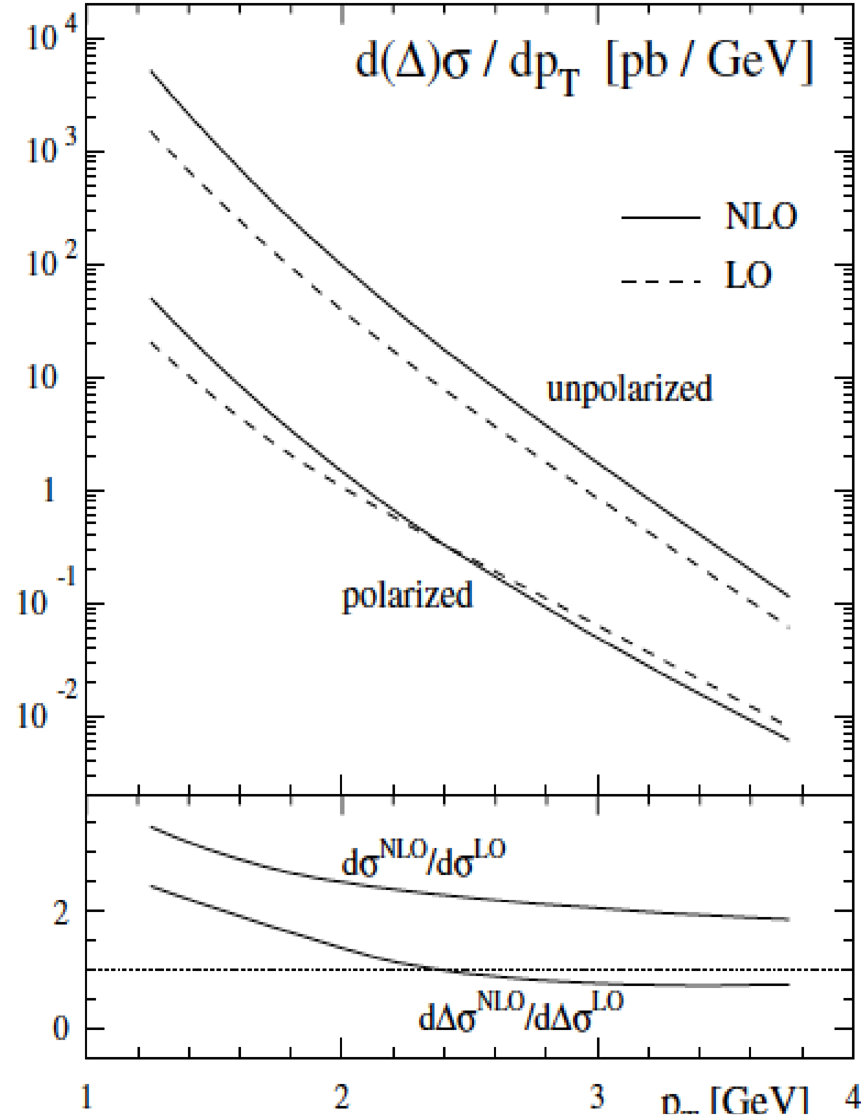
→ Radiative contributions calculatic however small, has been calculatec **A. Afanasiev.**



Unpolarized and polarized cross-sections at LO and NLO
B. Jaeger, M. Stratmann, V. Wogelsang

Unpolarized **Cross sections: The Measurement**

$$\frac{1}{2\pi\, p_T}\cdot\frac{d^2\sigma}{dp_T dy} \Rightarrow \frac{1}{L^*}\cdot\frac{1}{2\pi\, p_T}\cdot\frac{d^2N}{dp_T dy} \Rightarrow \frac{1}{2\pi p_T}\frac{N_{h\pm}(p_T)}{\int Ldt\,\epsilon_{Acc}\Delta p_T\Delta\eta}$$

$\int Ldt$ → Integrated luminosity: 142.4 pb^{-1}

$N_{h\pm}(p_T)$ → Number of hadrons in a p_T bin.

ε_{Acc} → Detector's geometrical acceptance, reconstruction algorithm, detection efficiencies.

Δp_T → Bin width (250 MeV)

$\Delta\eta$ → Rapidity width (w.r.t. to theory calculation)

The Experiment:

COMPASS @CERN (Prevessin):

COMMON APPARATUS FOR MUON SPECTROSCOPY:

Tertiary beam of positive muons produced in the M2 beamline at the CERN SPS.

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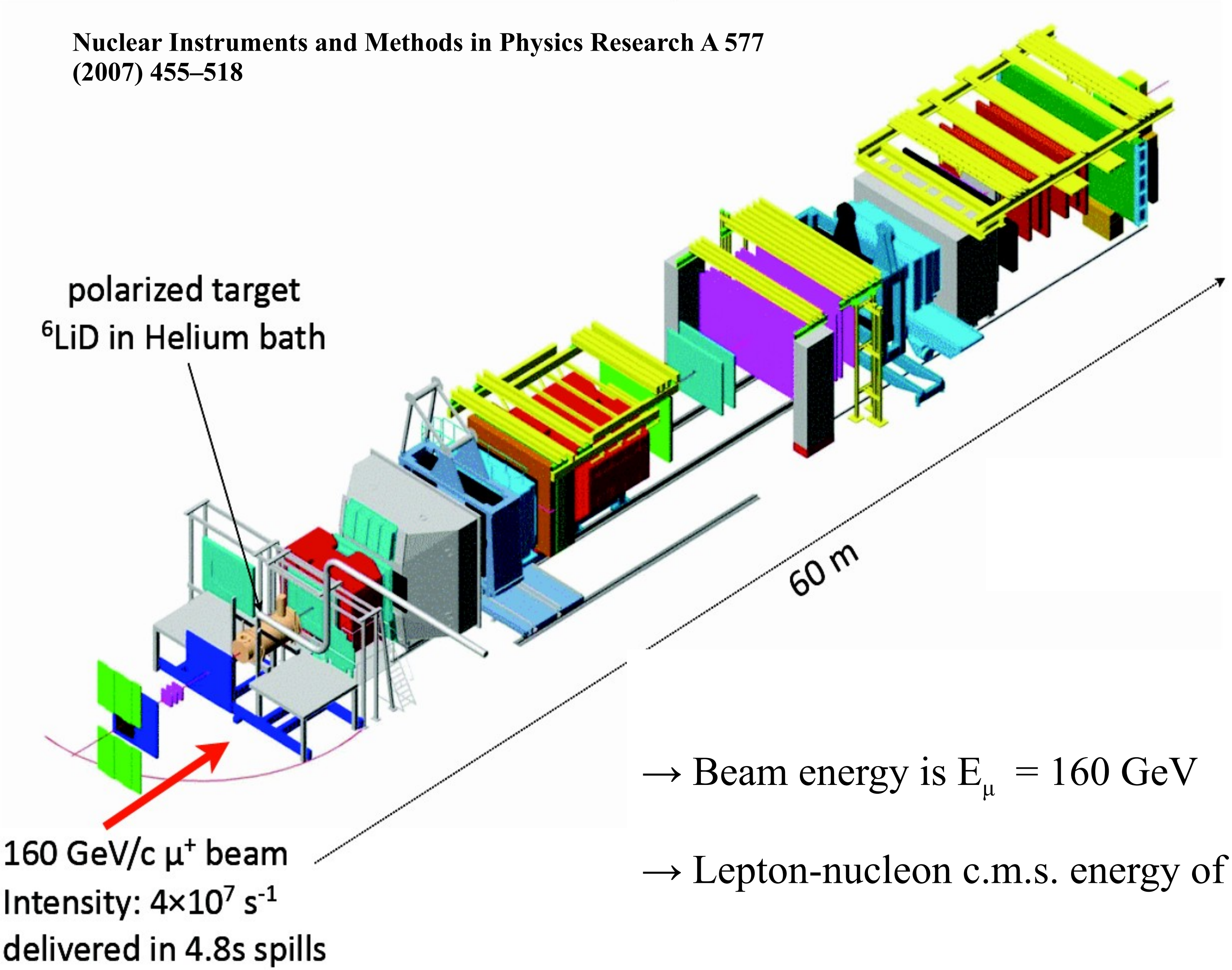
The COMPASS detector at CERN's SPS

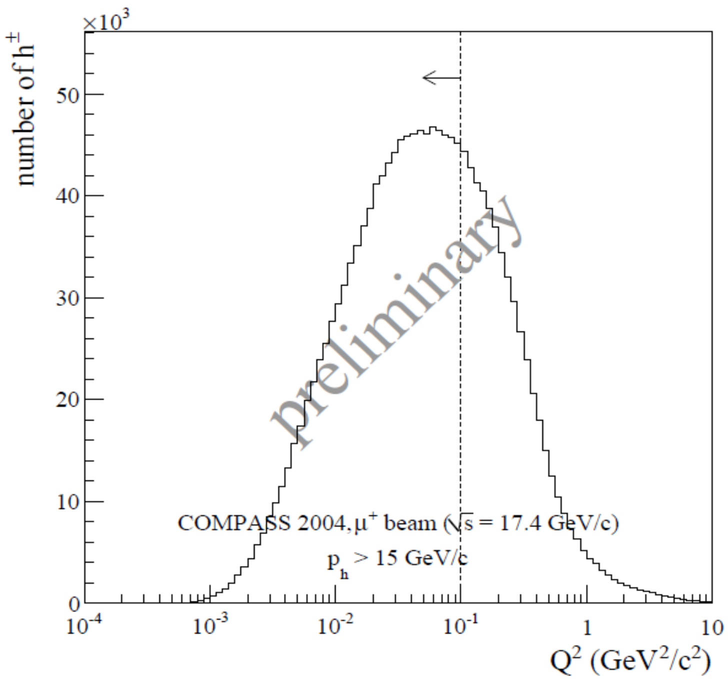
Nuclear Instruments and Methods in Physics Research A 577 (2007) 455–518



→ Beam energy is E_μ = 160 GeV

→ Lepton-nucleon c.m.s. energy of $\sqrt{S} \simeq$ 17 GeV.

Kinematic Distributions



The kinematic cuts:

- $Q2 < 0.1\ GeV^2/c^2$

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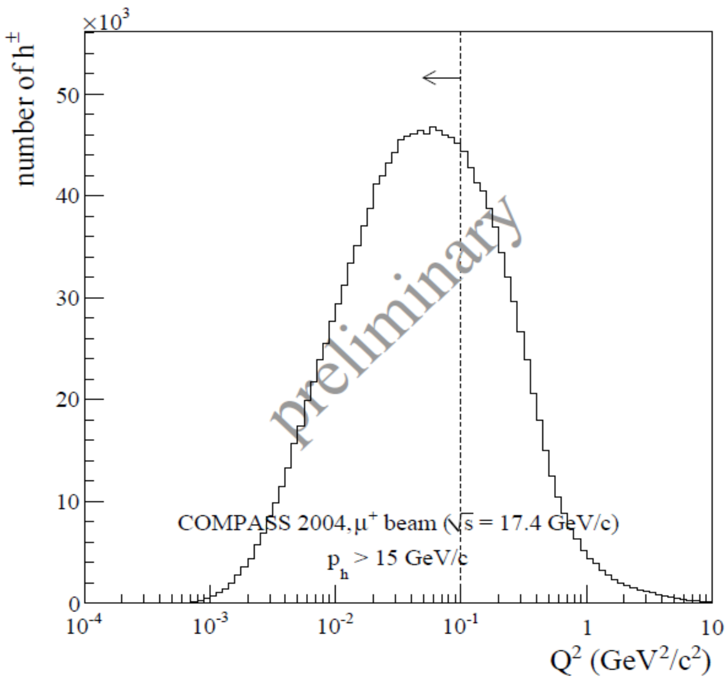

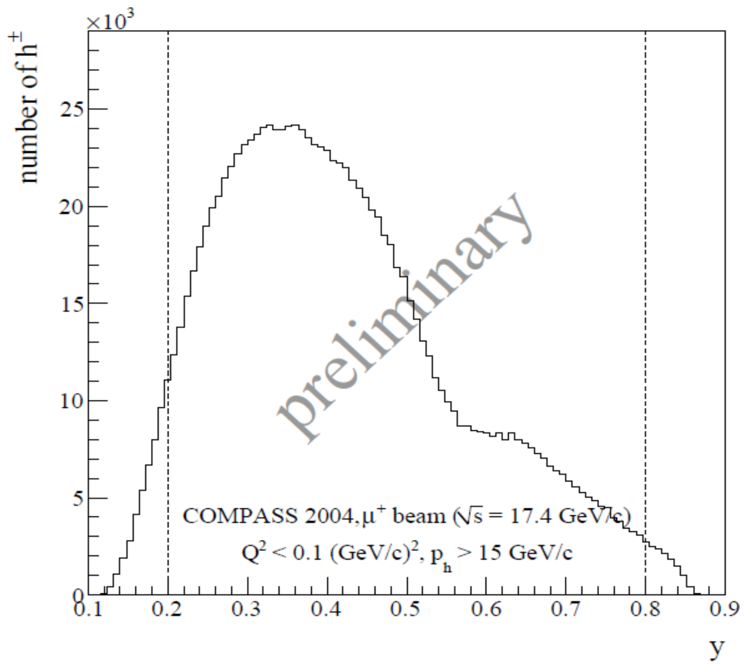

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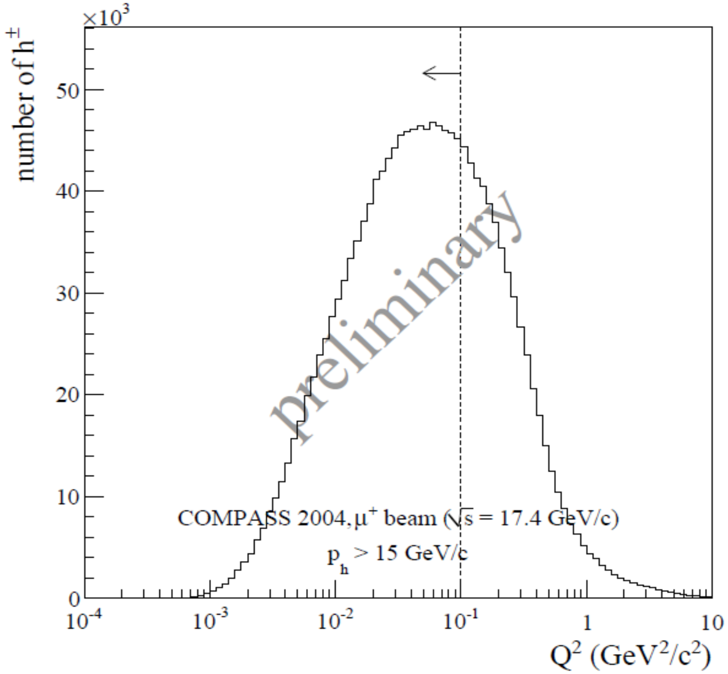
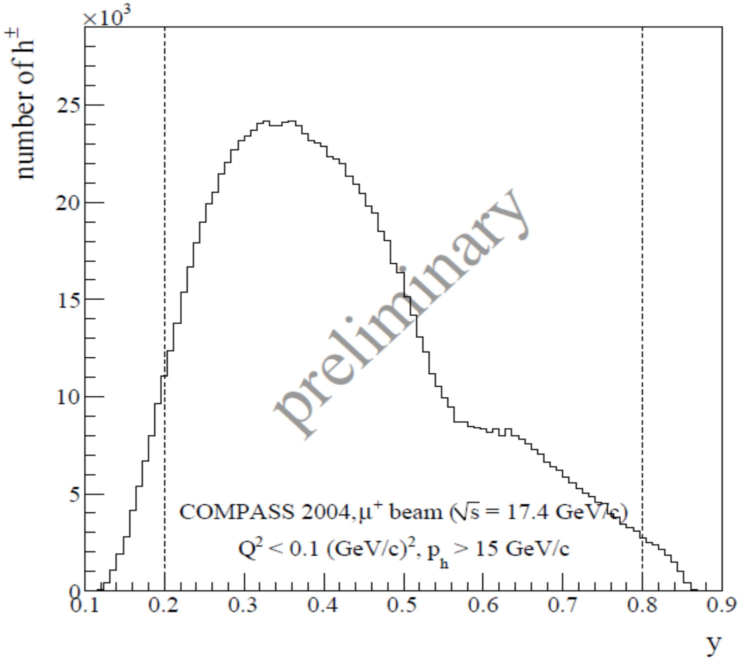
Kinematic Distributions





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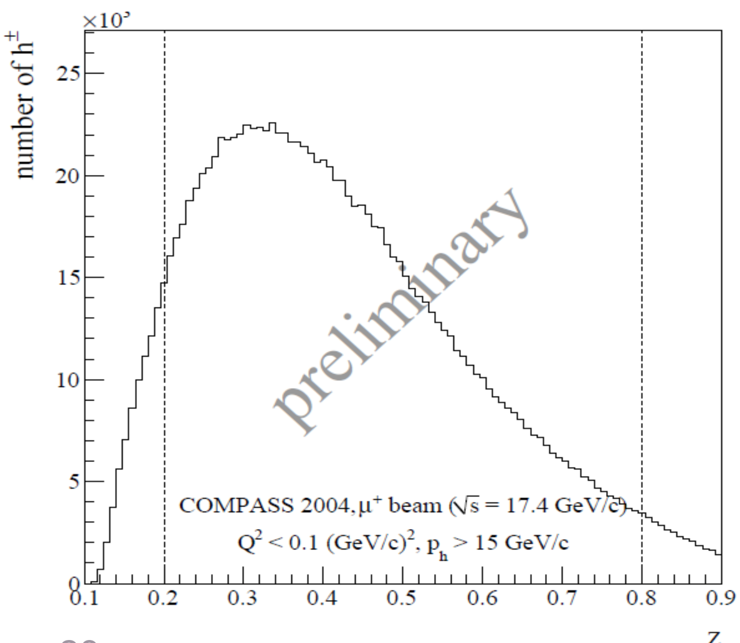
- Q2 < 0.1 GeV^2/c^2
- Y: From 0.2 to 0.8
- Z: 0.2~0.8



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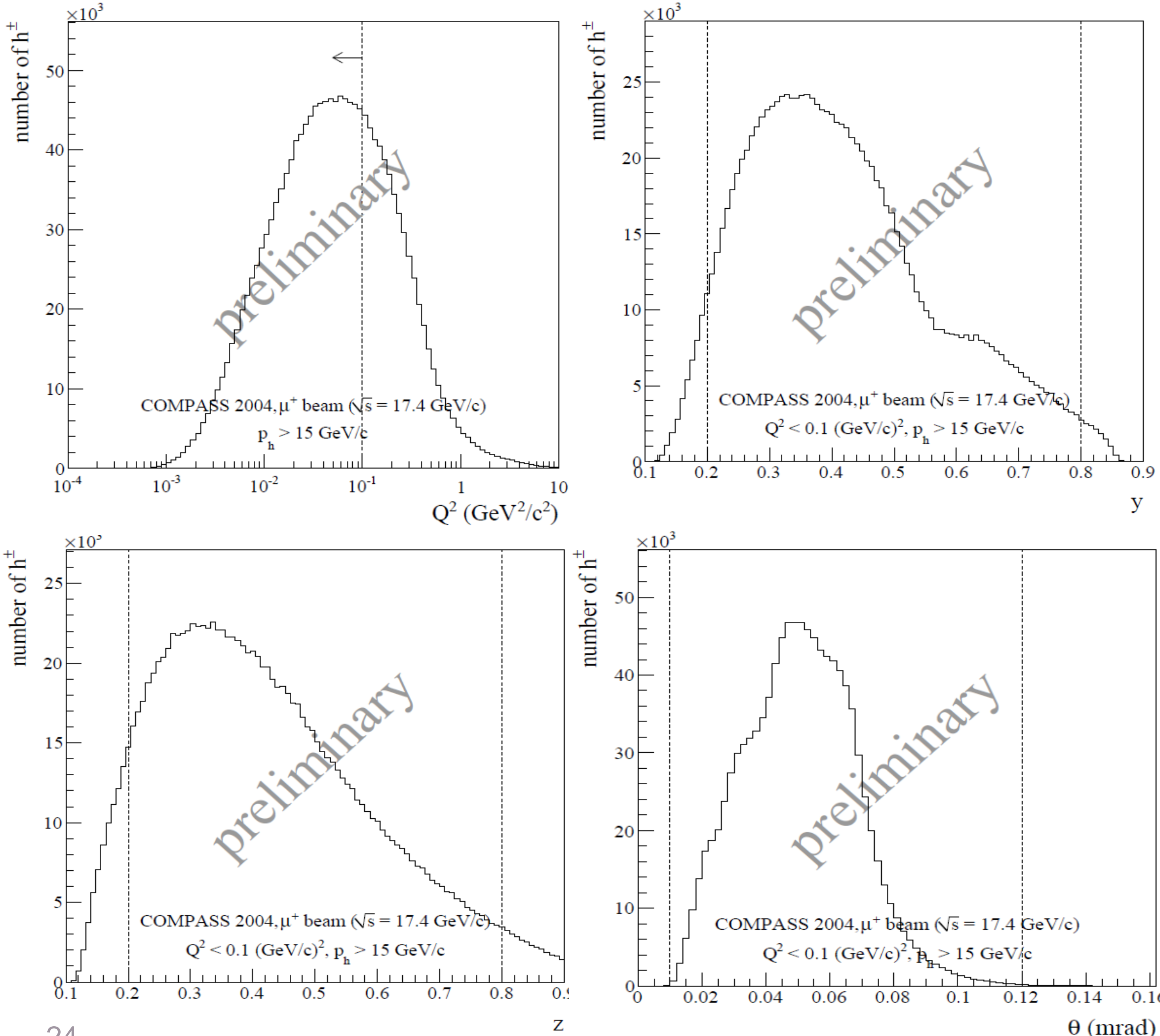


The kinematic cuts:

- $Q2 < 0.1\ GeV^2/c^2$
- Y: From 0.2 to 0.8
- Z: 0.2~0.8
- **θ** :
  20 - 120mrad
  → translates to
  $-0.1 < \eta_{cm} < 2.4$
- p_T >1 GeV/c

Luminosity

→ Luminosity is measured using the beam scalers spill by spill.

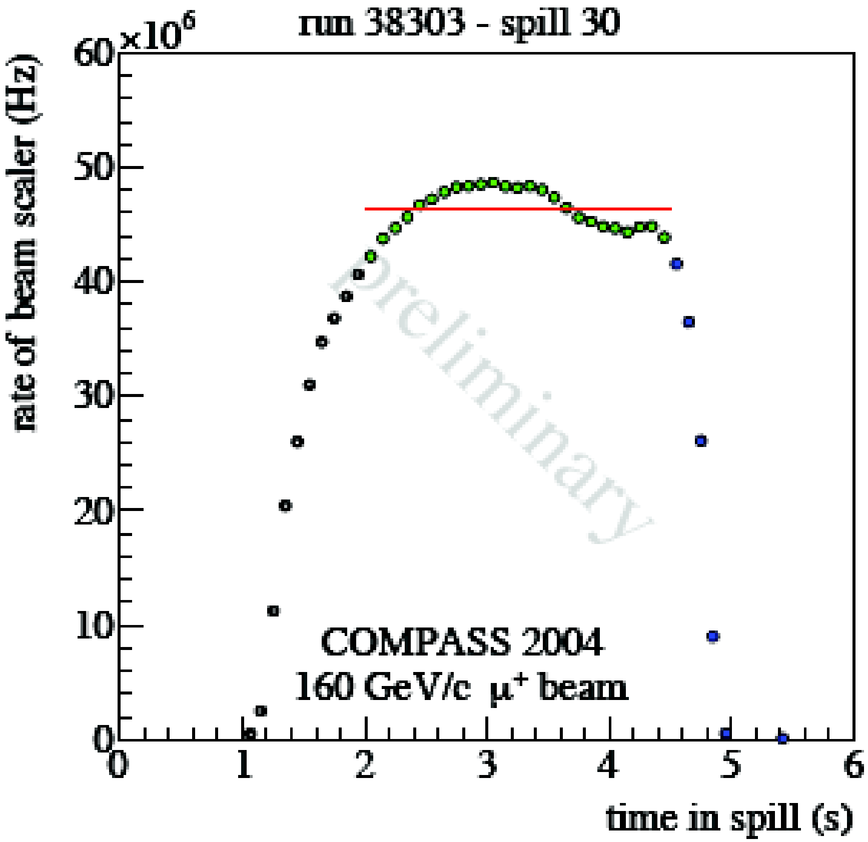
→ Each spill corresponds to the beam delivered by SPS.

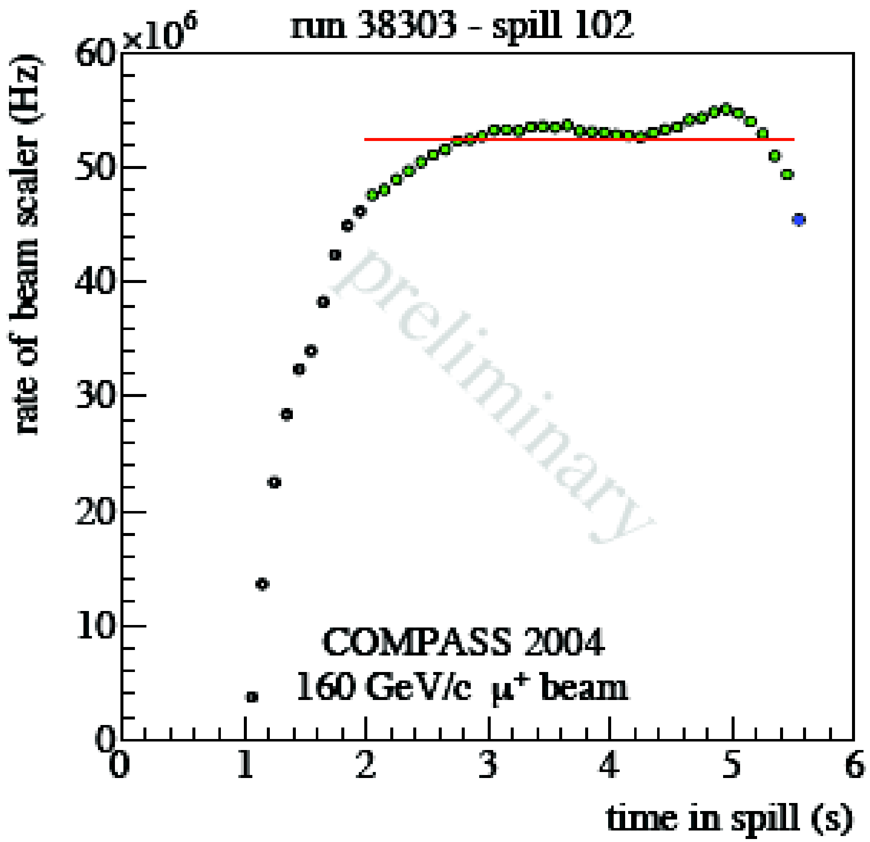
-Every 16.8 seconds (Flattop duration of 4.8 seconds).

→ Detector effects which affect the total beam rate are accounted for: Acquisition, veto (beam halo) deadtimes.

For the data sample of interest the luminosity has been determined within 10% accuracy.

Luminosity: Flattop selection

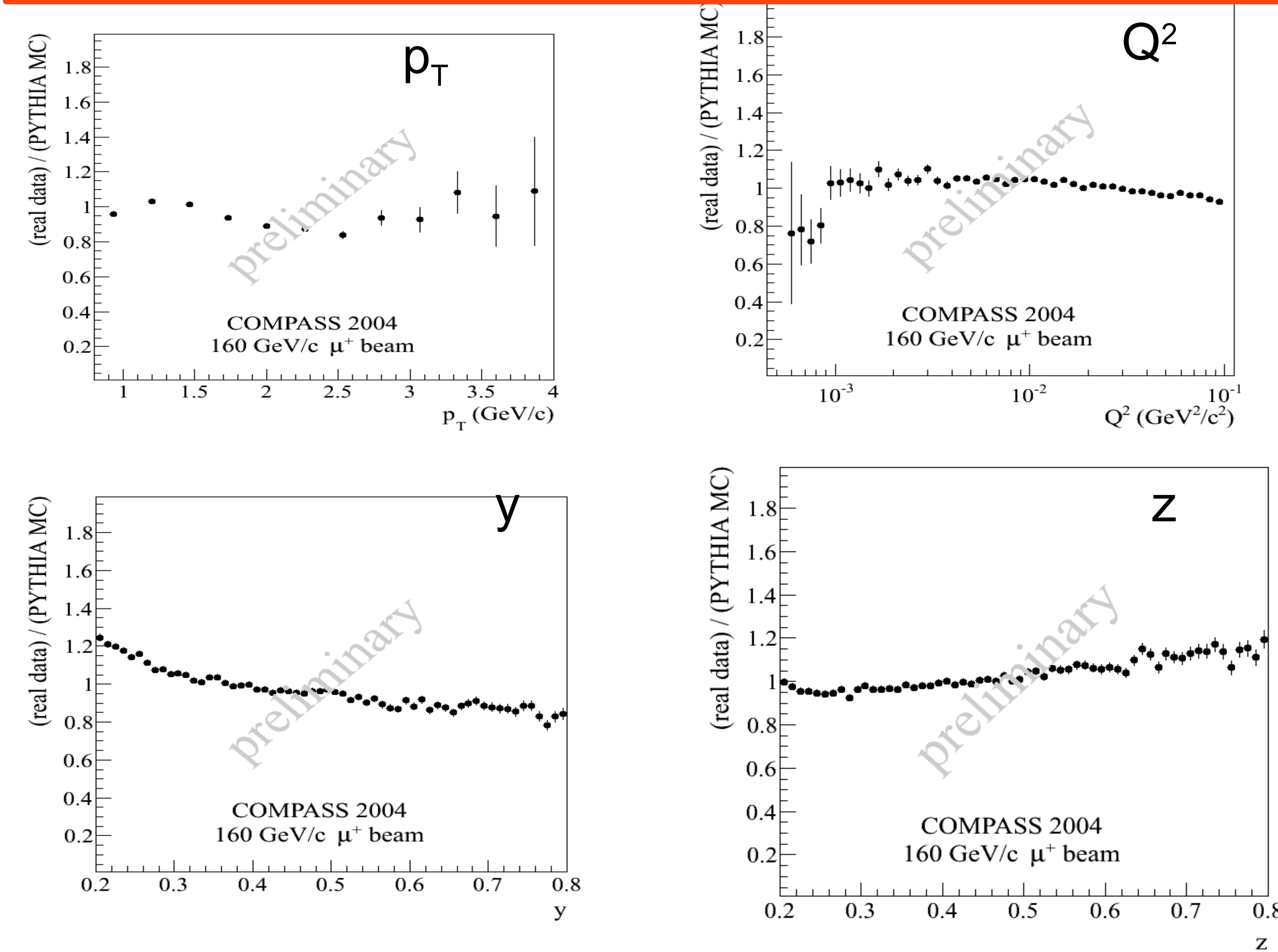




→ Evaluate the spill rates as seen by the beam scaler as a function of time.

→ Only events within the flattop are considered (red line)

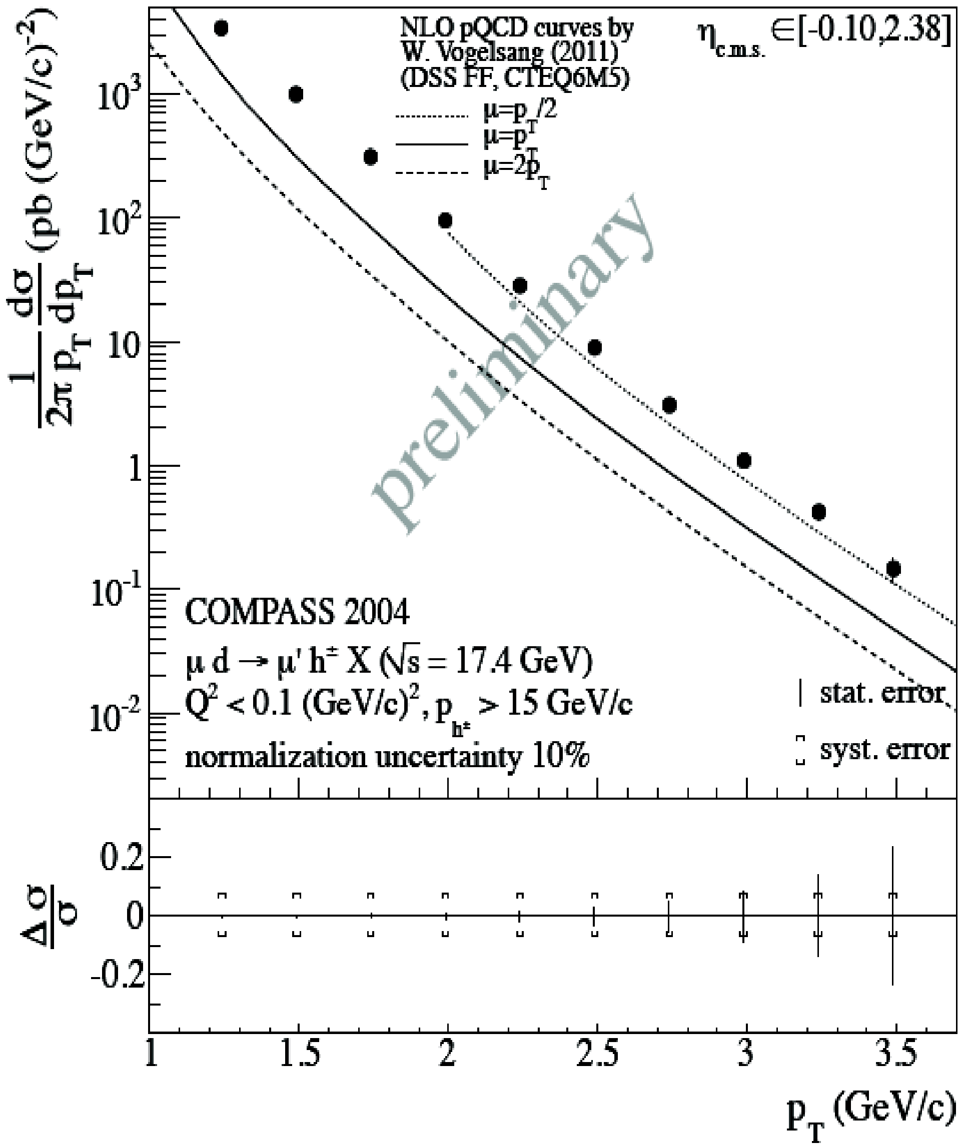
Data/MonteCarlo



→ MC used only for extraction of acceptance
(PYTHIA6, GEANT3, COMPASS' data reconstruction)

→ 7% Systematic error

Cross-sections of h±



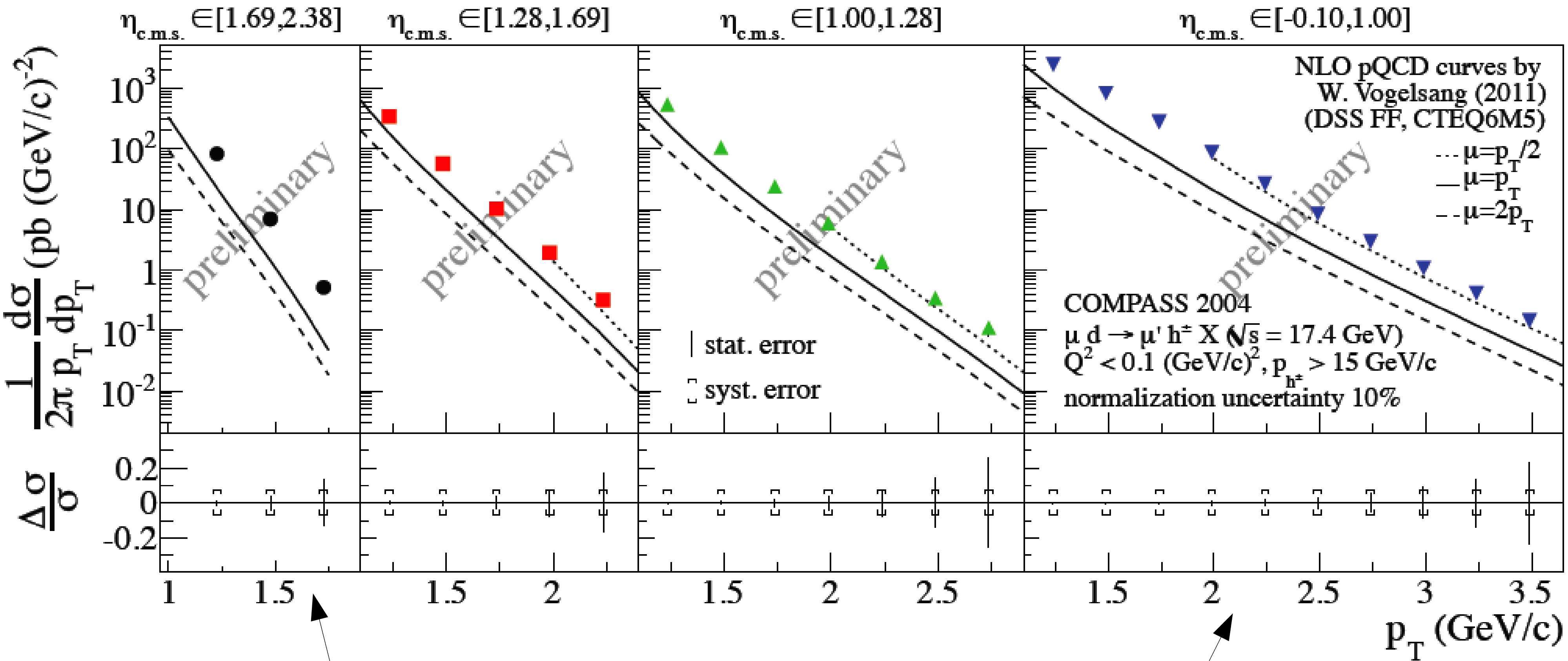
$\mu^+d \rightarrow \mu^+h^{\pm}X$: Cross-sections.

•2004 **μ^+-d** : 4 Weeks of Data.

•Systematic error contributions:
-Background and multi-dimensional acceptance extraction.

Quasi real photo production compared to NLO pQCD

Cross Sections Separated by Rapidity Bins

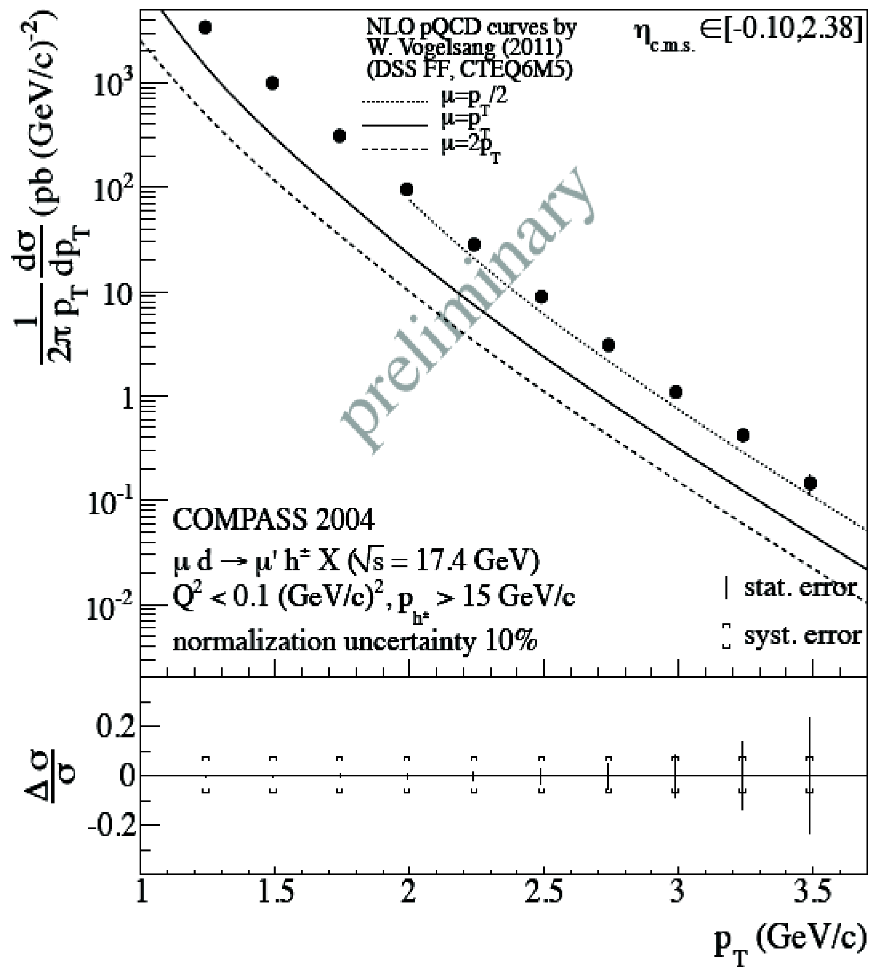


Most Forward Rapidity
Accessible in the Data

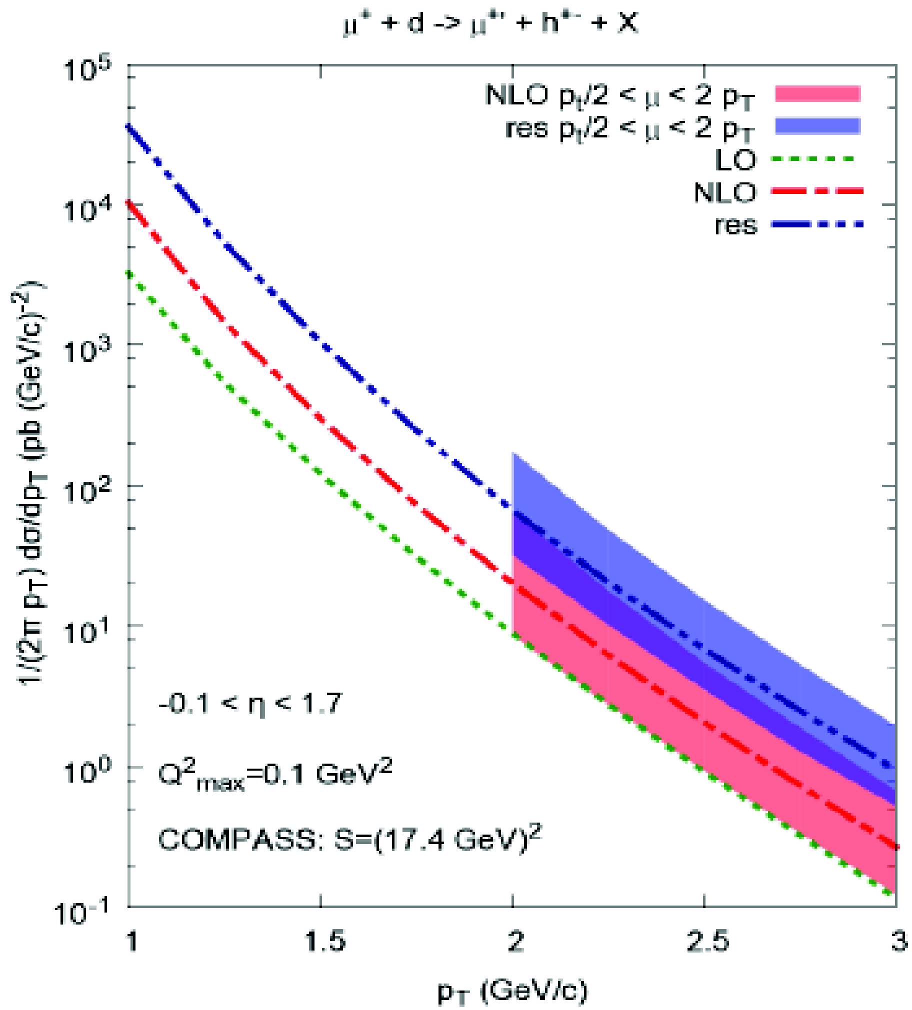
Most Central rapidity

Slope variations as a function of rapidity

Preliminary updated calculations with resummations.
(de Florian, Pfeuffer, Schaeffer, Vogelsang)



COMPASS

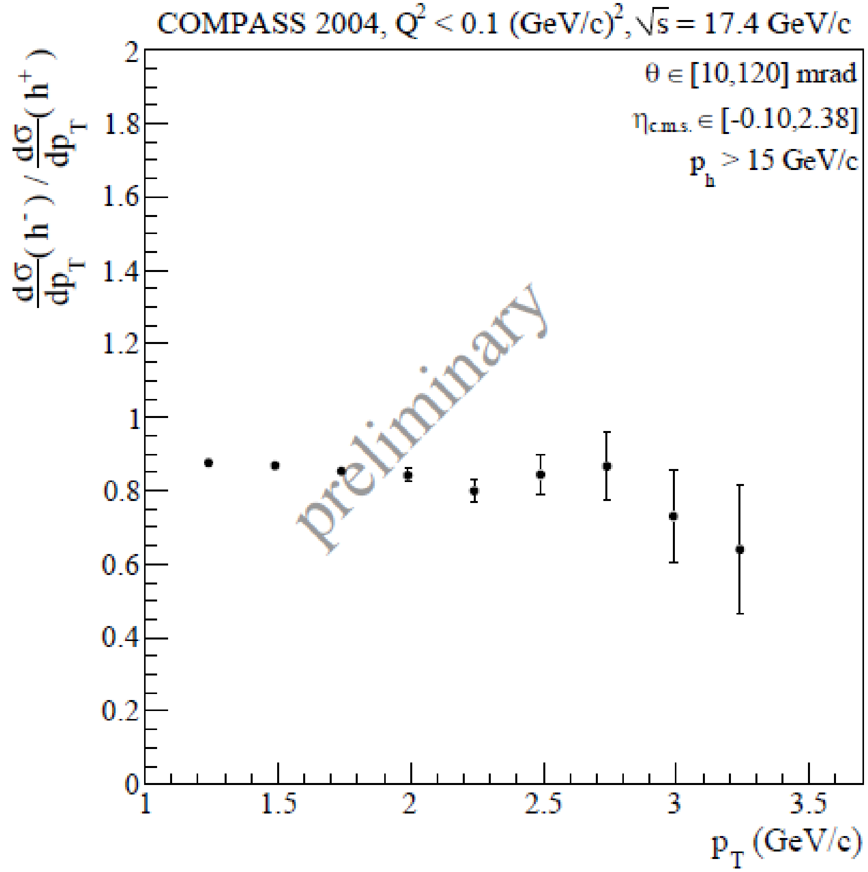


de Florian, Pfeuffer, Schäfer, WV (prel.)

Theory paper under preparation

Ratio h^-/h^+

More up quarks in the final state: Conservation of charge.

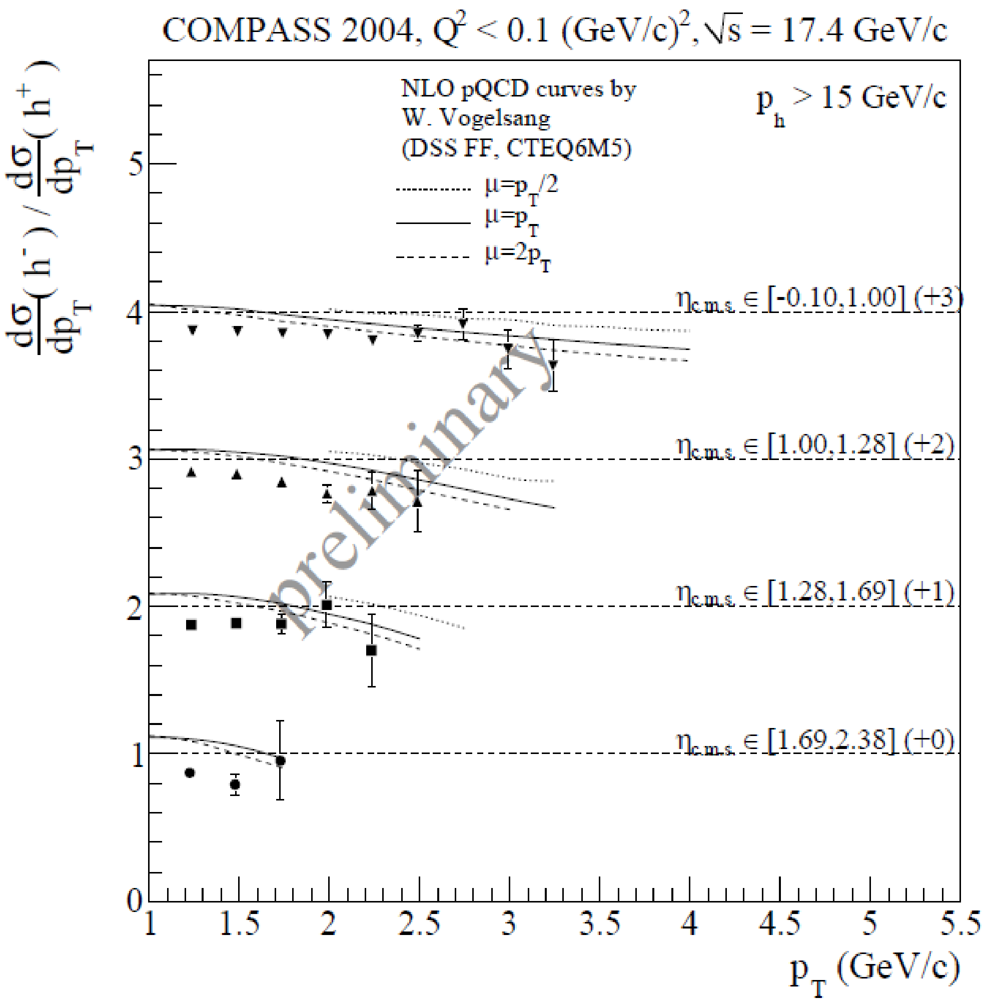


→ Flat as a function of p_T

→ Sensitive to fragmentation functions.

Integrated over all rapidity accessible in the dataset

Ratio h^-/h^+



→ Flat as a function of p_T

→ Sensitive to Fragmentation functions.

→ Disagreement observed with calculation.

← Most Forward rapidity accessible to the data.

Theory **does not agree** with experimental results. → Fragmentation Functions?

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Summary

→ COMPASS has measured the cross sections of the SIDIS process
$\mu^+ d \rightarrow \mu^+ h^\pm X$ at high p_T and low Q^2

→ Results show that within the theory's errors, the data is well described.
*settles the theory framework (**ΔG**) through that process.*

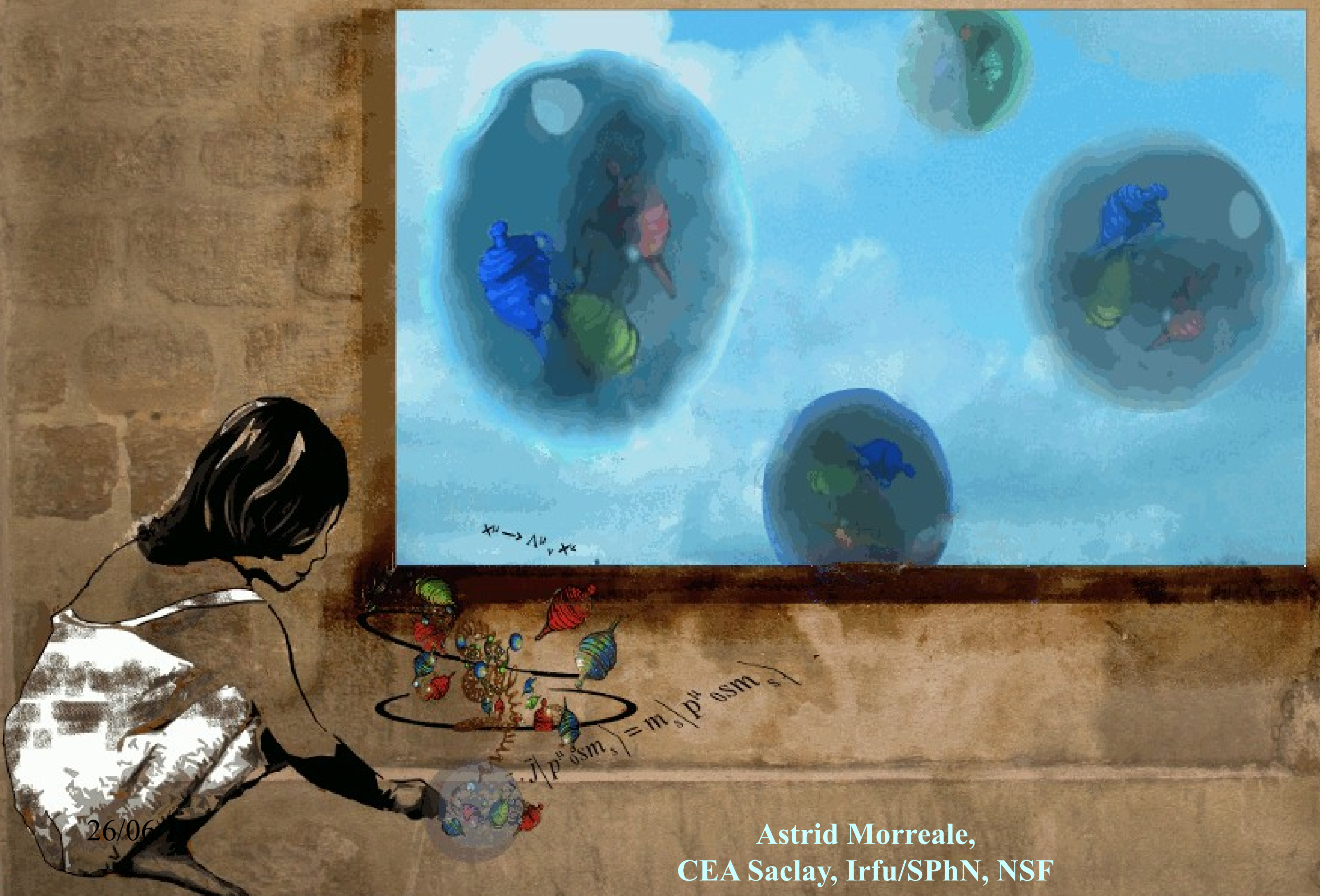
→ **Ratio** of negative to positive cross-sections show a discrepancy at low p_T

→ Updated **theory calculations** with resummations are under paper preparation.

→ **Results** of these work is finished → under paper preparation.

→ **Asymmetries and ΔG. Ongoing work**

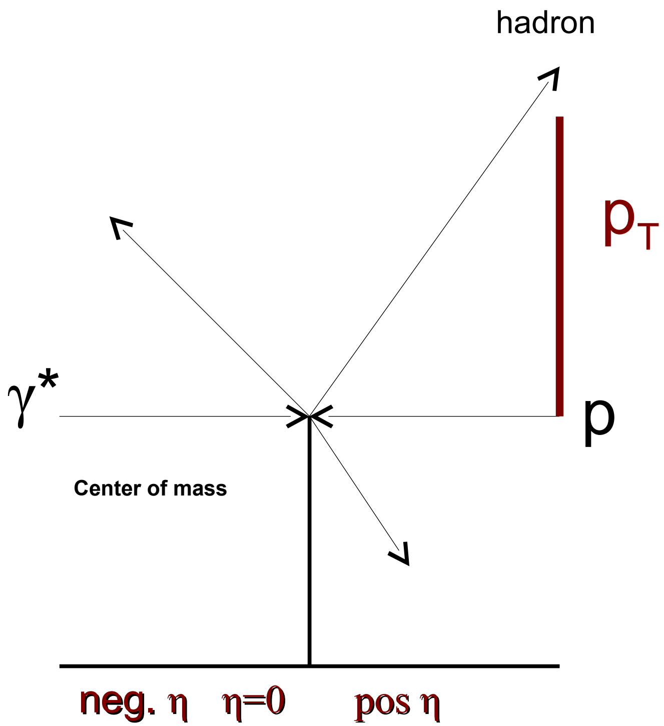
Thank You

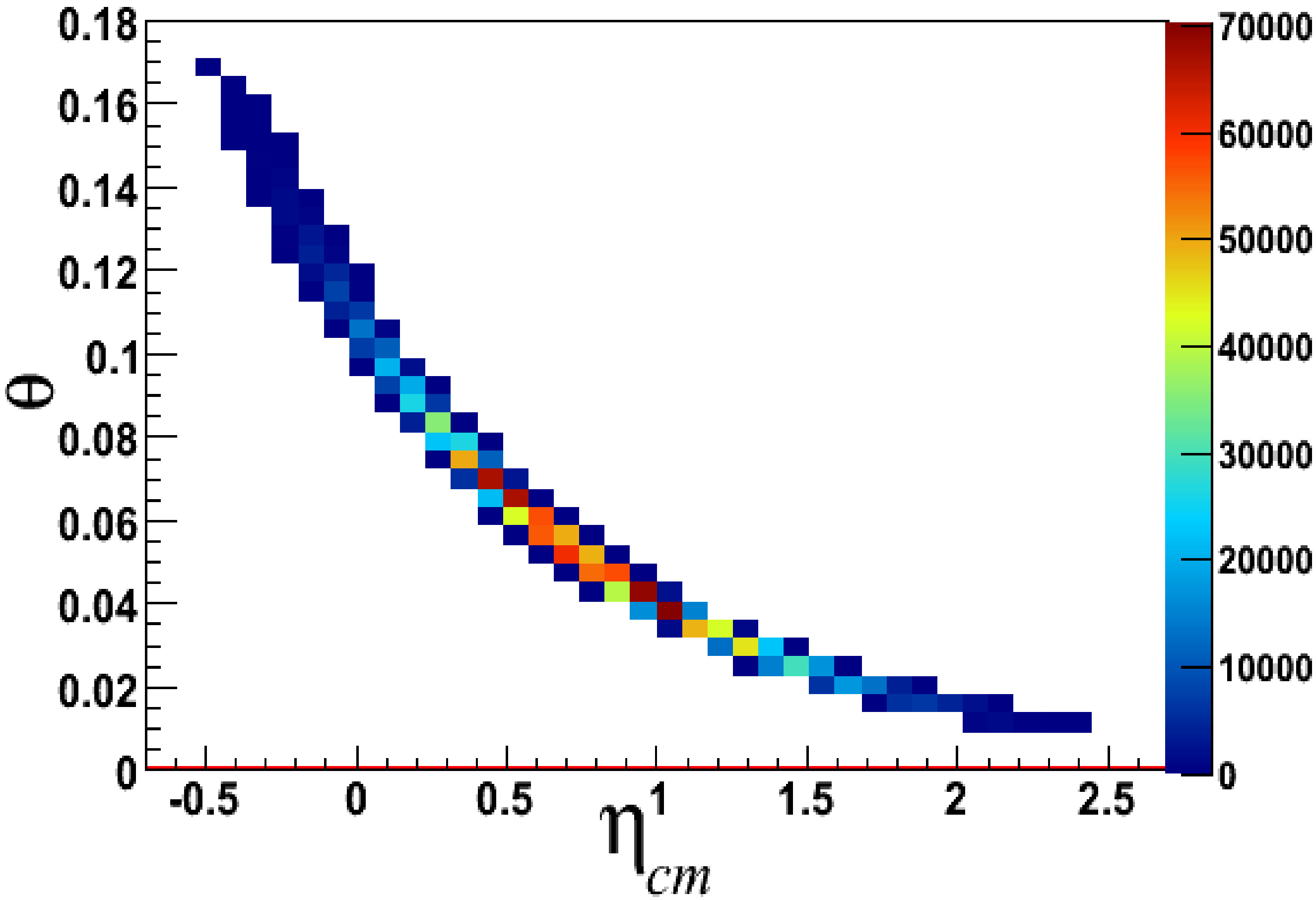


Astrid Morreale,
CEA Saclay, Irfu/SPhN, NSF

η_{cms}

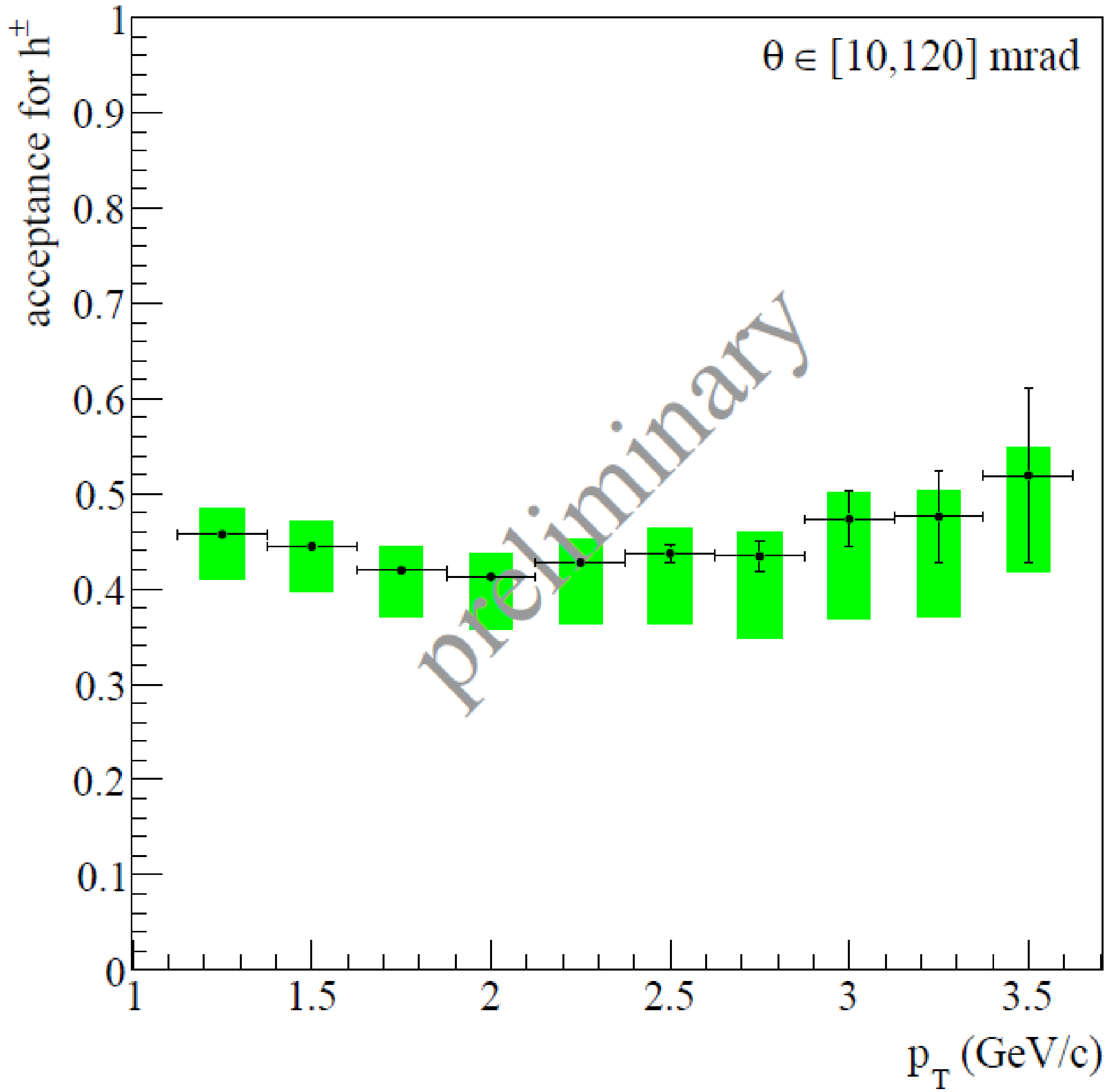
$$\eta_{cms}=-\log(\tan(\theta/2))-0.5*\log(2P_{beam}/M_p)$$





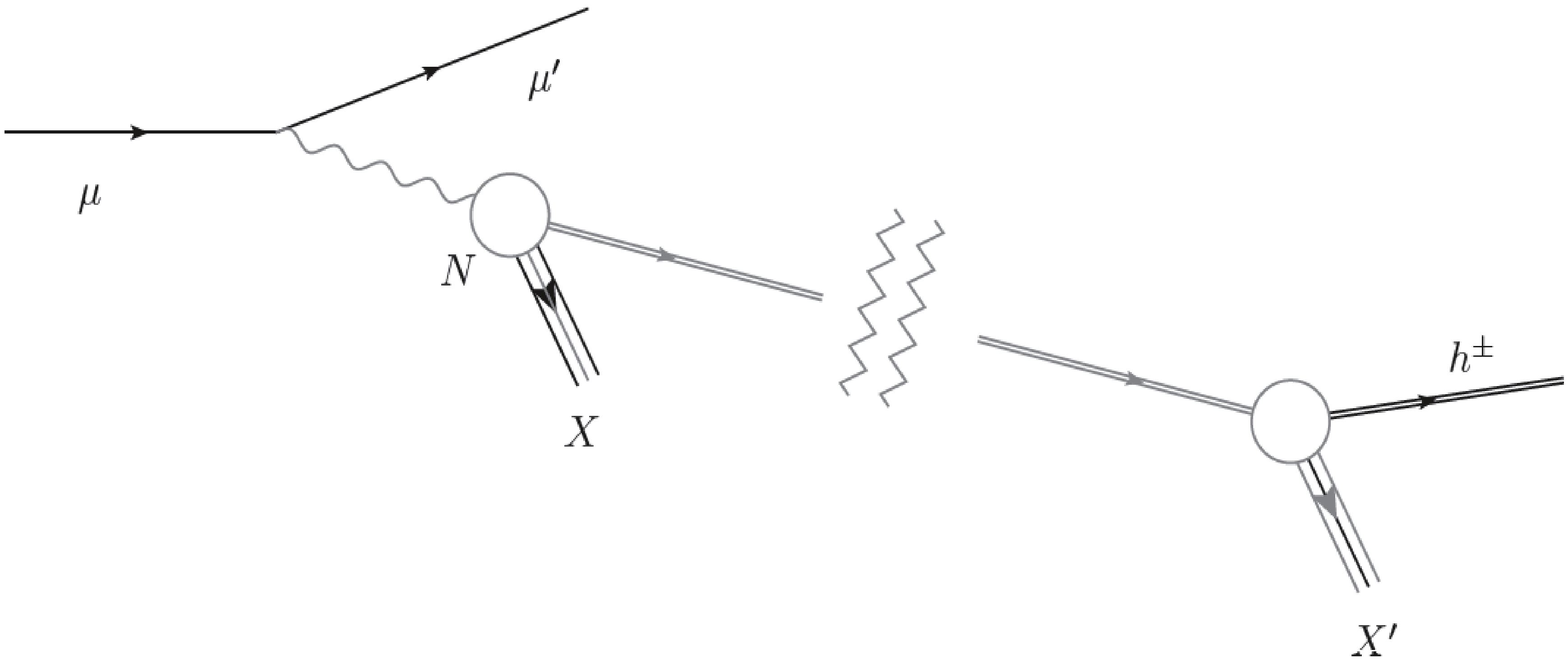
Low θ →Forward $\eta_{cm.}$ High θ →Central $\eta_{cm.}$ **(Hard Scattering)**

Acceptance



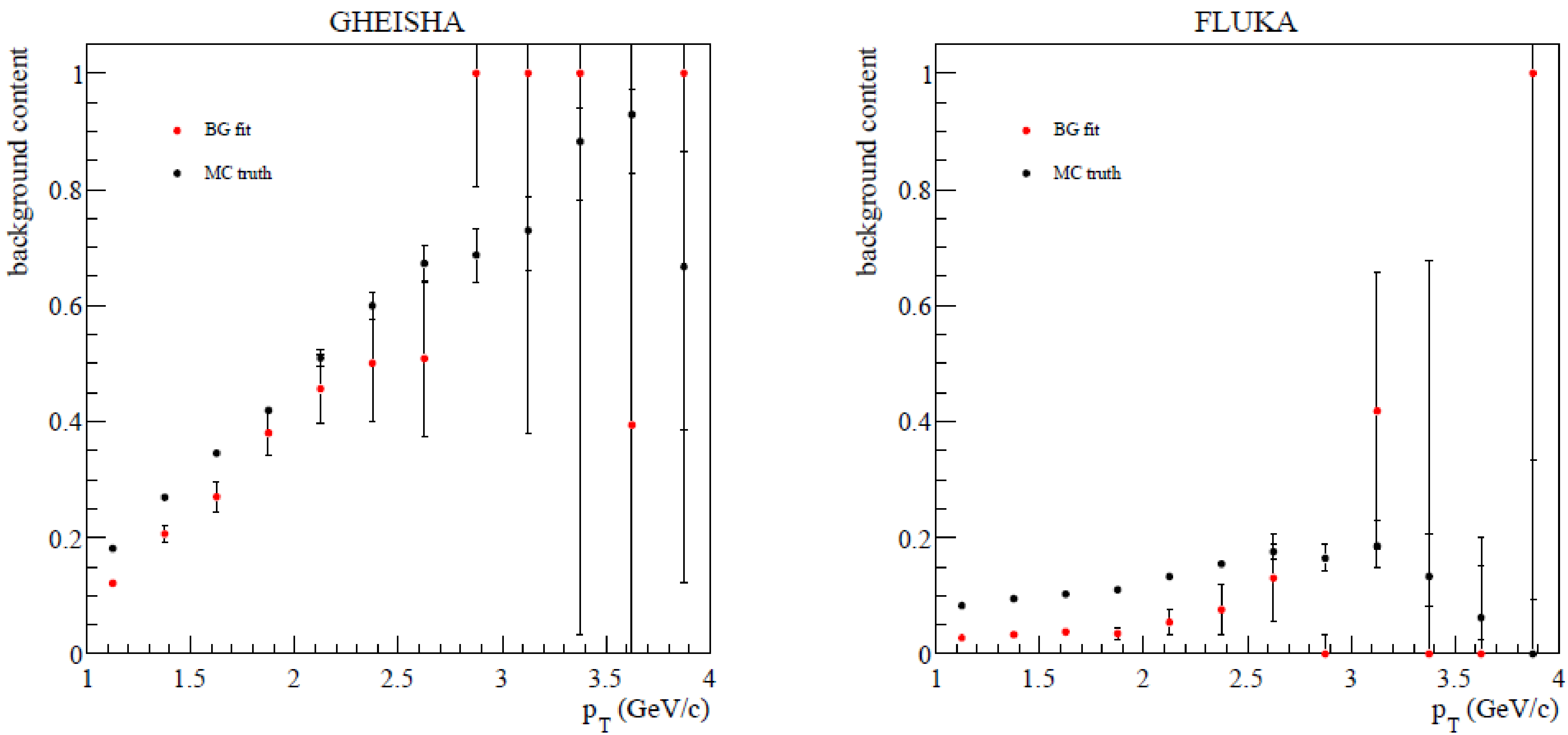
Flat as a function of p_T

Secondary interactions in the target



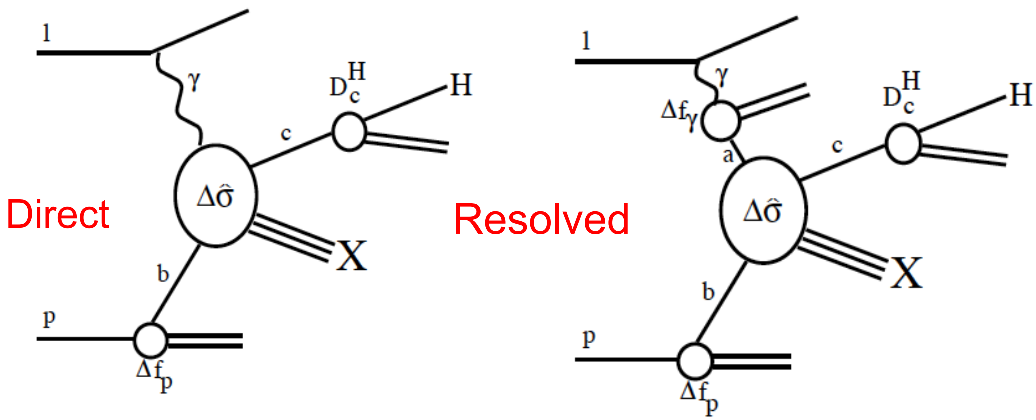
→ A hadron produced in the primary vertex
→ Sometimes it will re-interact with nuclear material in the target
→ Kinematics will be modified introducing a smeared spectrum

Background Estimate

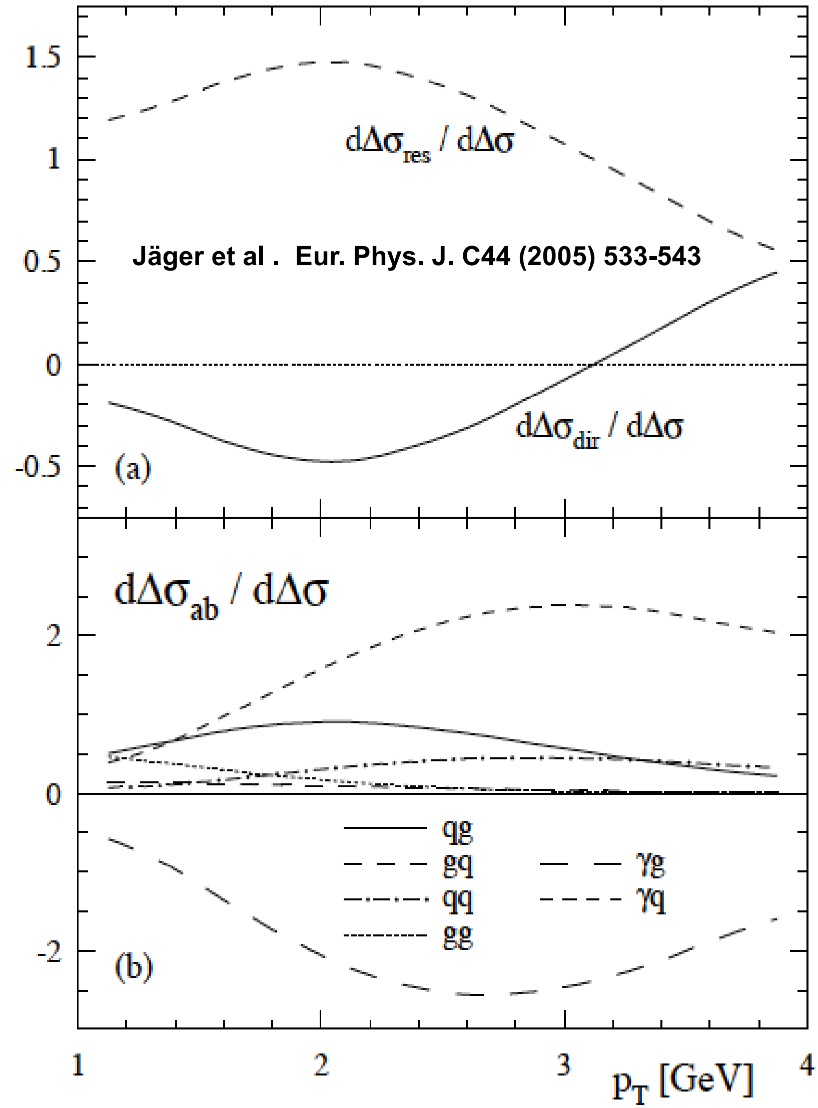


Both models were parametrized and compared to data
Fluka agreed while GHEISHA failed to reproduce
the data → **GHEISHA discarded**

NLO pQCD: Quasi Real Photo-production of high p_T hadrons

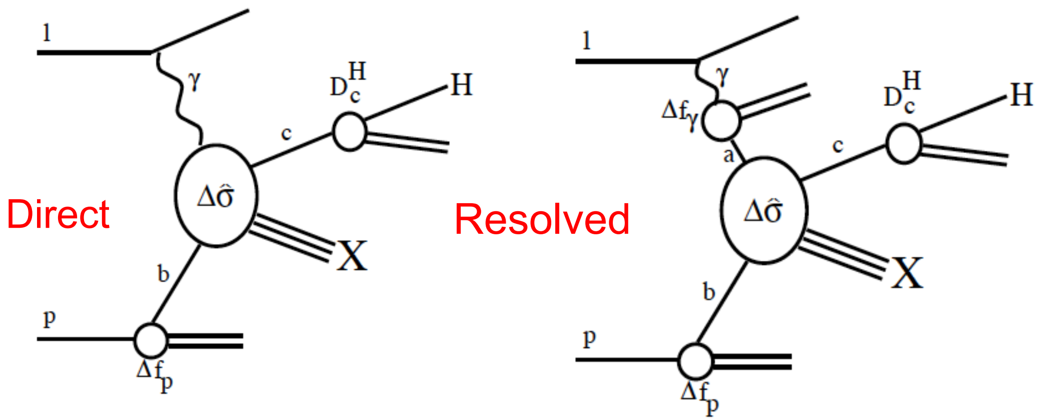


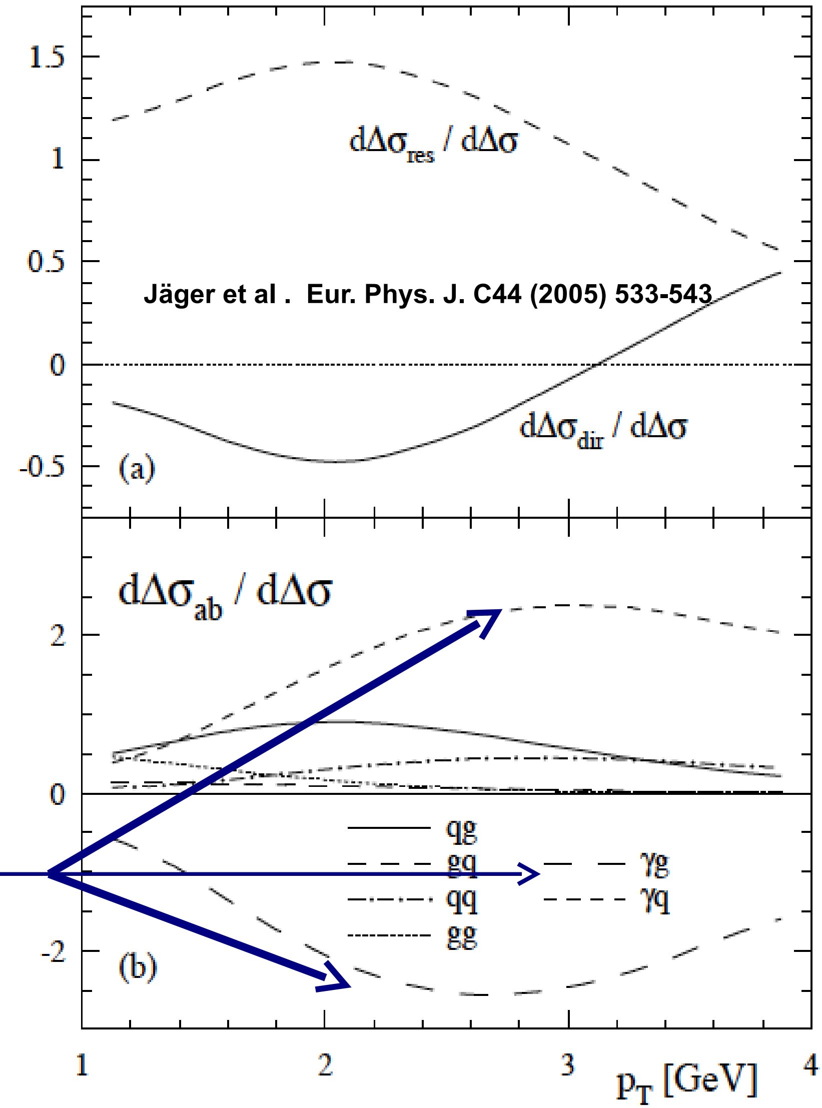
→ Low Q^2 (<0.1GeV/c) and high p_T.
→ NLO Calculation exists for Compass Kinematics.
→ This process has an advantage of higher production rates of hadrons than in (DIS) electro-production.
→ The selected hadron H is at high p_T(>1GeV/c) : large momentum transfer, p_T sets the scale



Partonic contributions to the production of high p_T hadrons at low Q^2 (<0.5GeV²) in lepton nucleon scattering. c.m= 18 GeV

NLO pQCD: Quasi Real Photo-production of high p_T hadrons





- → Low Q^2 (<0.1GeV/c) and high p_T.
- → NLO Calculation exists for Compass Kinematics.
- → This process has an advantage of higher production rates of hadrons than in (DIS) electro-production.
- → The selected hadron H is at high p_T(>1GeV/c) : large momentum transfer, p_T sets the scale
- → **Direct Processes** contribute with different sign (γg, γq)

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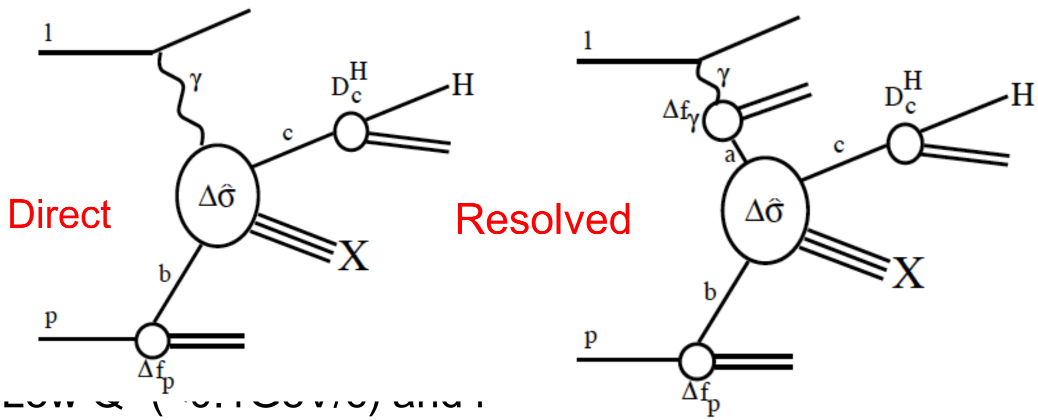

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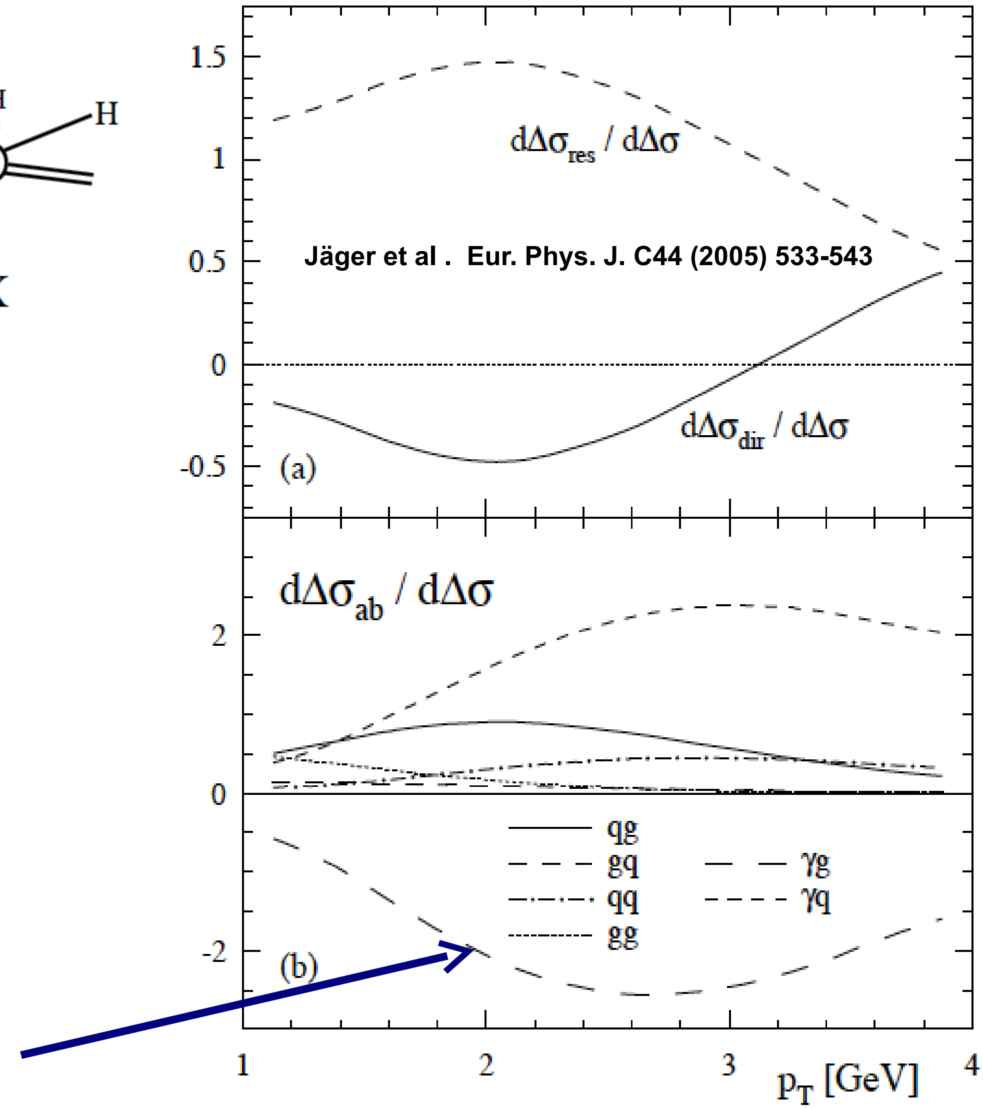
→ Direct Processes contribute with different sign (γg, γq)

→ **Resolved processes** contribute with the same sign for a positive ΔG (qg, gq, qq, gg)



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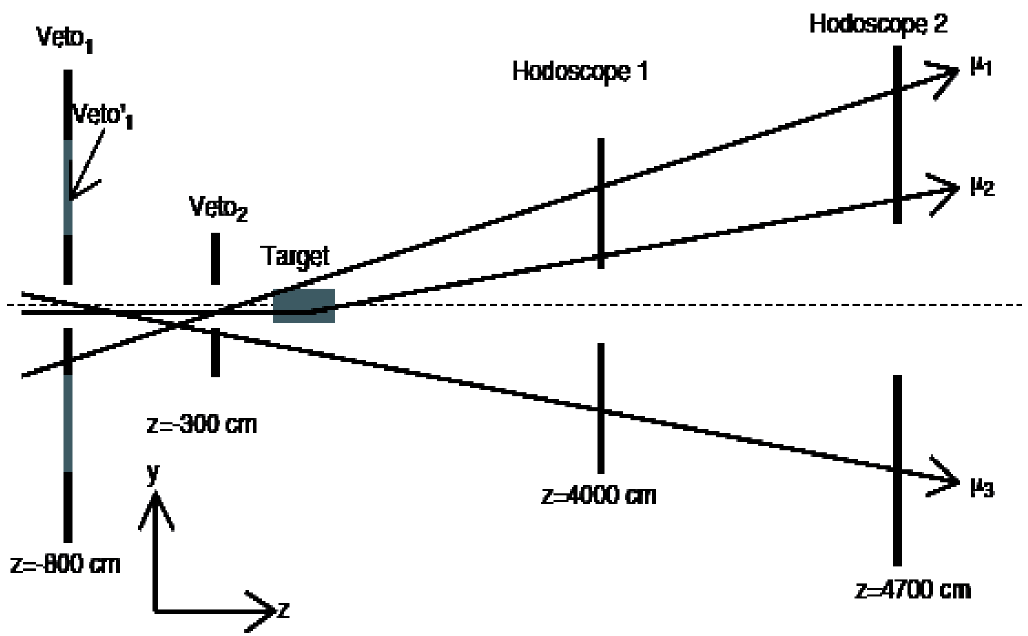
COMPASS Veto System

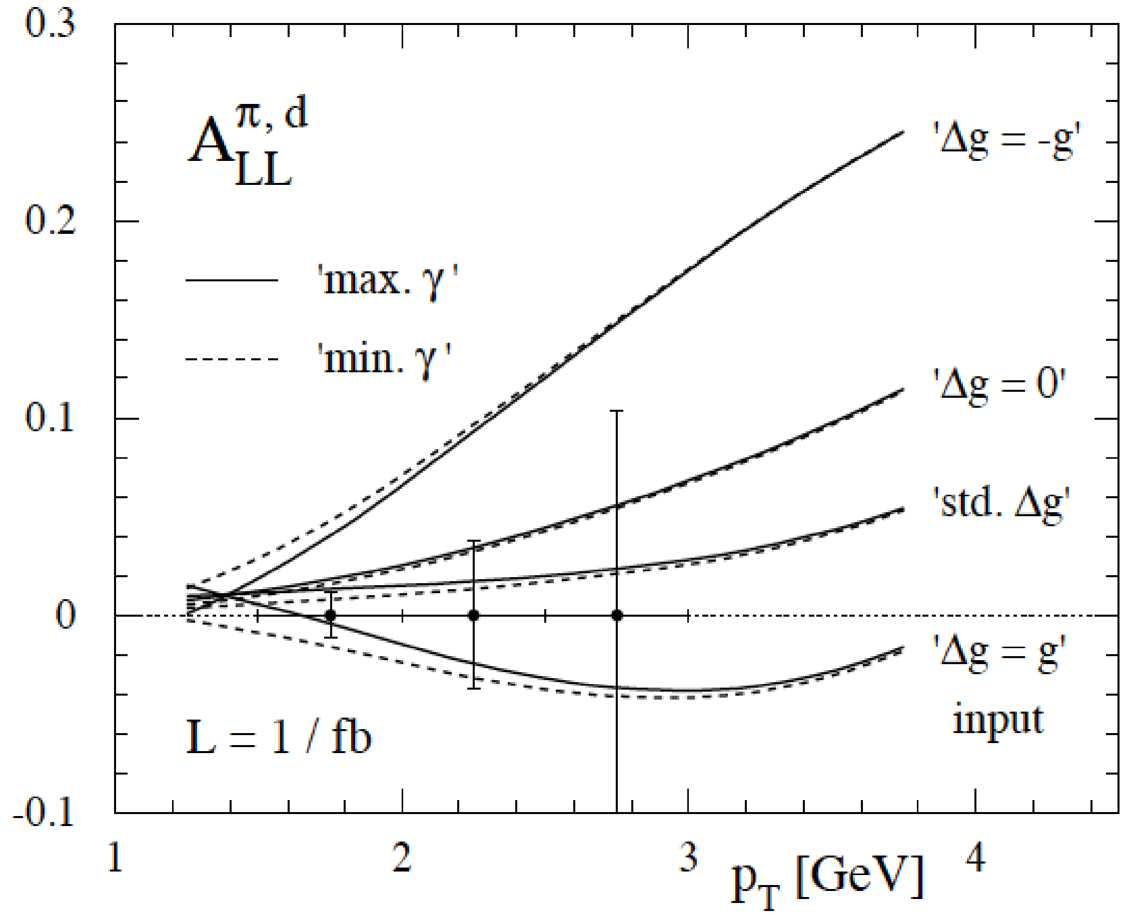
Bernet et al. NIMA 550(2005) 217-240.



The compass veto system prevents a large fraction of beam halo tracks from contaminating the trigger sample

During high veto signal times no triggers are taken (this includes good events)
→ **The "dead time" effect is taken into account in the Luminosity calculation**

The NLO pQCD parametrizations: Asymmetries



Max γ and min γ correspond to minimal and maximal saturation of the polarized photon densities.

B. Jäger et al. Eur. Phys J. C 36, 371-374 (2004)

→ Additional ongoing effort by A. Afanasiev to produce a parametrization that takes into account higher twist effects.
→ We expect to make available the comparisons between these Models with compass measurements soon.

Sources of Systematic Errors

1.**Luminosity extraction** Dead times, acquisition. 10%

2.**Background Estimate**: MonteCarlo + Data studies.
Two different hadronic shower models studied
GHEISHA and Fluka, compared to real data. 5% .

3.**Acceptance calculation:**
Multi-dimensional acceptance studies in terms of y, w, charge, p_T 3%