Status Report of HERMES

Pasquale Di Nezza

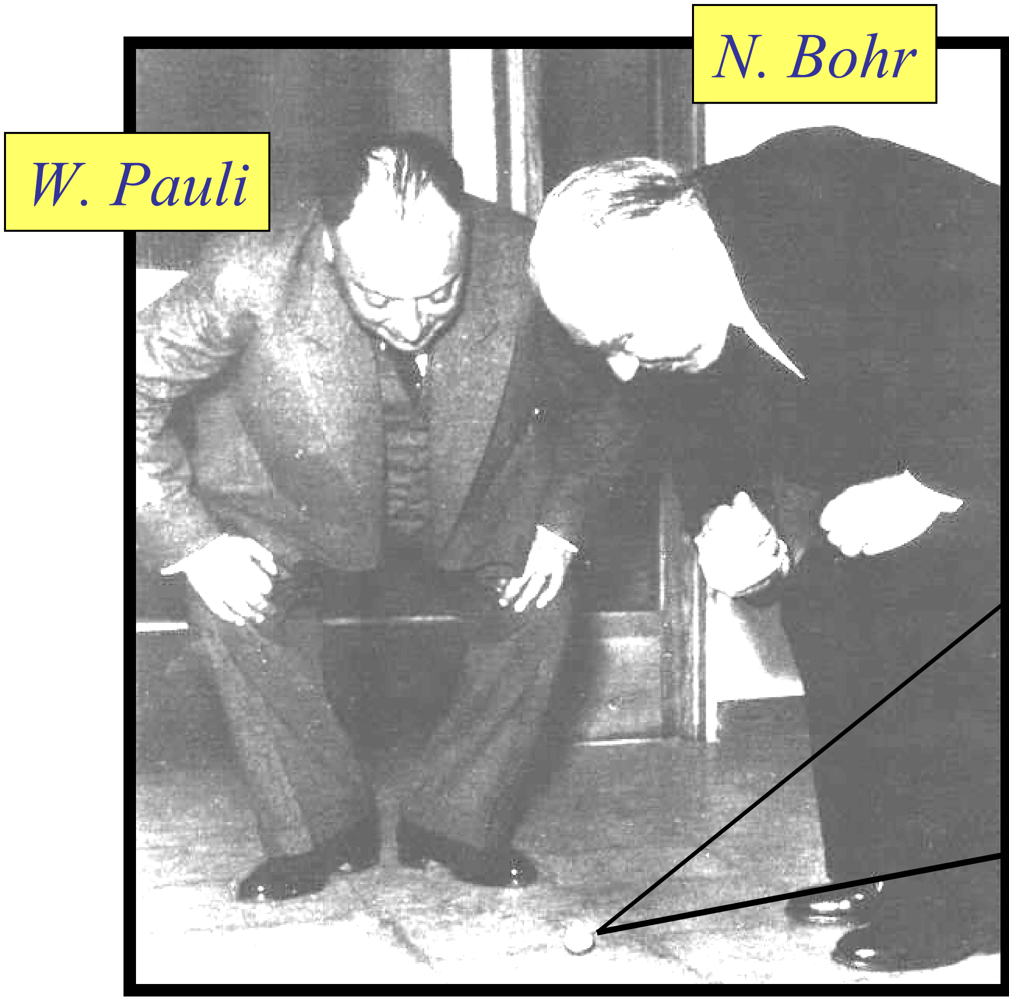
(on behalf of HERMES Collaboration)

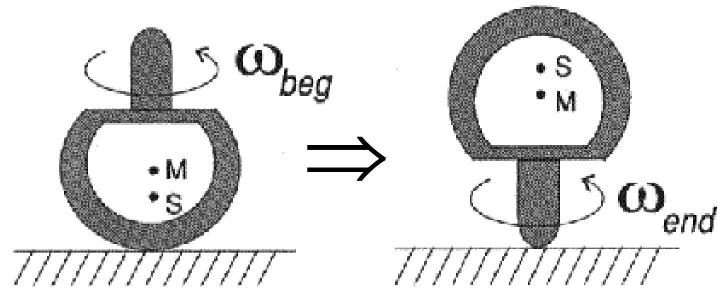
INFN Frascati

- First measurement of transversity
- Exotic baryons: the pentaquark
- The spectrometer and the data taking

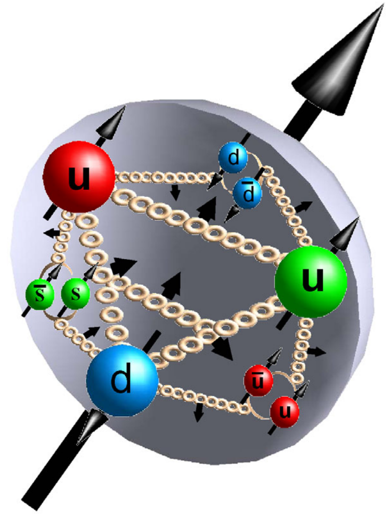
Physics Research Committee, DESY Oct 30/31, 2003

Even they were puzzled …





DIS + SIDIS cross section



$$d\sigma = d\sigma_{UU} + \cos 2\phi d\sigma_{UU} + \frac{1}{Q}\cos\phi d\sigma_{UU} + \lambda \frac{1}{Q}\sin\phi d\sigma_{LU}$$

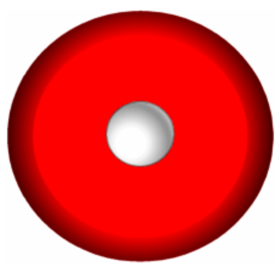
$$+ S_L\left[\sin 2\phi d\sigma_{UL} + \frac{1}{Q}\sin\phi d\sigma_{UL}\right] + \lambda S_L\left[d\sigma_{LL} + \frac{1}{Q}\cos\phi d\sigma_{LL}\right]$$

$$+ S_T\left[\sin(\phi+\phi_S)d\sigma_{UT} + \sin(\phi-\phi_S)d\sigma_{UT} + \sin(3\phi-\phi_S)d\sigma_{UT} + \frac{1}{Q}\sin(2\phi-\phi_S)d\sigma_{UT}\right]$$

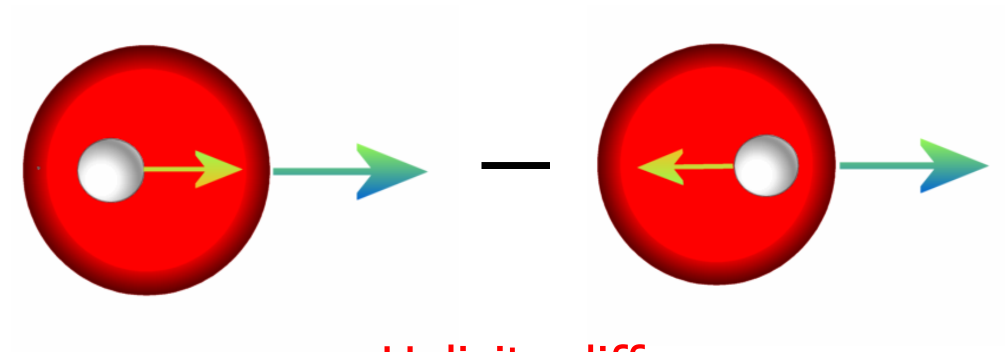
$$+ \lambda S_T\left[\cos(\phi-\phi_S)d\sigma_{LT} + \frac{1}{Q}\cos(2\phi-\phi_S)d\sigma_{LT} + \sin(3\phi-\phi_S)d\sigma_{UT}\right] + \ldots..$$

Operator decomposition of the Correlation Function at Twist-2

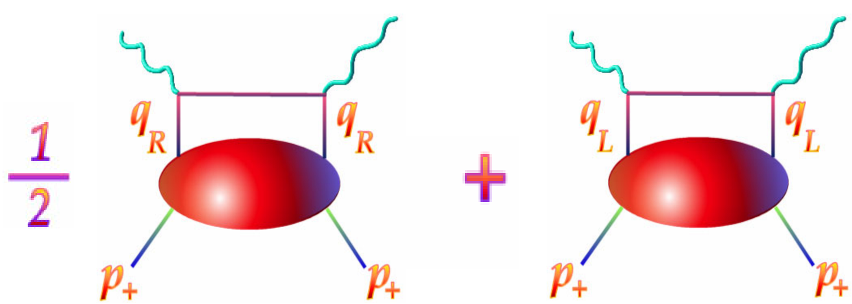
$$\Phi^{Tw2}_{Corr}(x) = \frac{1}{2}\left\{ f_1(x) + S_L g_1(x)\gamma_5 + h_1(x)\gamma_5 \gamma S_T \right\}\gamma^-$$

$f_1 =$ 

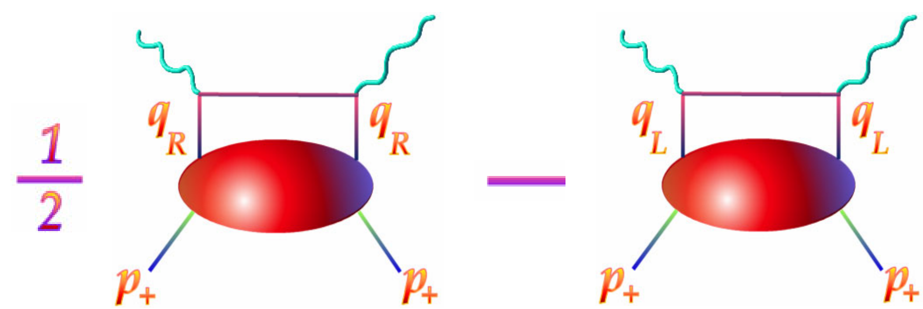
Unpolarized quark in
unpolarized nucleon

$g_{1L} =$ 

Helicity difference



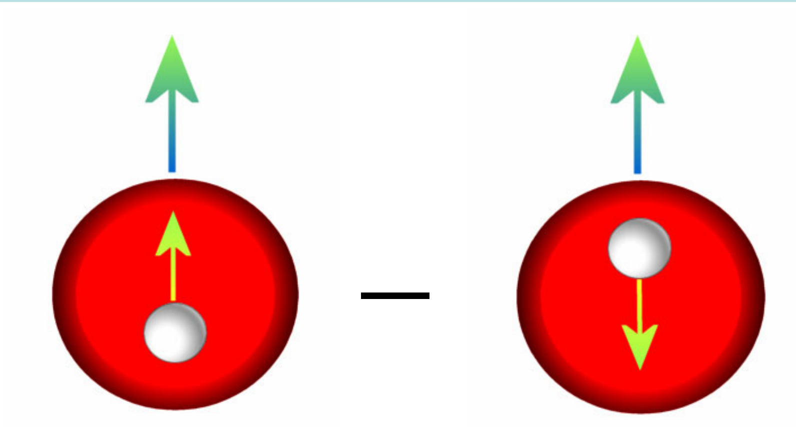
Extremely well known function

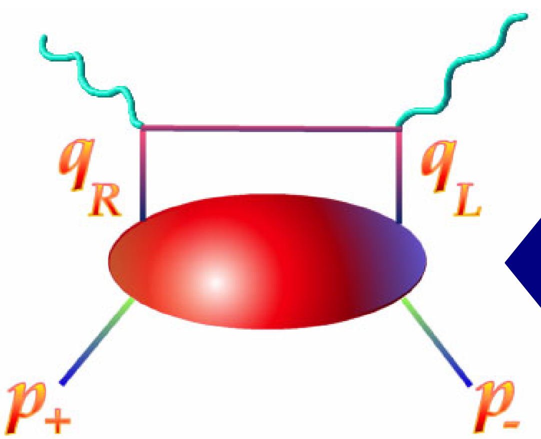


Function measured by HERMES
(EMC,SMC, E142-143-154-155)

Operator decomposition of the Correlation Function at Twist-2

$$\Phi^{Tw\,2}_{Corr}(x) = \frac{1}{2}\left\{ f_1(x) + S_L g_1(x)\gamma_5 + \boxed{h_1(x)}\gamma_5 \gamma S_T \right\}\gamma^-$$

$h_1 =$ 

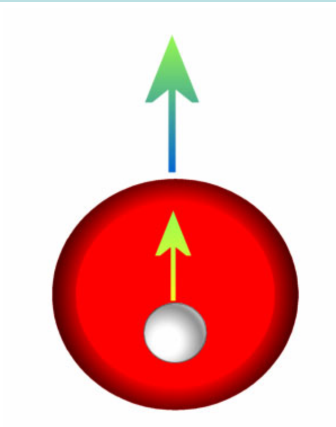


Single helicity flip

NOT ALLOWED IN E.M. INTERACTIONS

Operator decomposition of the Correlation Function at Twist-2

$$\Phi^{Tw\,2}_{Corr}(x) = \frac{1}{2}\{f_1($$

$h_1 =$  —

Peculiarity of transversity

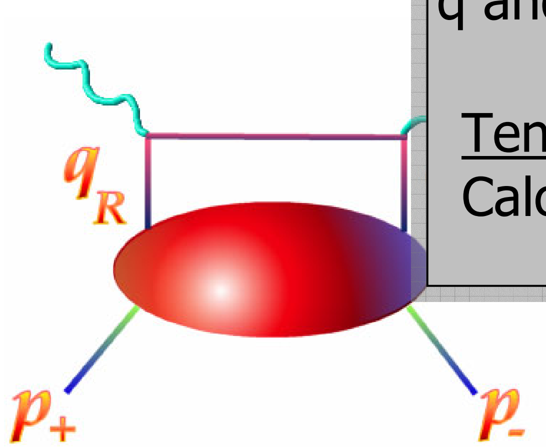
Relativistic nature of quark.
In absence of relativistic effects $h_1(x)=g_1(x)$

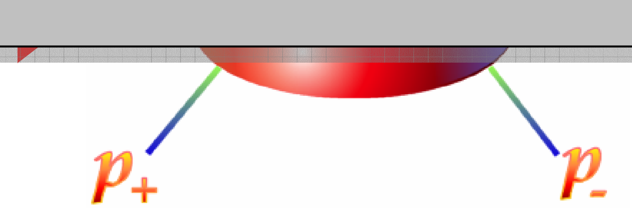
Q^2 -evolution. Unlike for $g_1^p(x)$,
the gluon doesn't mix with quark in $h_1^p(x)$

High sensitivity to the valence quark polarization
q and $\bar{q}$ have opposite sign.

Tensor charge: first moment of h_1.
Calculable by lattice QCD.

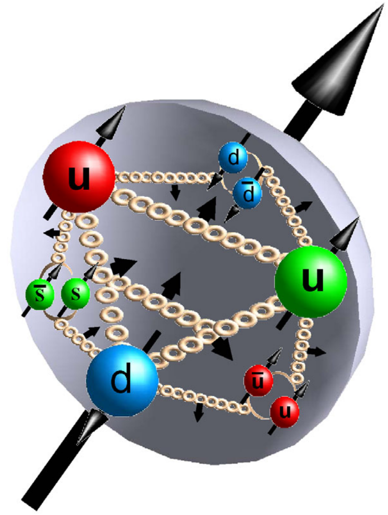
Single helicity flip





flip

DIS + SIDIS cross section



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$$+ S_T\Big[\underbrace{\sin(\phi+\phi_S)\, d\sigma_{UT}}_{h_1 \otimes H_1^{\perp}} + \underbrace{\sin(\phi-\phi_S)\, d\sigma_{UT}}_{f_{1T}^{\perp} \otimes D_1} + \mathrm{si}\ldots$$

$$\ldots s(\phi-\phi_S \ldots$$

(Collins)

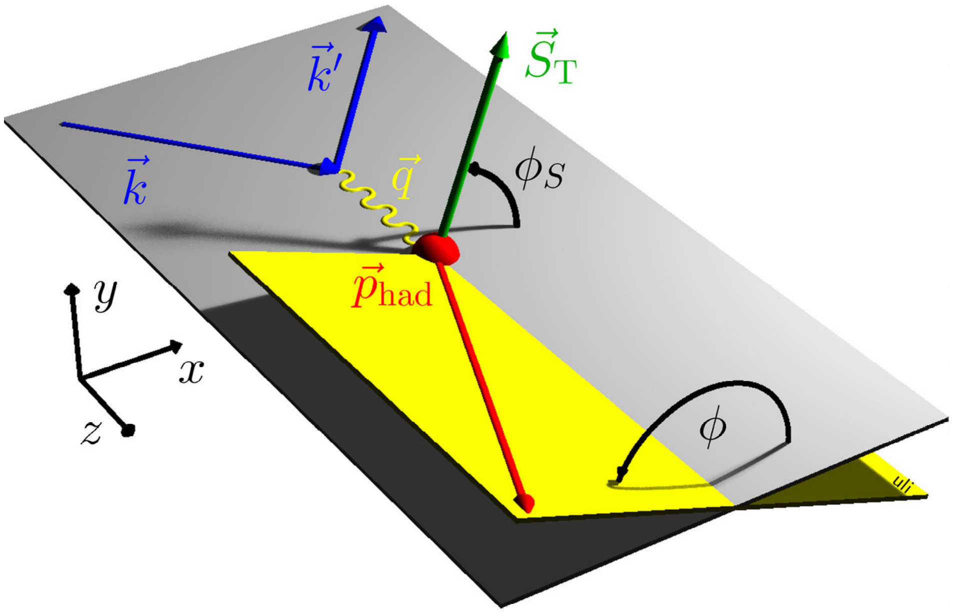
(Sivers)

Peculiarity of $f_{1t}^{\perp}$

- Chiral-even naïve T-odd DF
- Related to parton orbital momentum
- Violates naïve universality of PDF

\- Different sign of $f_{1t}^{\perp}$ in DY

Definition of Angles and Asymmetries



$$(\phi - \phi_S)$$

Angle of hadron relative to <u>initial</u> quark spin (Sivers)

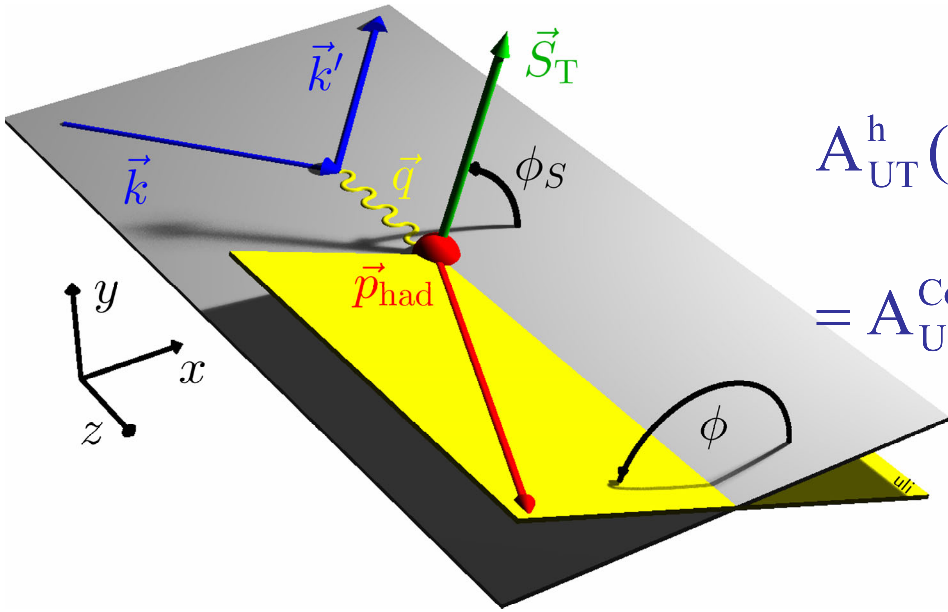
$$(\phi + \phi_S)$$

Angle of hadron relative to <u>final</u> quark spin (Collins)

- Sivers-Collins effects can be distinguished only with transverse polarised target.

- Large asymmetry has been measured in inclusive π production ($p^{\uparrow}p \rightarrow \pi X$) → jet axis not known. Both mechanisms involved.

Definition of Angles and Asymmetries



$$A_{UT}^{h}(\phi,\phi_S)=\frac{1}{|S_T|}\frac{N_h^{\uparrow}(\phi,\phi_S)-N_h^{\downarrow}(\phi,\phi_S)}{N_h^{\uparrow}(\phi,\phi_S)+N_h^{\downarrow}(\phi,\phi_S)}=$$

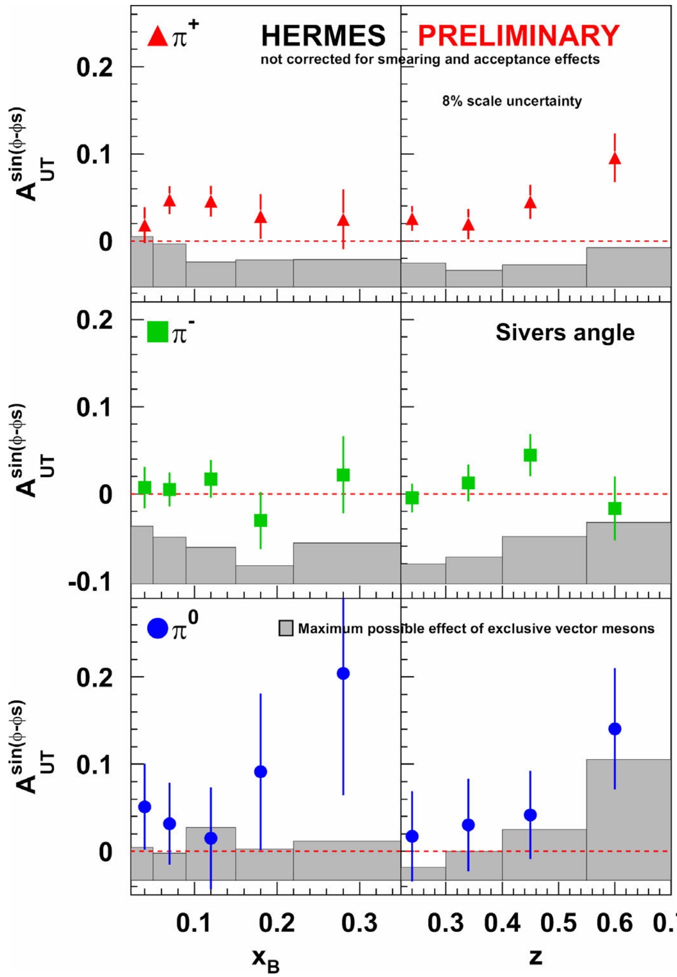
$$=A_{UT}^{\mathrm{Collins}}\sin(\phi+\phi_S)+A_{UT}^{\mathrm{Sivers}}\sin(\phi-\phi_S)$$

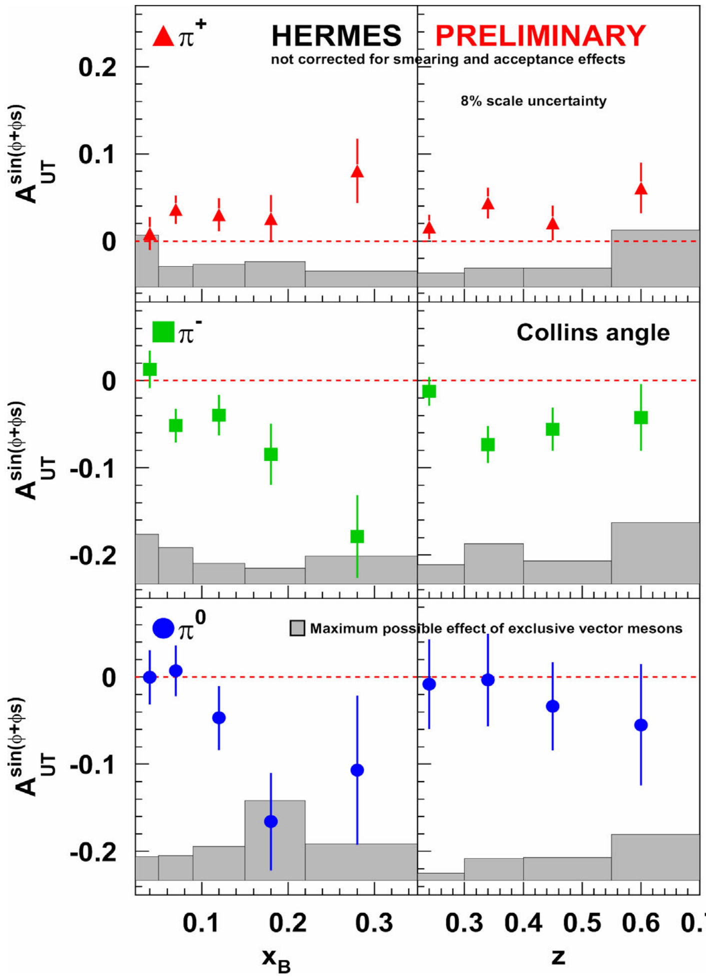
$$A_{UT}^{\mathrm{Collins}}=\frac{\left\langle |p_{h\perp}|/M_h\cdot\sin(\phi+\phi_S)\right\rangle_{UT}}{\left\langle 1\right\rangle_{UU}}=|S_T|\frac{\sum_q e_q^2 h_1^q H_1^{\perp(1),q\to h}}{\sum_q e_q^2 f_1^q D_1^{q\to h}}\cdot\frac{1-y}{1-y+y^2/2}$$

$$A_{UT}^{\mathit{Sivers}}=\frac{\left\langle |p_{h\perp}|/M_p\cdot\sin(\phi-\phi_S)\right\rangle_{UT}}{\left\langle 1\right\rangle_{UU}}=|S_T|\frac{\sum_q e_q^2 f_{1T}^{\perp,q} D_1^{q\to h}}{\sum_q e_q^2 f_1^q D_1^{q\to h}}$$

Transverse asymmetry for π^+, π^-, π^0

Sivers Moments | Collins Moments



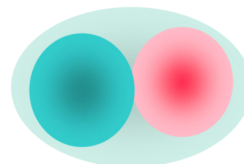


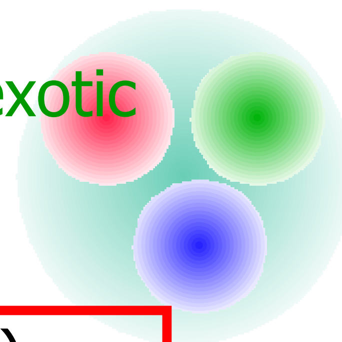
- First measurement of naïve T-odd DF in DIS (orbital mom)
- Opposite sign from RHIC DY ?

- Much of plausible value ranges of transversity and disfavoured Collins function are excluded

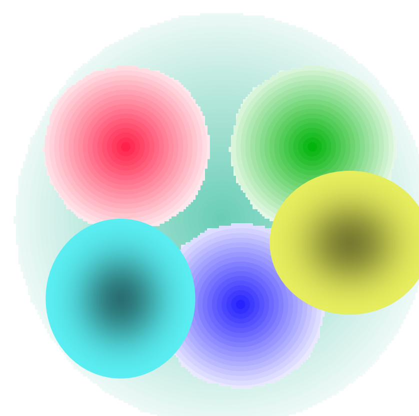
Hadron spectroscopy

- Standard Quark Model
  - allows hadrons as
    - mesons ($q\bar{q}$)
    - baryons (qqq)





  - also allows "non-standard" or exotic hadron states
    - multiquark mesons ($qq\overline{qq}$)
    - multiquark baryons ($qqqq\bar{q}$)
      -> appear as baryon resonances
    - hybrid states ($q\bar{q}g$ or $qqqg$)
    - dibaryons ($qqqqqq$)
    - glueballs



Search for Exotic Baryon States

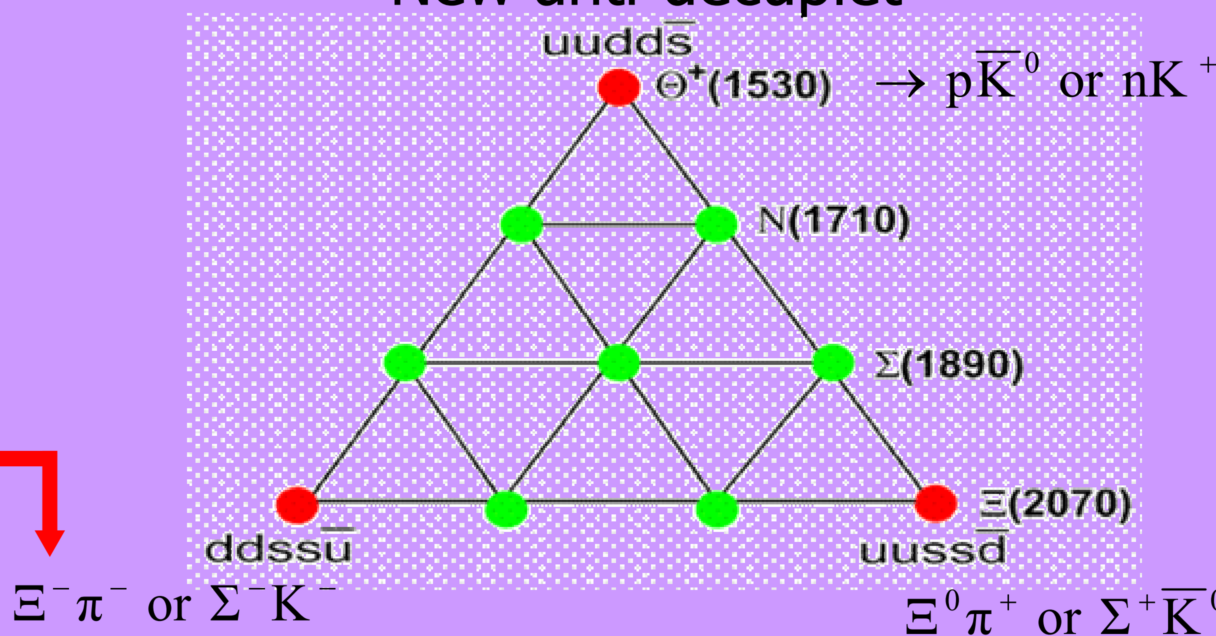
<u>Predictions:</u>

Bag models (Jaffe ’77; De Swart ’80): 1.8-1.9 GeV

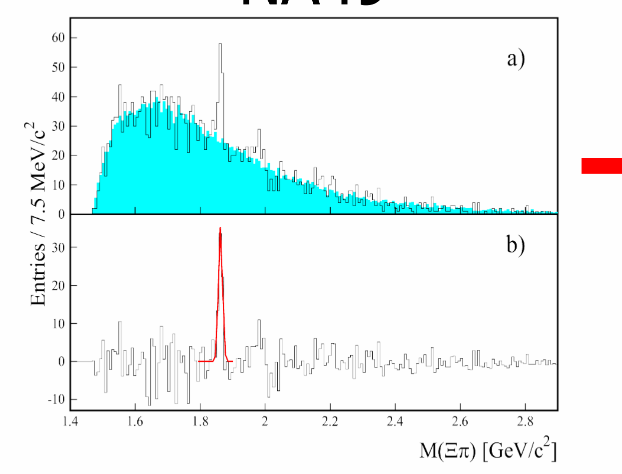
Skyrme model (Praszalowicz ’87, Walisser ’92): 1.3 – 1.8 GeV

Chiral-Soliton Model (Diakonov, Polyakov ‘97)

New anti-decuplet

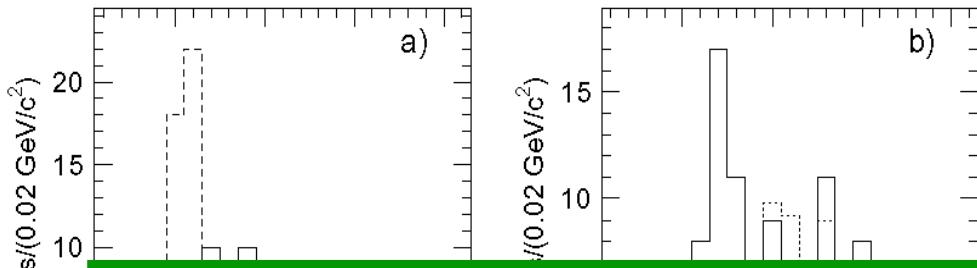


NA49

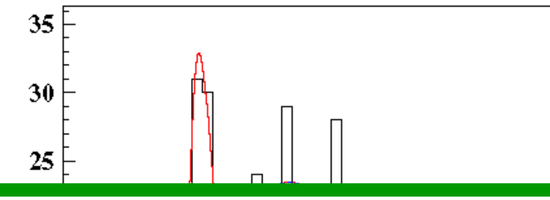


The 3 corners are exotics

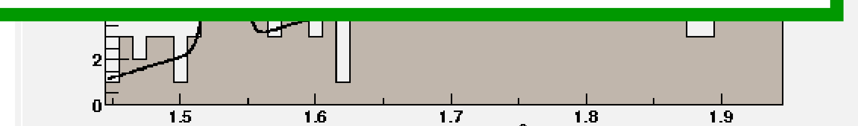
Spring-8



CLAS

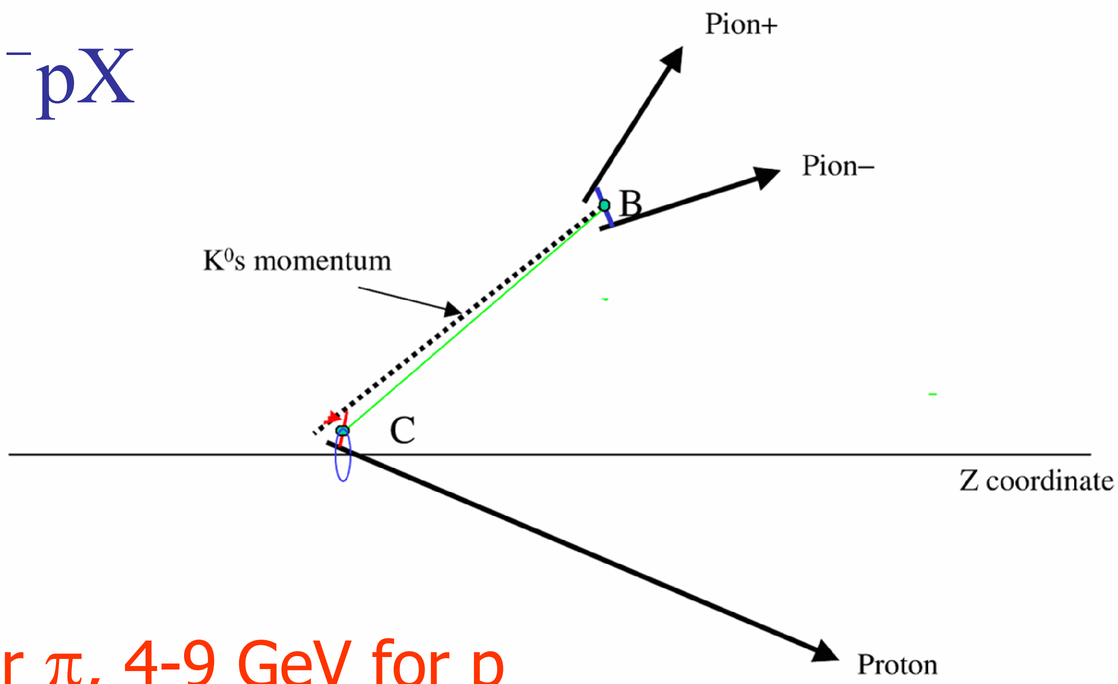


- Complete Particle Identification with high efficiency: 98% (π), 88% (K), 85% (p)
- Direct reconstruction: detection of each decay ptc, Inv mass reconstuction (other exp. missing mass)
- Excellent invariant mass systematics: ± 2 MeV



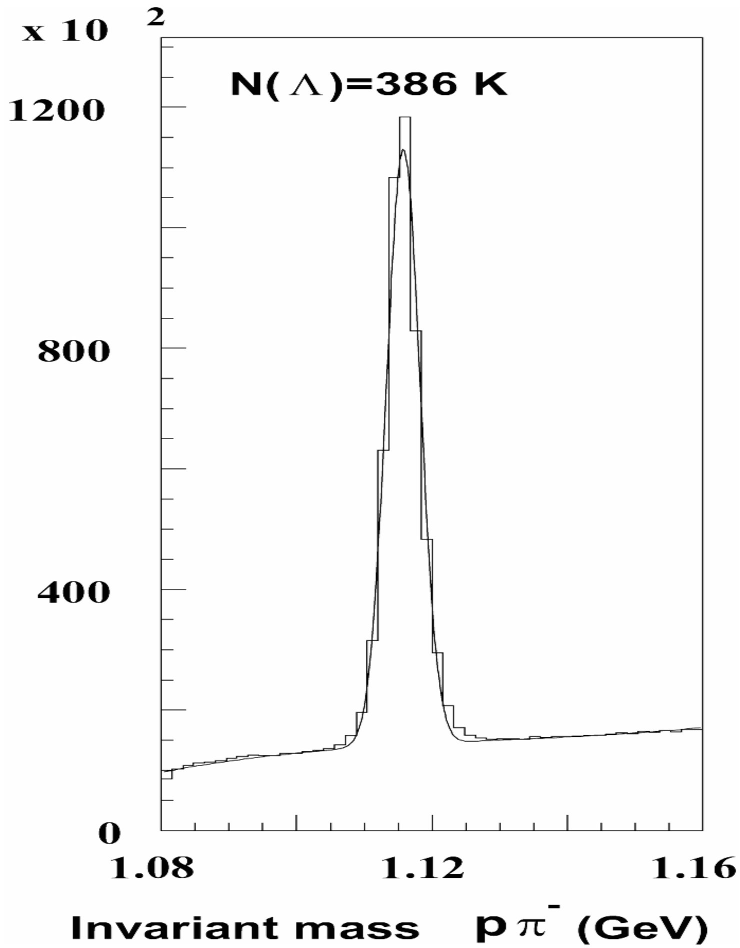
Event Reconstruction

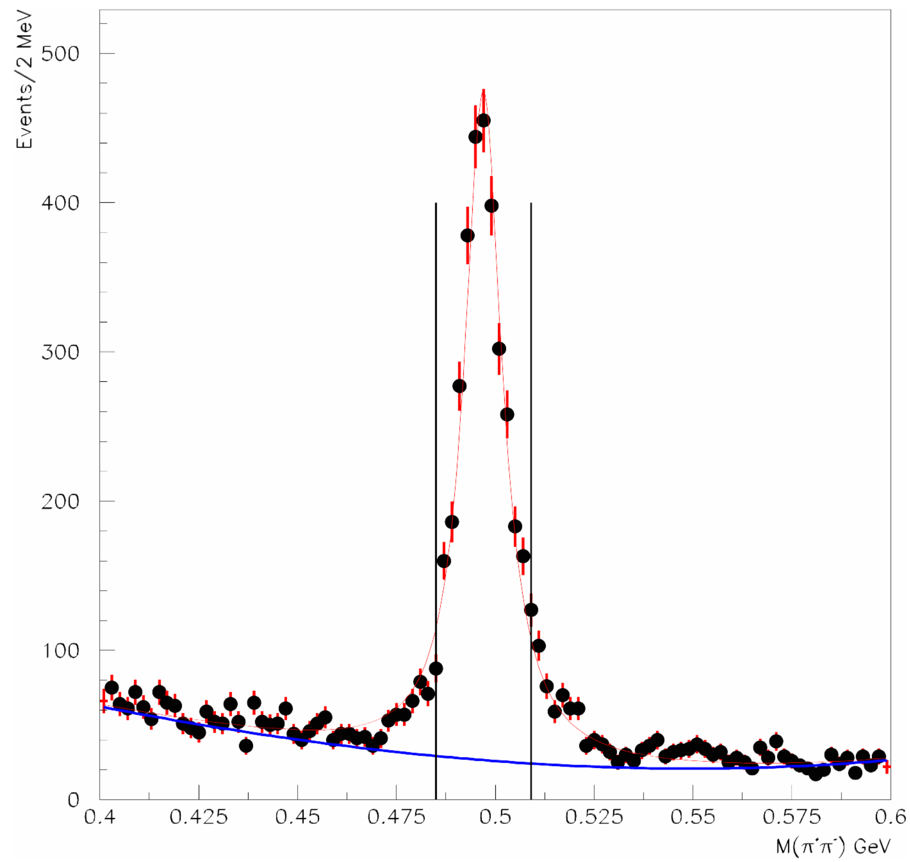
$$e^+d \rightarrow K_S^0 pX \rightarrow \pi^+\pi^- pX$$



- RICH ID: 1-15 GeV for π, 4-9 GeV for p
- K_S decay length>7 cm
- Distance cut: $\pi^+\pi^-$, K_S p, θ^+ beam
- Collinearity K_S $\pi\pi$ < 45 mrad
- 485< K_S-mass<509 MeV
- No Λ

Particle Identification Proof

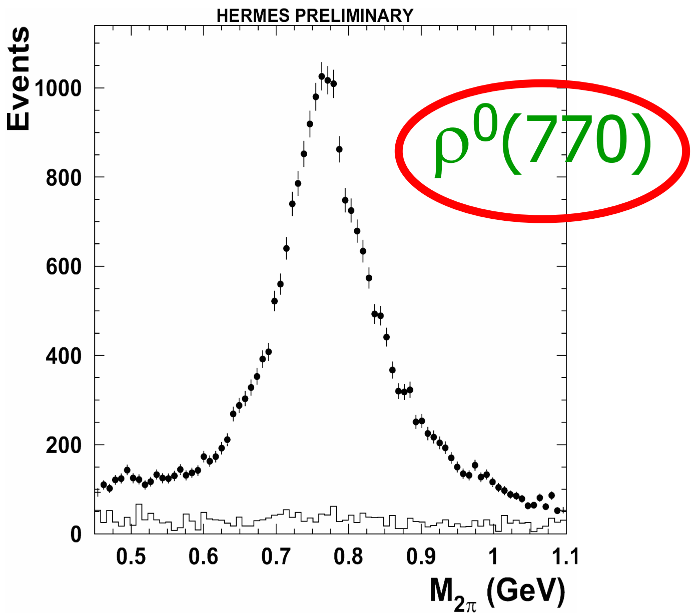


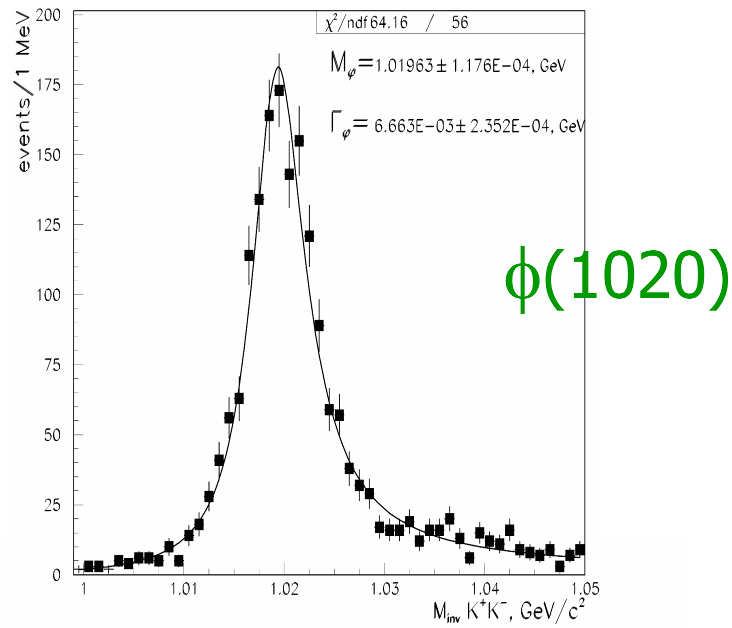


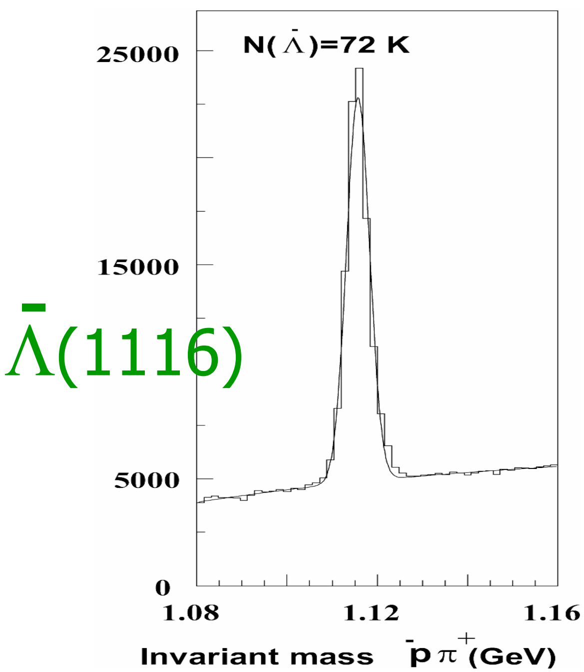
Good identification of Λ means clear identification of p

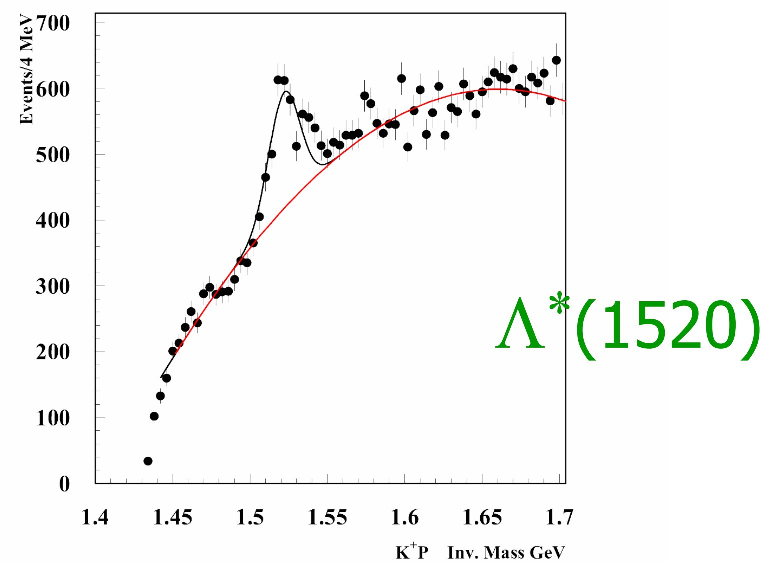
Good K_s identification within the kinematical cuts of this analysis

Detector Mass calibration









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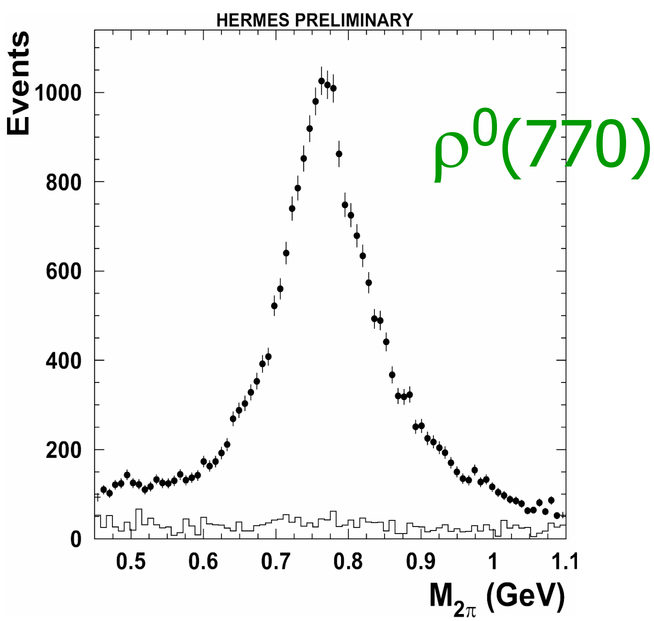

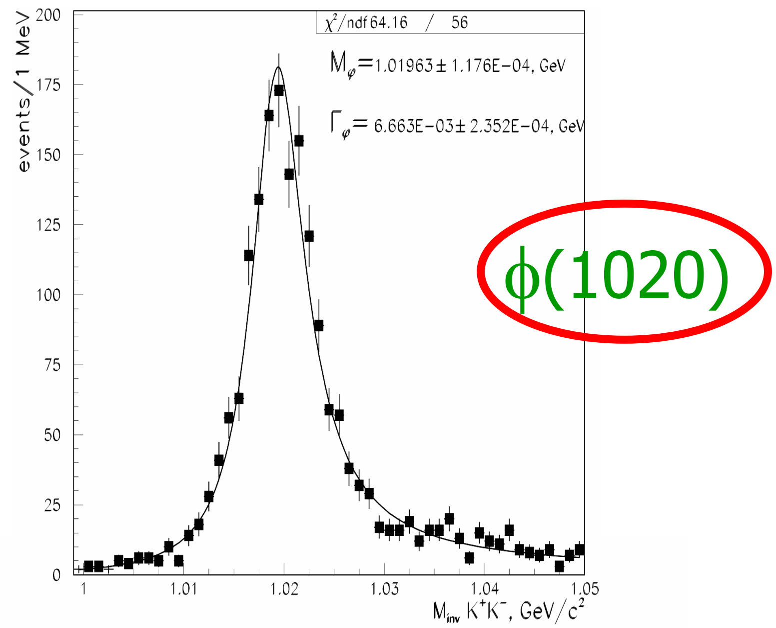

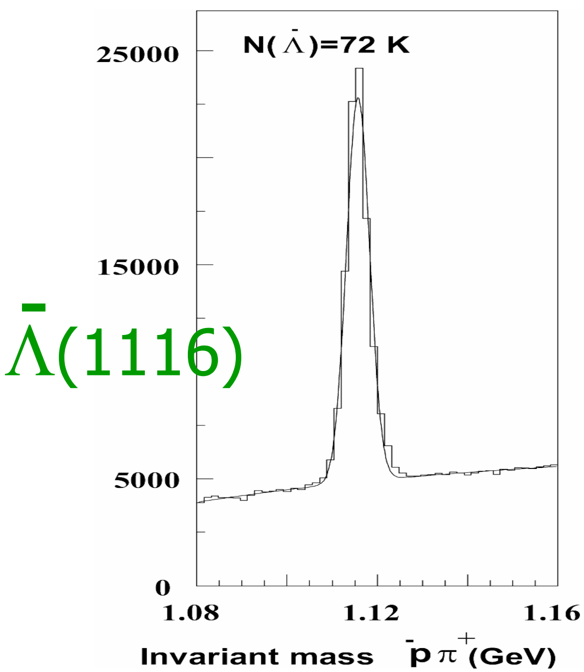

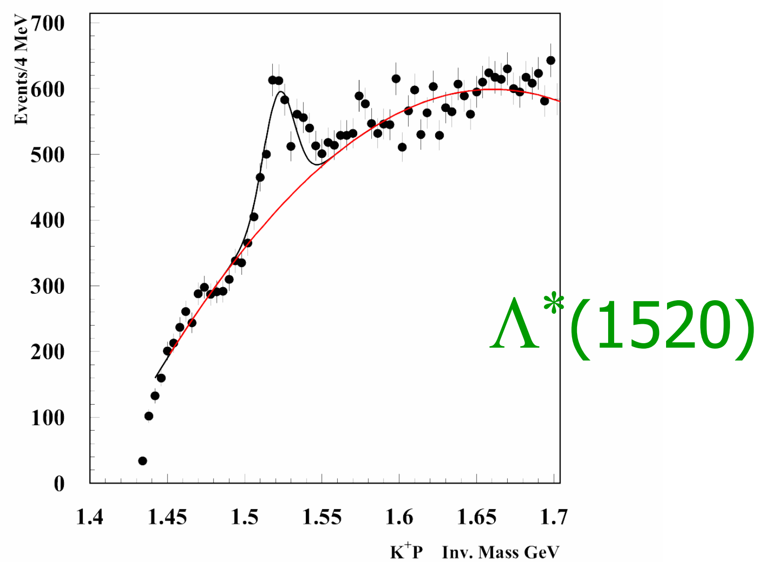

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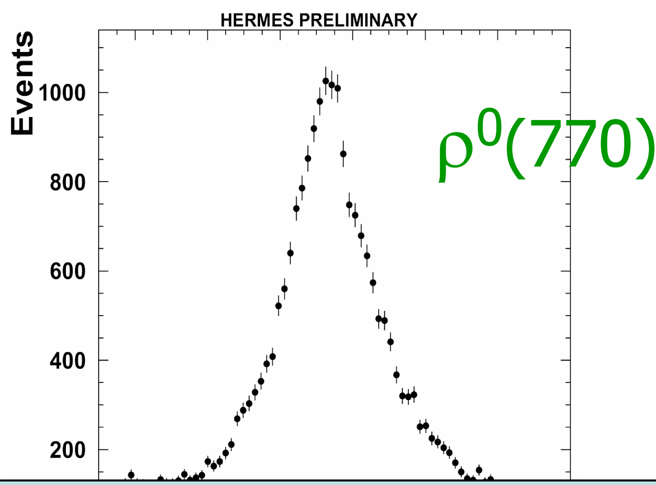
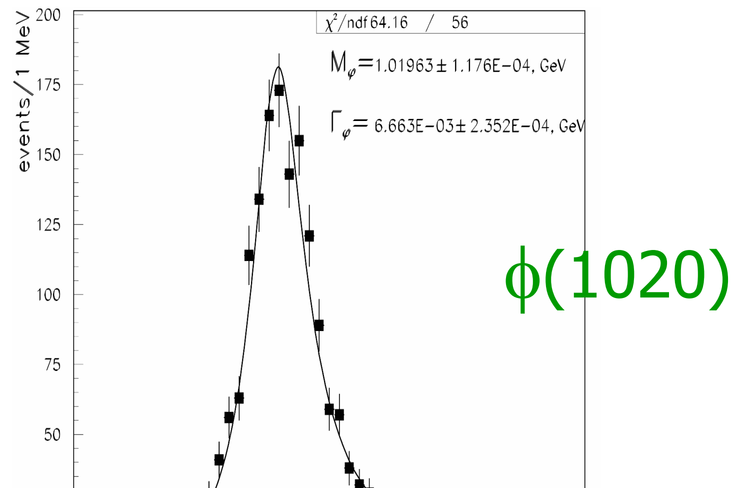
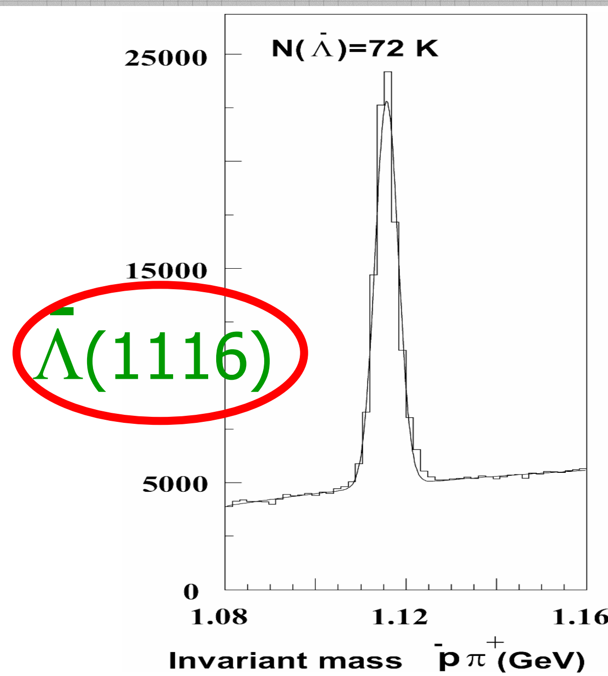
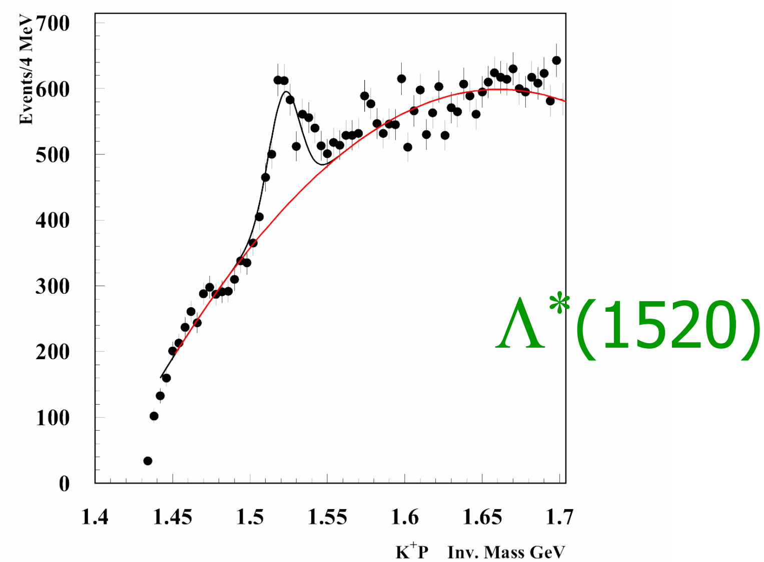




Masses in agreement with PDG values ± 2 MeV

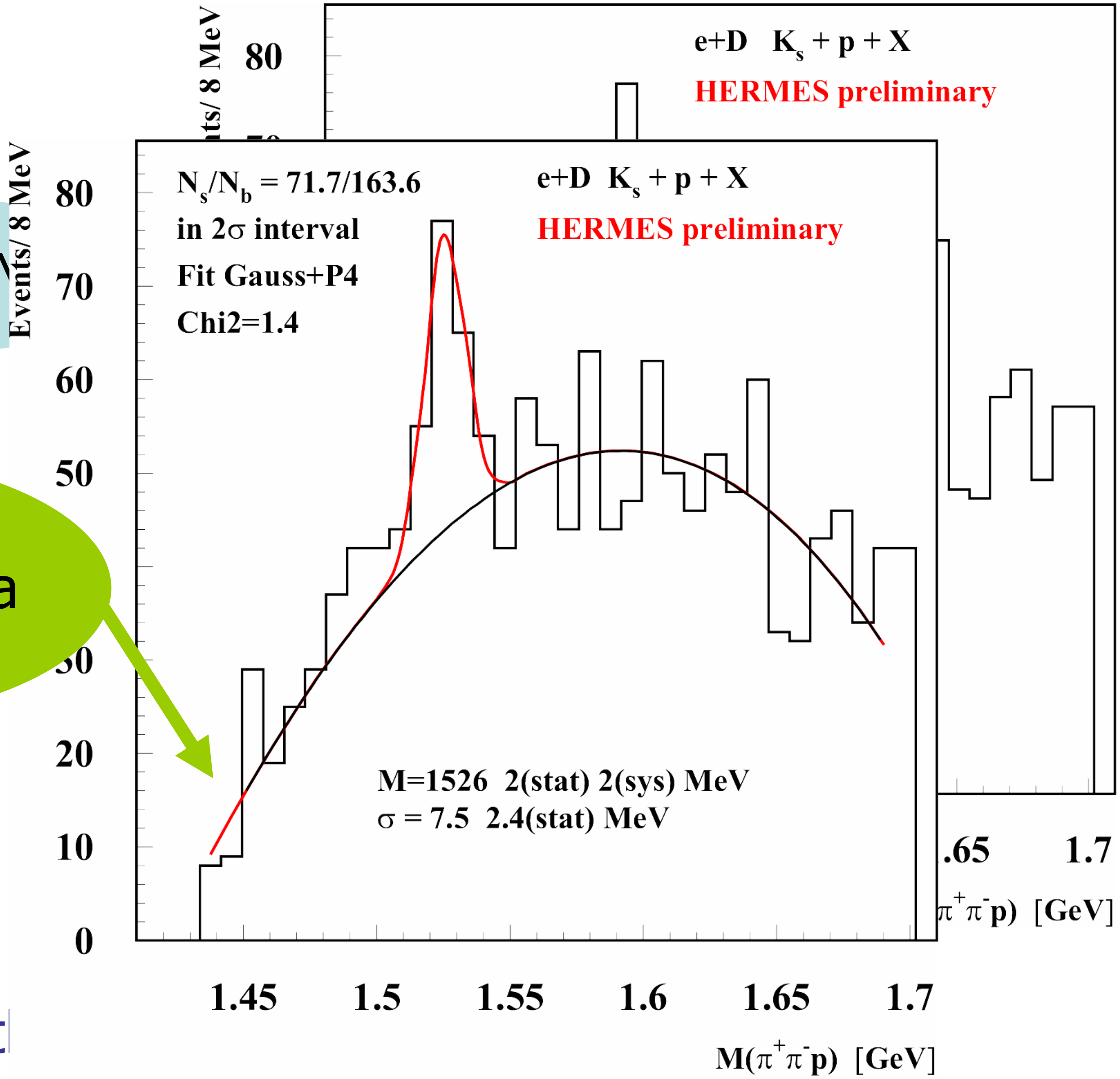




Measured Invariant Mass

Excess at 1526 M

Background approximated by a polynomial

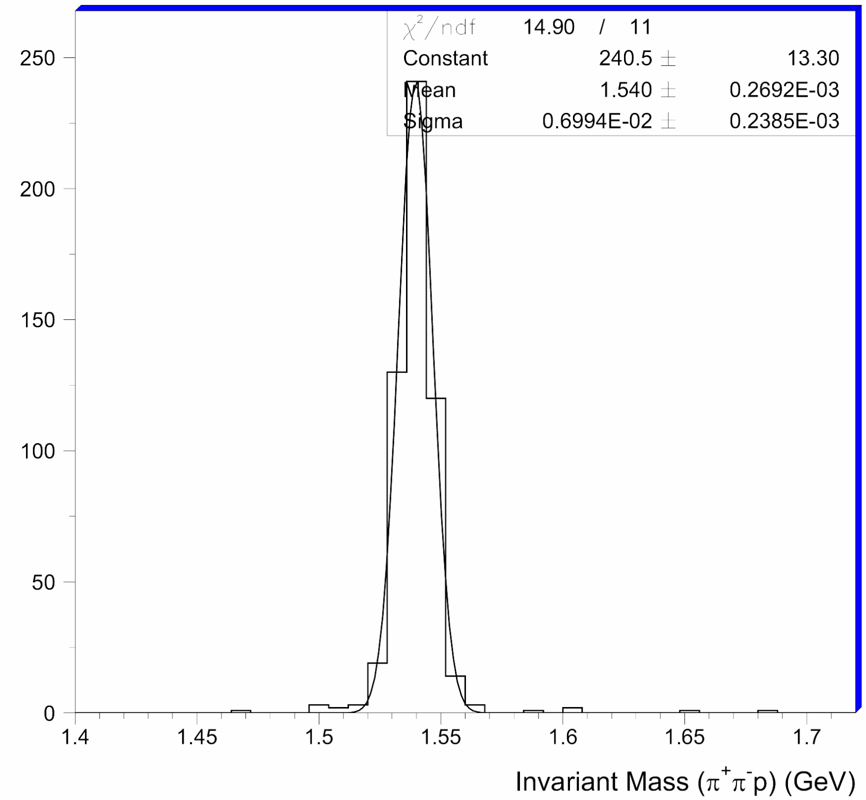


Widt

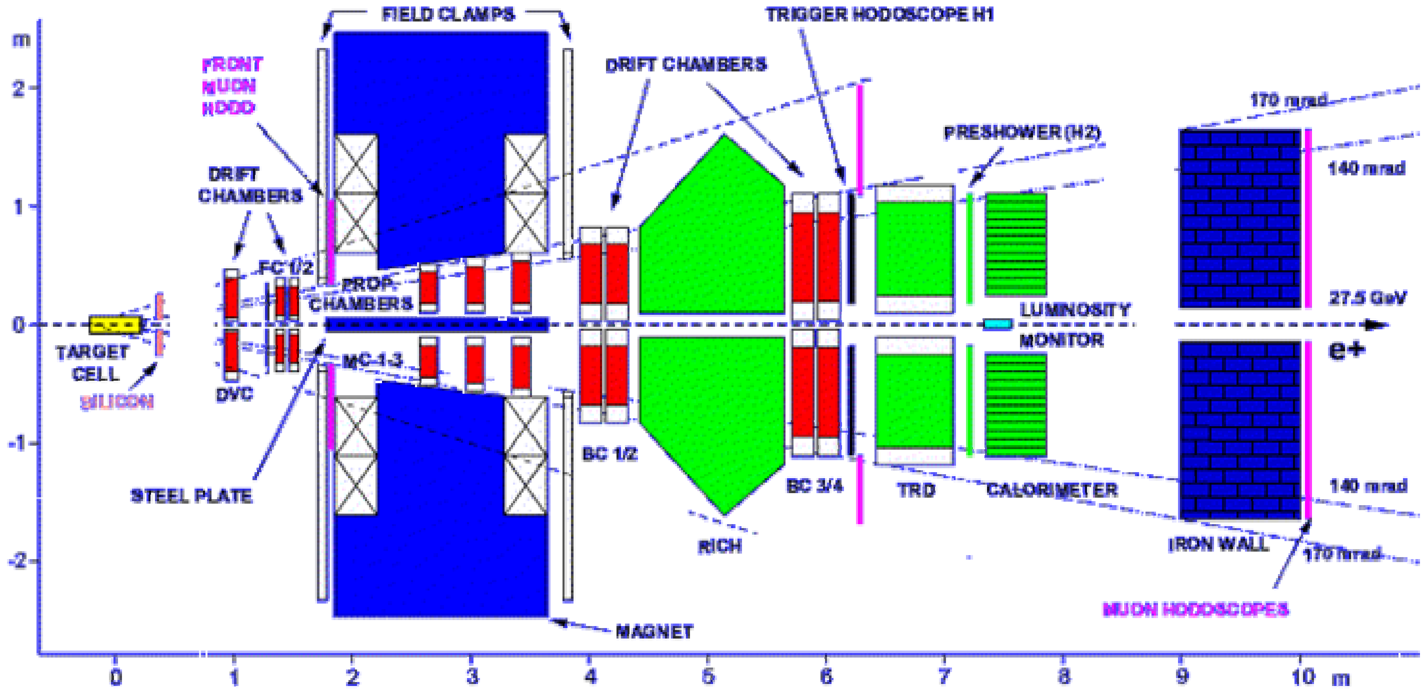
Monte Carlo Simulation

- Simulated resonance at 1540 MeV
- Simulated Γ=2 MeV
- Decay in $K_S p$
- Full detector simulation

- Recons. Mass at 1540 ± 0.3 MeV
- Recons. σ=7 ± 0.2 MeV



Status of the Spectrometer



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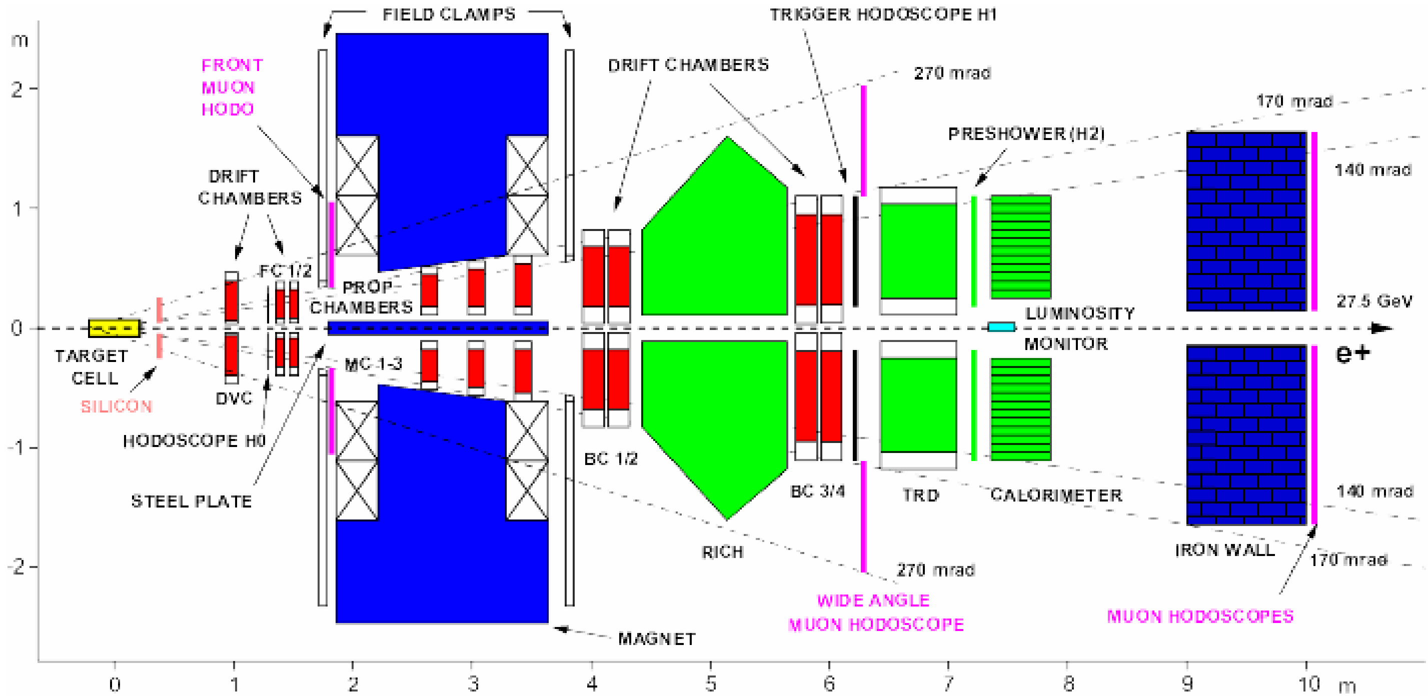

Spectrometer fully debugged after the shutdown
Each single detector is operative!
80K DIS collected in 2003-runII with transverse polarized hydrogen target

Conclusions

- First observation of non-zero Sivers effect
- Sizeable Collins asymmetries measured for π^0 and π^-
- A kind of brain storm is underway for model interpretation

2003: milestone from HERMES transverse asymmetries
>2004: results from HERMES, COMPASS, BELLE (RHIC-rIII, CLAS)

Conclusions

- First observation of non-zero Sivers effect
- Sizeable Collins asymmetries measured for π^0 and π^-
- A kind of brain storm is underway for model interpretation
- A narrow exotic baryon resonance has been directly reconstructed
- Most precise determination of the mass $\begin{cases} M=1526 \pm 2 \pm 2 \text{ MeV} \\ \sigma=7.5 \pm 2.4 \text{ MeV} \end{cases}$
- Background description and Monte Carlo simulation

Taking data for physics

Pasquale Di Nezza

INFN Frascati