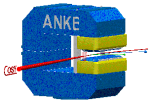


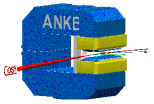
ANKE Experiment at COSY

Andro Kacharava
(Erlangen University)
ANKE Collaboration

Outline

- Experimental Program
- Experimental Tools
- Selected Results
- Summary & Outlook

Introduction: experimental program



Goal:

Study of 3-body final states aiming to extract basic spin-dependent two-body scattering information

Tools:

- Hadronic probes (p, d)
- Double polarization (beam/target)

Topics:

1. NN scattering	↔	**Nuclear forces**
2. Meson production	↔	**ChPT, phenomenological models, FSI**
3. Hyperon production	↔	**SU(3) symmetry**

COSY proposal #152
ArXiv:nucl-ex/0511028

Status:

Towards the double-polarization measurements (January 2007)

Experimental tools: COSY, ANKE, STT, PIT

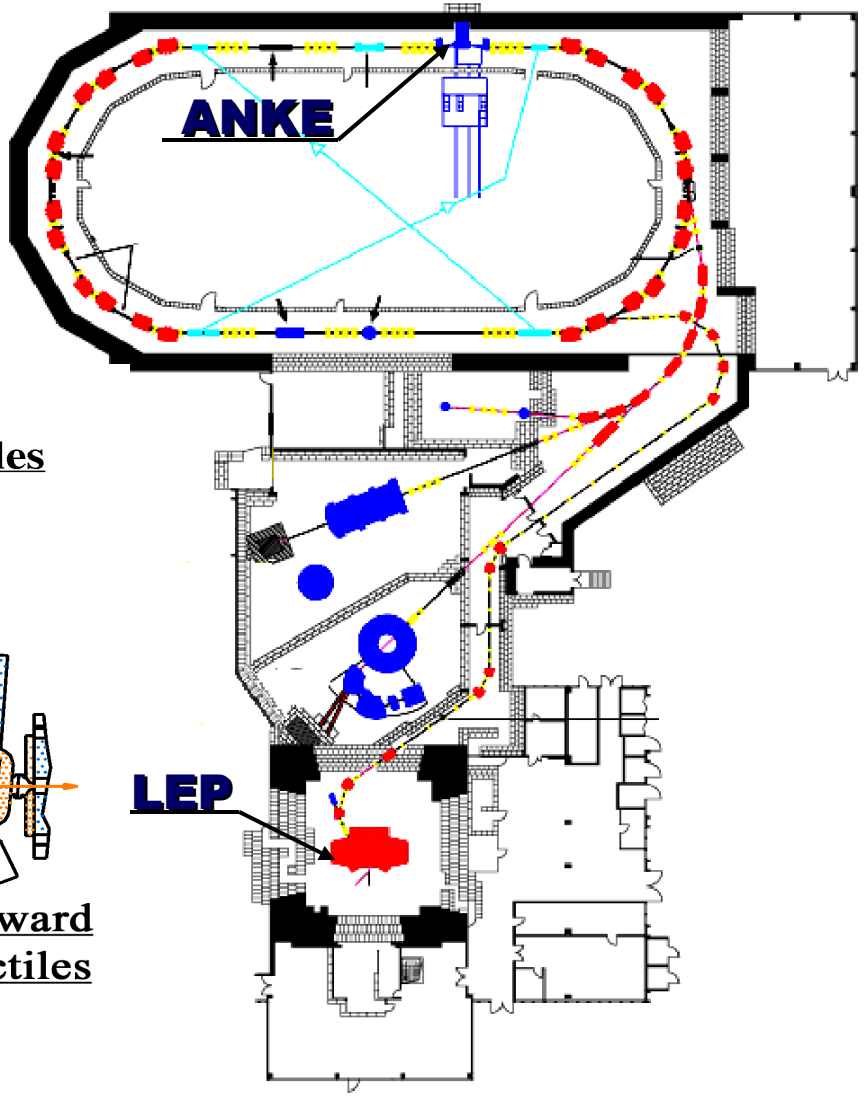
- **ANKE** Magnetic Spectrometer
- **STT**- **S**ilicon **T**racking **T**elescope
- **PIT** - **P**olarized **I**nternal **T**arget:

  ABS - **A**tomic **B**eam **S**ource

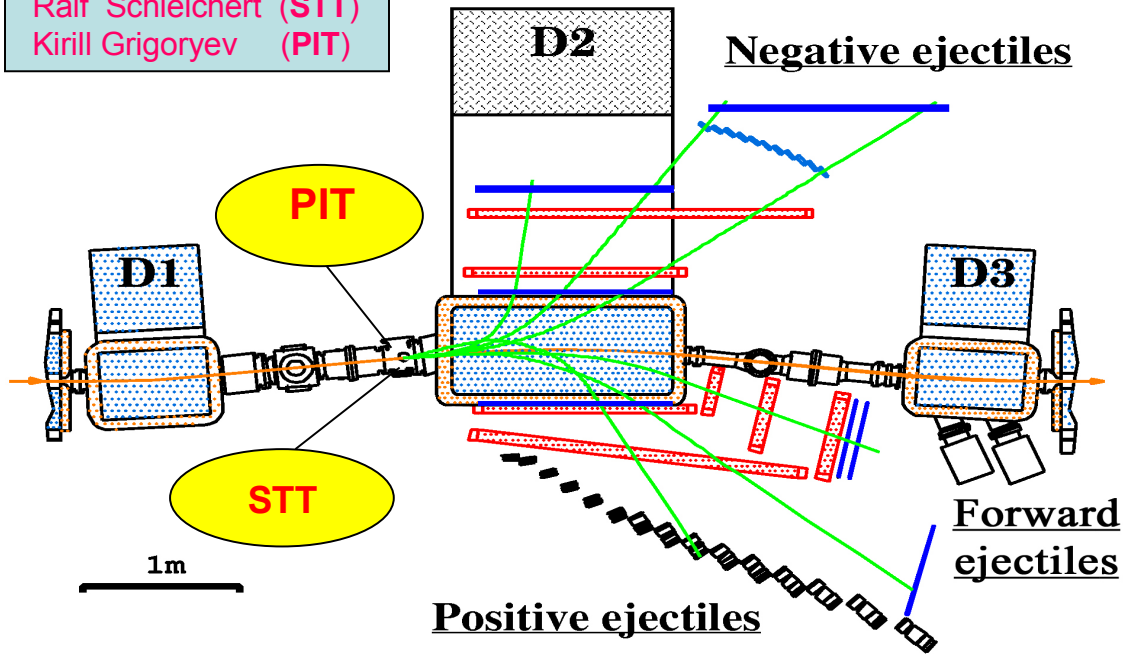
  SC - **S**torage **C**ell

  LSP - **L**amb-**S**hift **P**olarimeter

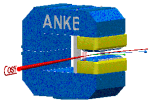
COSY: Polarized/Unpolarized beams



Ralf Schleichert (**STT**)
Kirill Grigoryev (**PIT**)



NN scattering: spin observables



np system

- Polarized charge-exchange reaction $dp \rightarrow (2p)n$
- Direct reconstruction of the spin-dependent *np* amplitudes

- **Single spin experiment (✓)**

  Measurement of: $\frac{d\sigma}{dq}, T_{20}, T_{22} \Rightarrow |\gamma|^2 + |\beta|^2, |\delta|^2, |\varepsilon|^2$

  ► overall magnitudes of np spin-amplitudes (0.6 -1.15 GeV)

- **Aim of the double-polarization measurement**
  - Measurement of spin-correlations $C_{y,y}$ & $C_{x,x}$ ► relative phases

► Polarimetry standards for double-polarized nuclear reactions

NN scattering: analyzing powers

$\vec{d}p \rightarrow (pp)_{^1S_0} n$

Transition from deuteron to $(pp)_{^1S_0}$:

pn → np spin flip

np spin-dependent amplitudes:

$$\frac{d\sigma}{dq}, T_{20}, T_{22} \Rightarrow |\gamma|^2 + |\beta|^2, |\delta|^2, |\varepsilon|^2$$

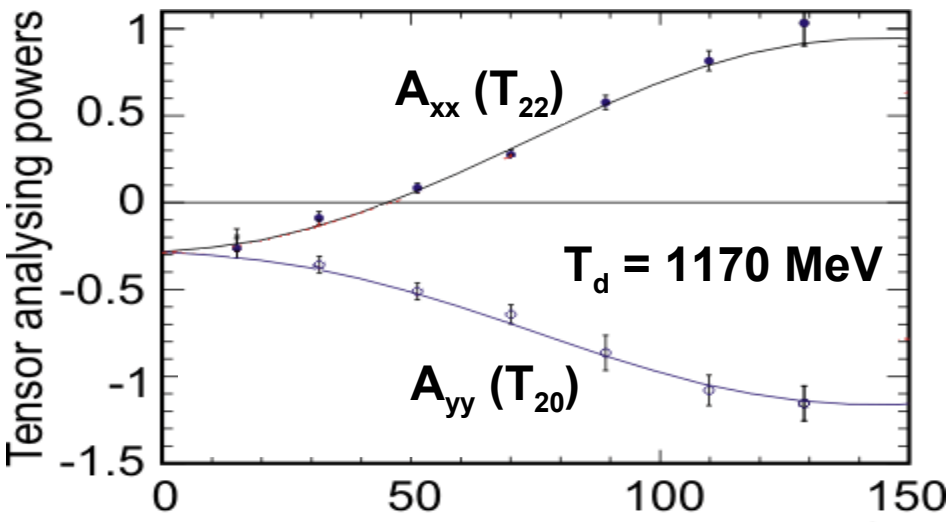
Results:

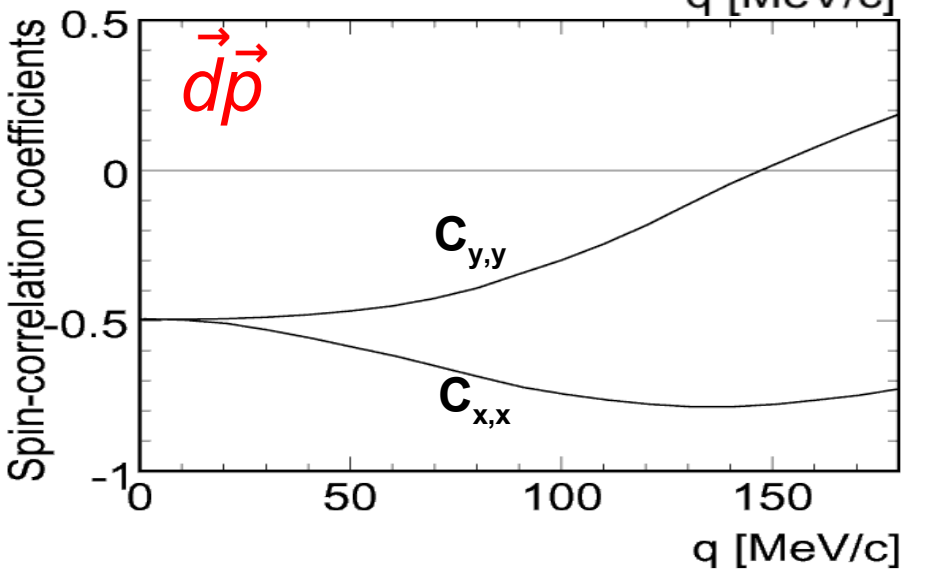
- Method works at T_n = 585 MeV
- Application to higher energies
- T_d=2.3 GeV (*in progress*)

Next step:

- Double polarized → $C_{y,y}$, $C_{x,x}$
  => relative phases

D.Chiladze et al. Phys. Let. B 637, 170 (2006)





Meson production: π meson

- $pp \rightarrow (pp)_s \pi^o$ T_p= 350 … 950 MeV
- $pn \rightarrow (pp)_s \pi^-$ T_p= 350 MeV

- low energy:
  provide data of relevance for ChPT studies
- higher energies:
  crucial extra test of pion production dynamics

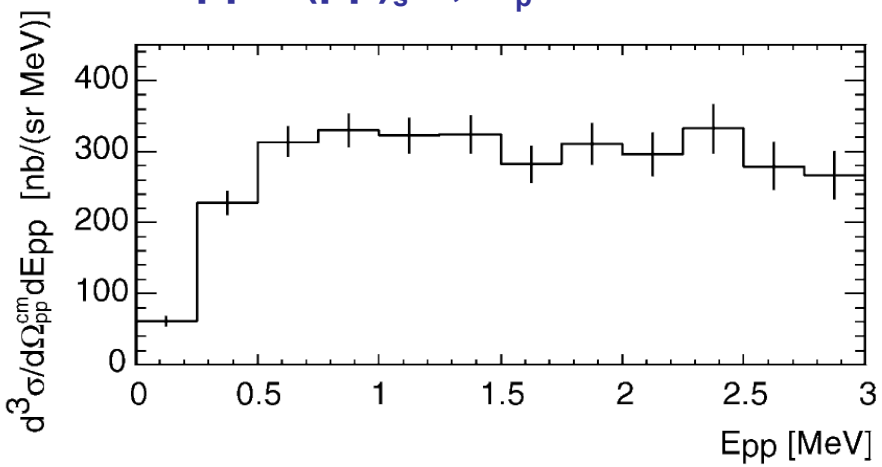
Result:

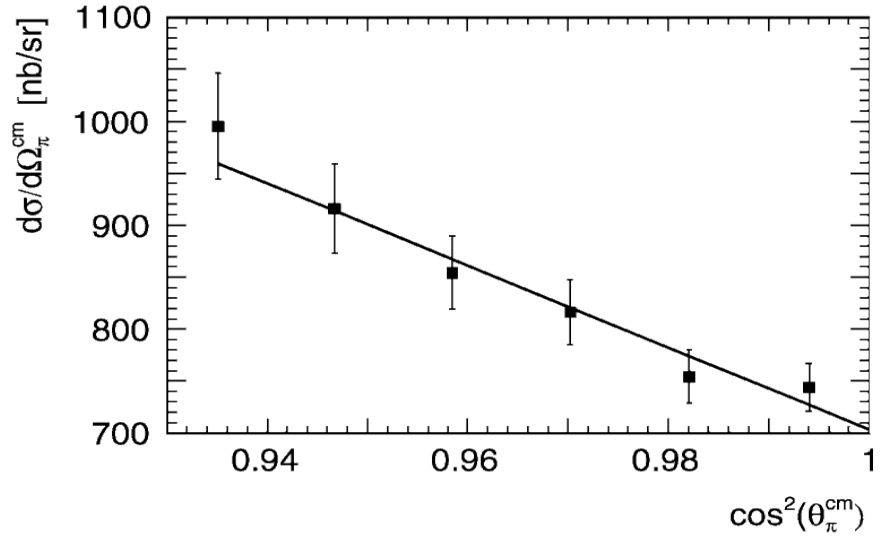
- unexpectedly large slope

Next step:

- single-polarized: A_y (II- 2007)
- double-polarized: A_{yy}, A_{xx} (II-2008)

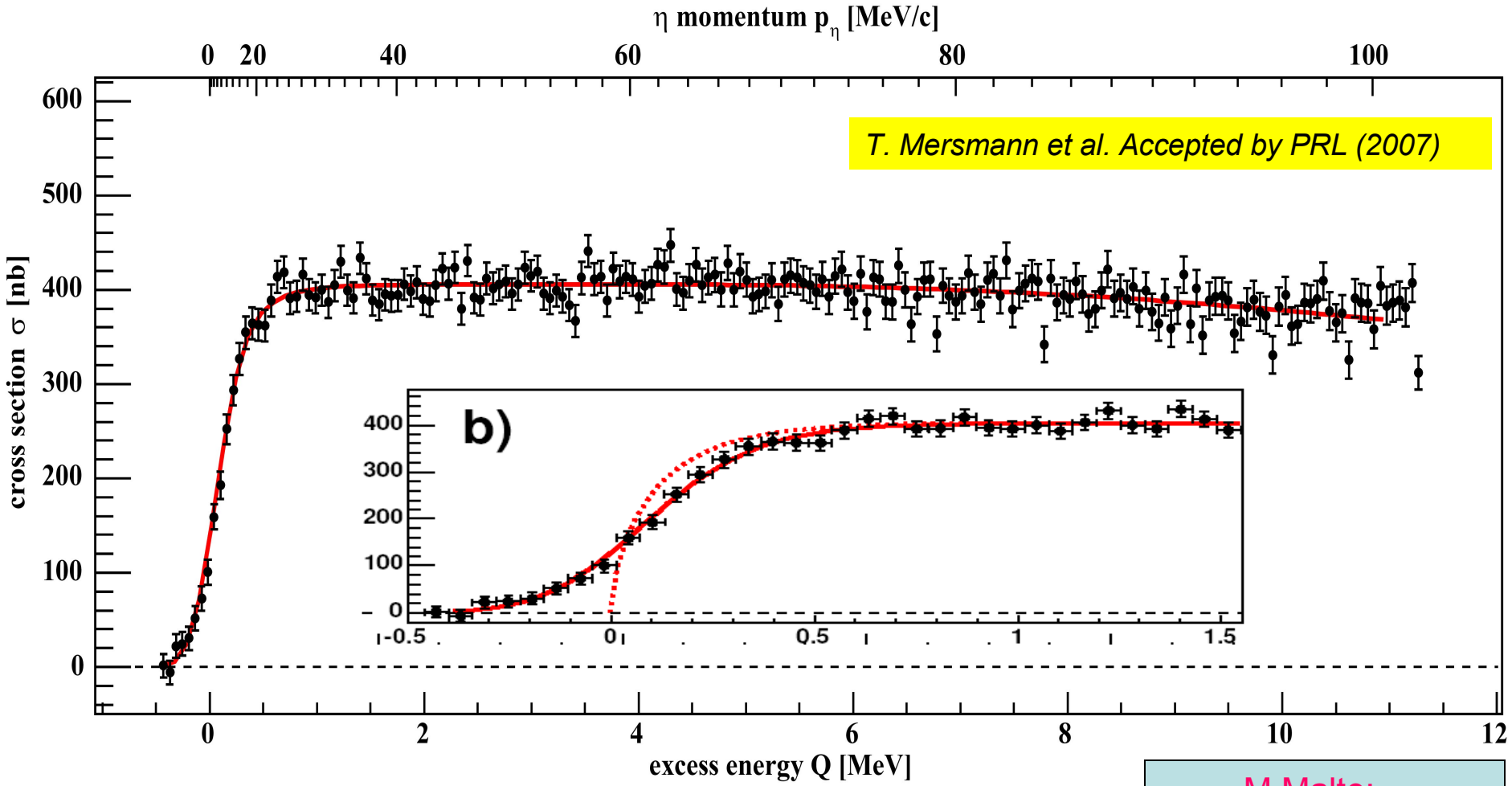
$pp \rightarrow (pp)_s \pi^o$, T_p= 800 MeV





S. Dymov et al. Phys. Let. B 635, 270 (2006)

Meson production: ^{3}Heη (cross section)



M.Malte:
"ANKE analysis"

- **is the FSI interpretation valid ?**
- **contributions from the entrance channel ?**

Meson production: ^{3}Heη (T_{20}, C_{yy})

Production amplitude for dp→^{3}He+η (π^0):

$$f_B = \bar{u}_\tau \vec{p}_p \ (A\vec{\varepsilon}_d + iB\vec{\varepsilon}_d \times \vec{\sigma})u_p$$

strong FSI → weak dependence on entrance channel

→ same enhancement in both amplitudes

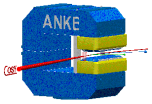
→ energy dependence of *A* and *B* amplitudes

$$\frac{d\sigma}{d\Omega} = \frac{1}{6} p_p p_\eta \ \left(|A|^2 + 2|B|^2\right) \qquad T_{20} = \sqrt{2} \ \frac{|B|^2 - |A|^2}{|A|^2 + 2|B|^2}$$

$$|A|^2 = \frac{p_p}{p_\eta}\left(1 - \sqrt{2}T_{20}\right)\frac{d\sigma}{d\Omega} \qquad |B|^2 = \frac{p_p}{p_\eta}\left(1 + \frac{1}{\sqrt{2}}T_{20}\right)\frac{d\sigma}{d\Omega}$$

$$T_{20} = \frac{2\sqrt{2}}{p_{zz}} \ \frac{d\sigma_0/d\Omega(\vartheta) - d\sigma/d\Omega(\vartheta)}{d\sigma_0/d\Omega(\vartheta)} \qquad \vartheta = 0^0 \, or \, 180^0$$

Hyperon production: scattering length



Spin/isospin dependence of $pN \to (N\Lambda)\, K^+$

- Both needed:

  $\vec{p}\vec{p} \to (p\Lambda)\, K^+$

  $\vec{p}\vec{n} \to (n\Lambda)\, K^+ \quad \Rightarrow$ via spectator detection

- ANKE is well equipped to provide:

  I_0 – unpolarized cross section

  A_{yy} – transverse spin-correlation

  (D_{yy} – spin-transfer parameter)

- $N\Lambda$ triplet final state can be isolated unambiguously from ~ $d\sigma(\uparrow\uparrow)/dm^2_{N\Lambda}$

  A. Gasparyan et al., PRC 69 (2004)

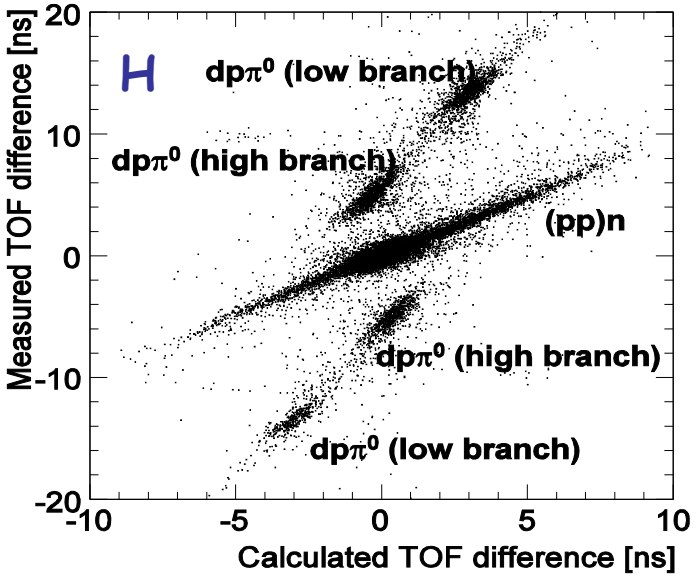
PIT commissioning: background studies

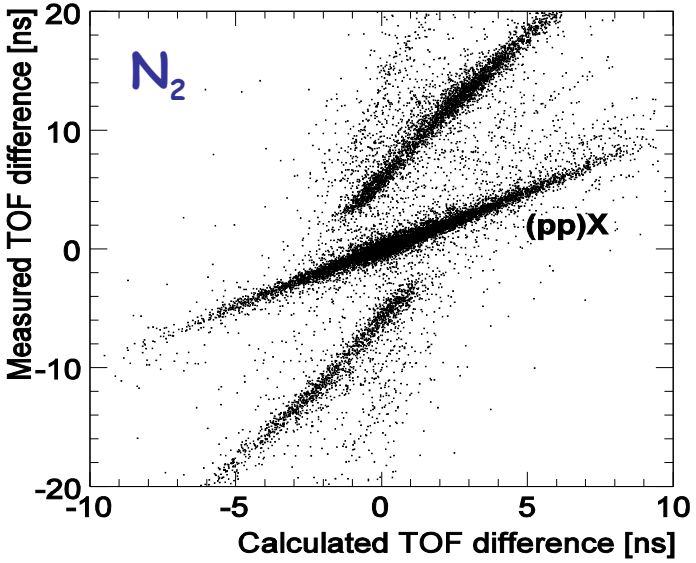
$\vec{d}\vec{p}$ (Jan´07), T_d=1.2 GeV, extended cell (20x15x390 mm³)

Cell was fed with H or N_2 gas:

- **N_2** flux adjusted to yield the same energy loss per unit of time in COSY compared to H flux, e.i. similar beam heating
- **N_2** gas used to obtain background shape from the cell wall (Al)

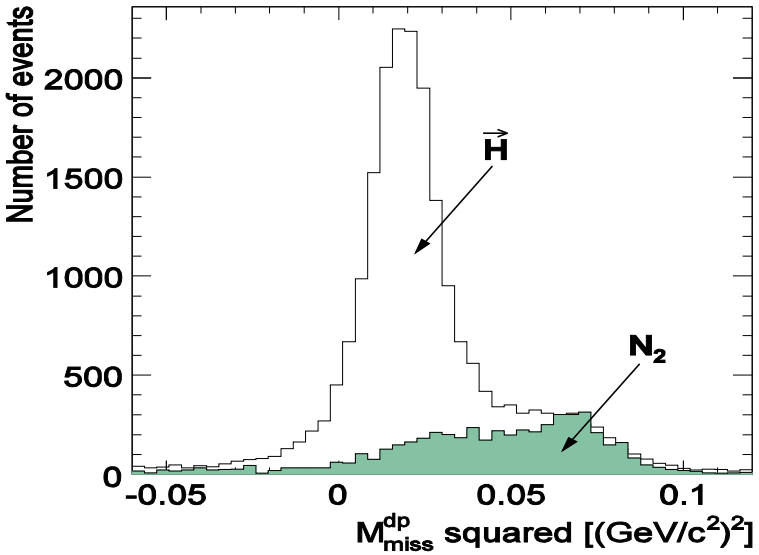
Kirill Grigoryev:
"PIT system"





PIT commissioning: reaction ID

$\vec{d}\vec{p}$, T_d=1.2 GeV, target H (N_2) gas

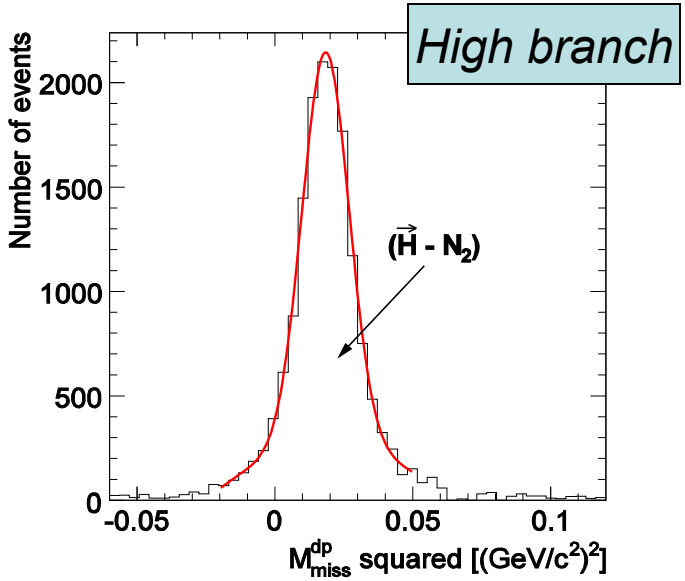


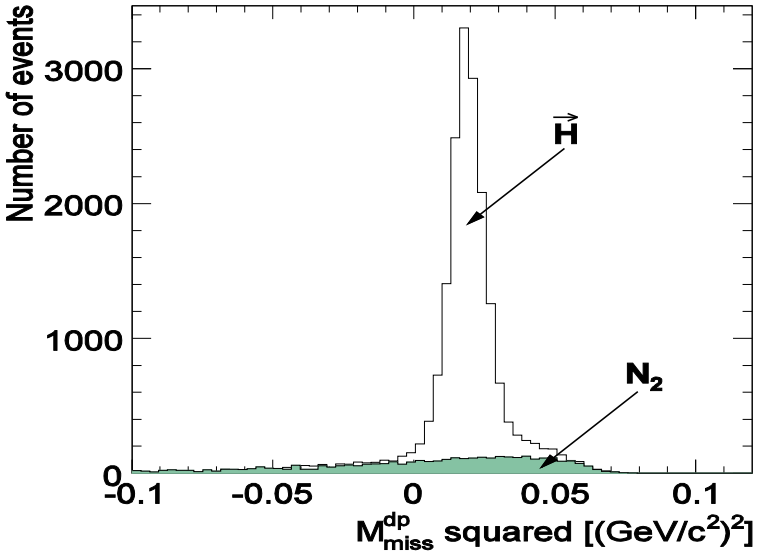
$dp \rightarrow (dp_{sp})\,\pi^o$

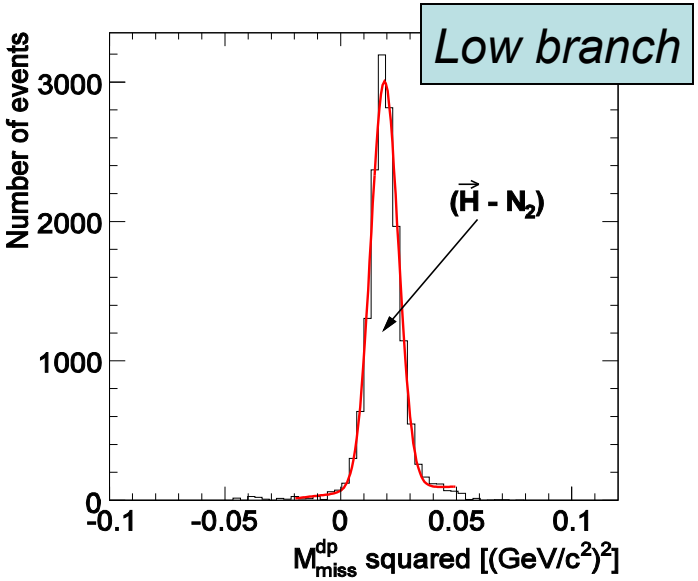
quasi-free

$np \rightarrow d\,\pi^o$

(High & Low branch)

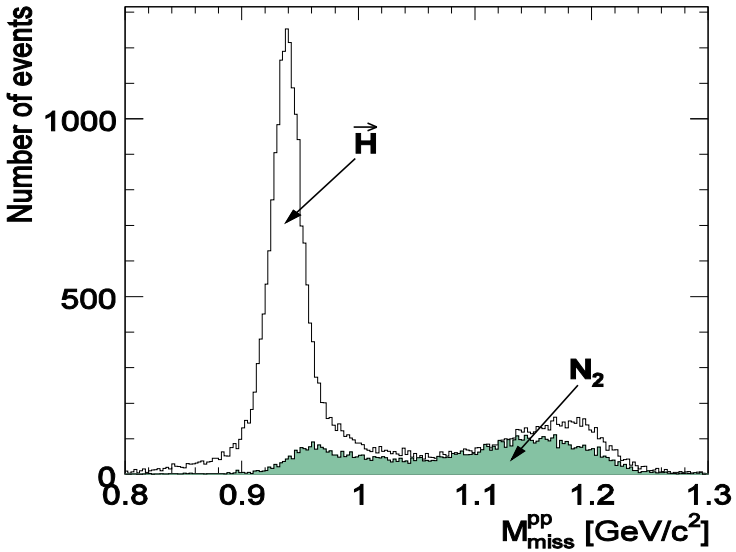




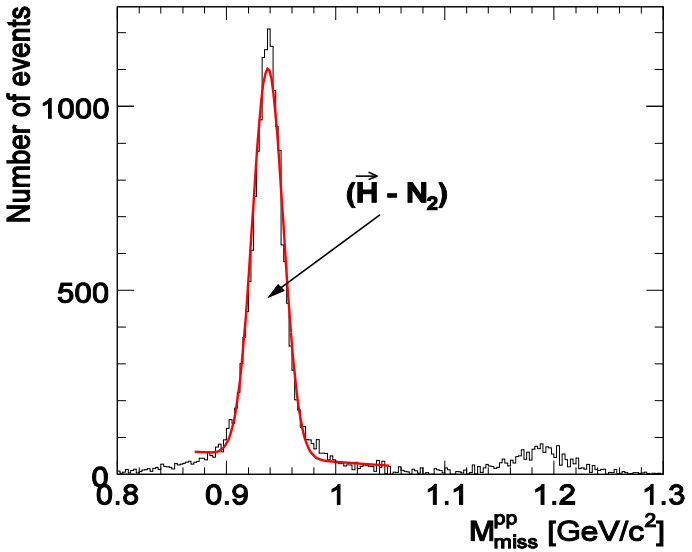


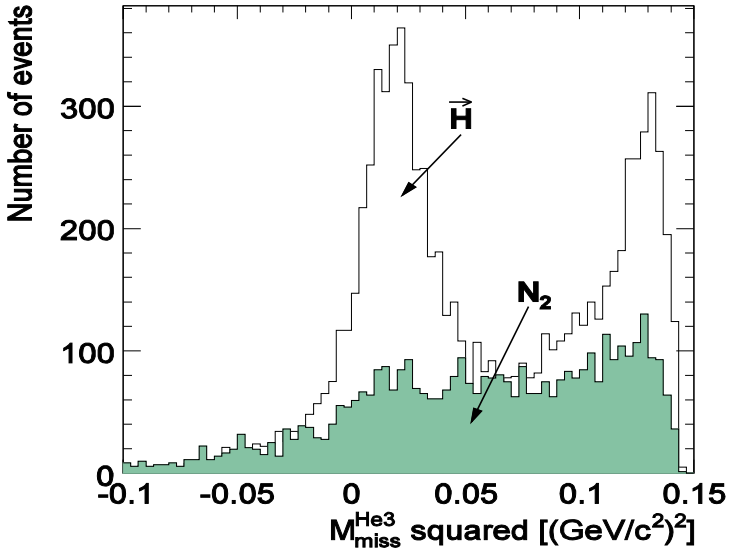
PIT commissioning: reaction ID

$\vec{d}\vec{p}$, T_d=1.2 GeV, target H (N_2) gas

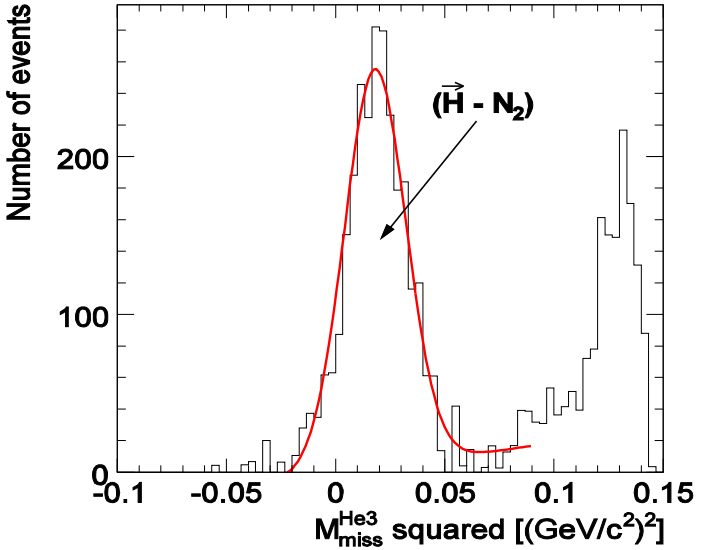


$dp \rightarrow (pp)n$



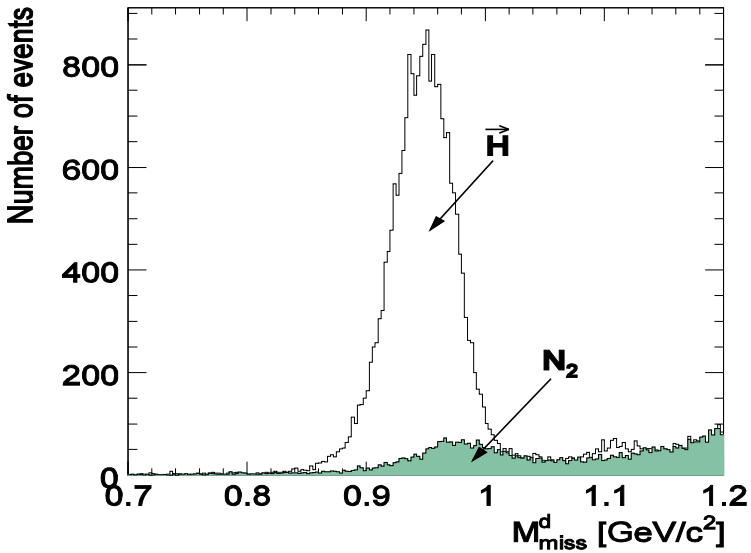


$dp \rightarrow {}^3He\,\pi^o$



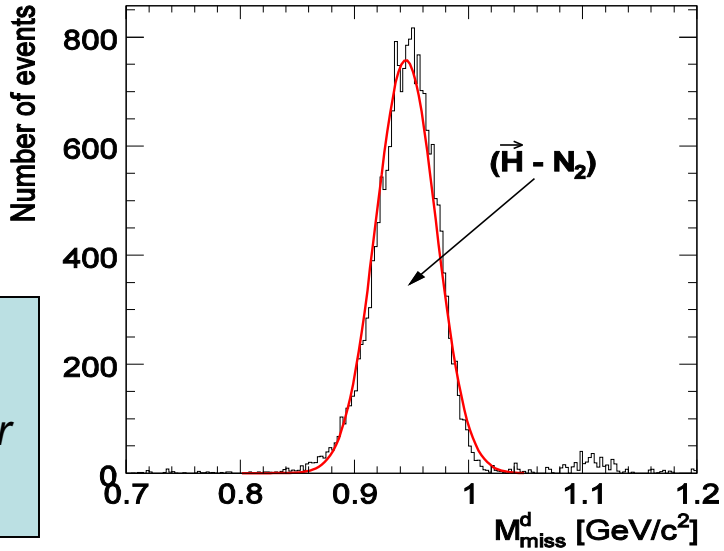
PIT commissioning: reaction ID

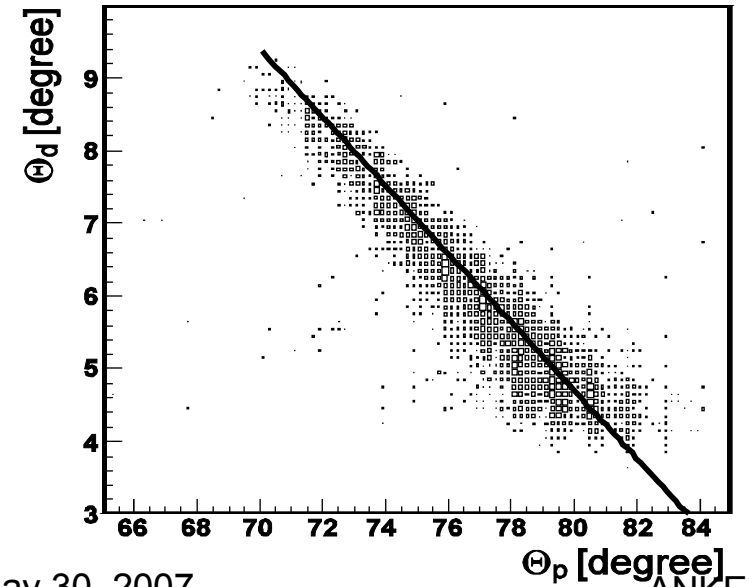
$\vec{d}\vec{p}$, T_d=1.2 GeV, target H (N_2) gas

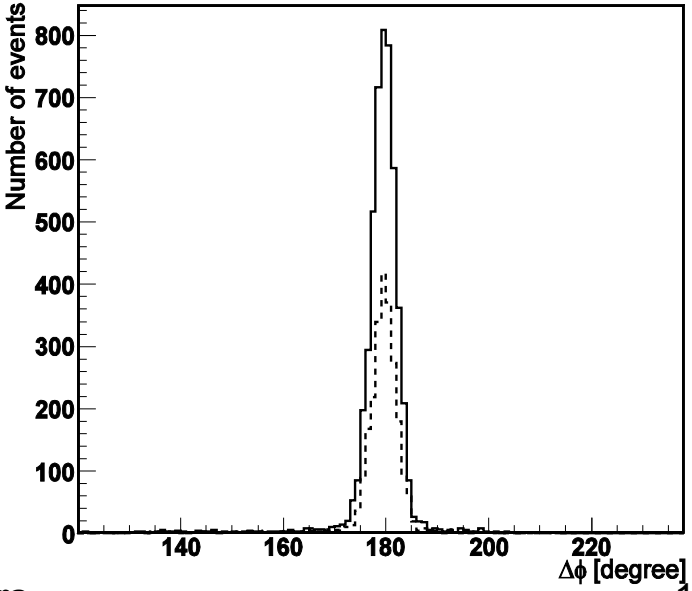


$dp \rightarrow dp$

d&p trigger:
***d** in FD detector*
***p** in STT*

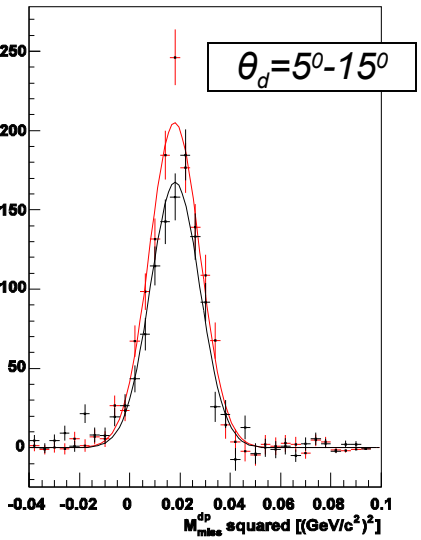


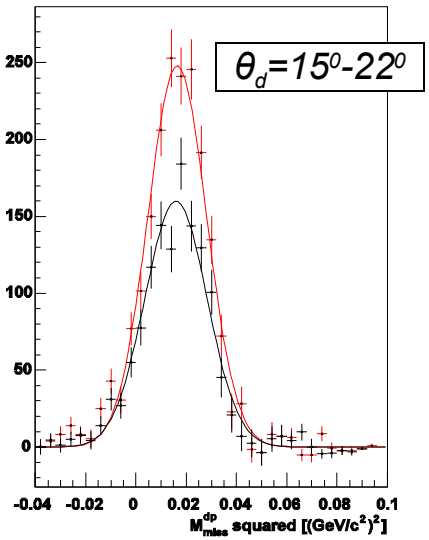


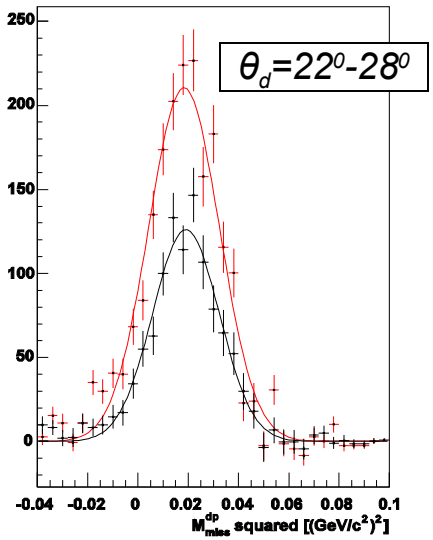


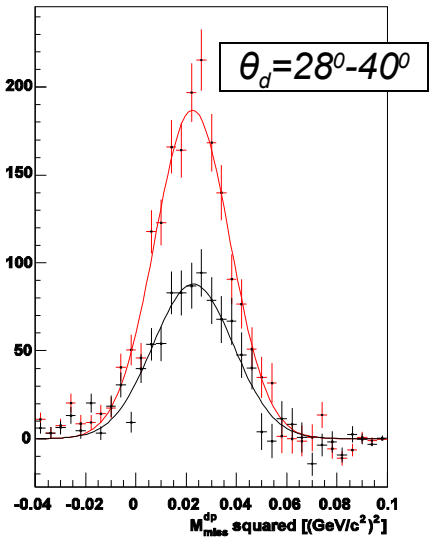
PIT commissioning: target polarization (Q_y)

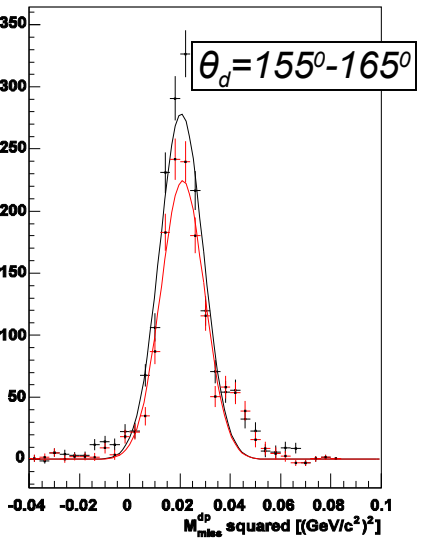
$d\vec{p}$, T_d=1.2 GeV, polarized H gas

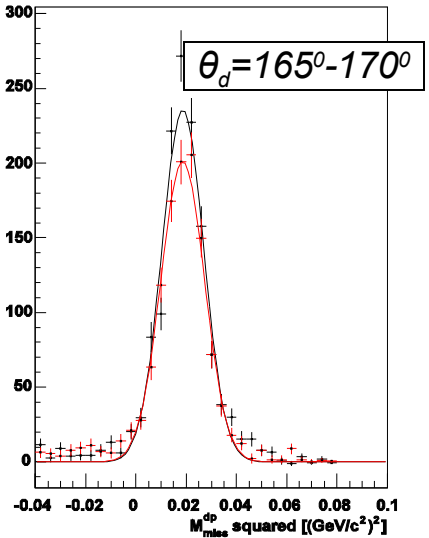


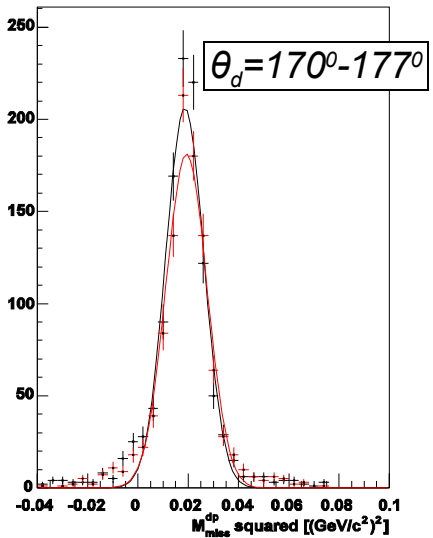












quasi-free

$np \rightarrow d\pi^0$

(High & Low branch)

$\langle Q_y \rangle = 0.75 \pm 0.06$

PIT commissioning: beam polarization (P_z)

David Chiladze: **"Polarimetry"**

$\vec{d}p$, T_d=1.2 GeV, unpolarized H_2 gas

Spin mode	P_z ideal	P_{zz} ideal	Intensity [I_0]	P_z (LEP)
1	0	0	1	-0.008 ± 0.008
2	-2/3	0	1	-0.545 ± 0.006
3	+1/3	-1	2/3	+0.257 ± 0.008
4	-1	+1	2/3	-0.723 ± 0.006
5	+1	+1	2/3	+0.597 ± 0.004

- $dC \rightarrow dC$
  - T_d = 75.6 MeV
  - $A_y(40°) = 0.61 \pm 0.04$

$\langle P_z \rangle = 0.66 \pm 0.003$

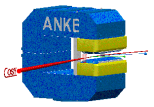
- $np \rightarrow d\pi^0$ *(quasi-free)*
  - T_n= 600 MeV
  - $A_y(\theta)$ = SAID

$\langle P_z \rangle = 0.64 \pm 0.05$

LEP

ANKE preliminary

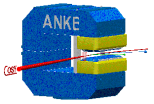
Summary: milestones



- L=1 x 10^{29} $s^{-1}cm^{-2}$ has been achieved for $\vec{d}\vec{p}$ at COSY.
- Clean reaction ID with extended cell target.
- Shape of background from the cell walls are defined.
- ABS source tuned with LSP,
  High target polarization Q_y=0.75 ± 0.06 by nuclear reaction.

- Establishing double-polarization standards.
- Extraction of spin correlation coefficients $C_{y,y}$ ($C_{x,x}$), $C_{yy,y}$
- ANKE is ready for double-polarized measurements
  (COSY proposal #172, I-2008).

Outlook: experiments beyond 2007



Long Term Physics Program:

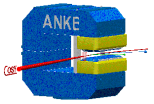
1. NN scattering ↔ Nuclear forces
2. Meson production ↔ ChPT, phenomenological models, FSI
3. Hyperon production ↔ SU(3) symmetry

► **Proposal #152:** ***Spin Physics from COSY to FAIR*** (nucl-ex/0511028)

Current Issues:

- Preparing Double Polarization Experiments
- Performing Single Spin Measurements
- Finalizing Unpolarized Measurements

Outlook: experiments beyond 2007



Long Term Physics Program:

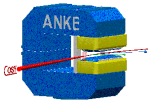
1. NN scattering ↔ Nuclear forces
2. Meson production ↔ ChPT, phenomenological models, FSI
3. Hyperon production ↔ SU(3) symmetry

► **Proposal #152:** ***Spin Physics from COSY to FAIR*** (nucl-ex/0511028)

Current Issues:

- Preparing Double Polarization Experiments
- Performing Single Spin Measurements
- Finalizing Unpolarized Measurements

Outlook: experiments in 2007–2009 (POF-I)



-

► **Proposal + Beam Request #169.2 : pd → pd (Spin Filtering)**

(Aut. 2007, PAC#34: approval+allocation of 2 + 2 weeks (I-2008)→ *D.Oellers*

► **Beam Request #175.1: pd → p_{sp}d ω**

(Aut. 2007, PAC#34: allocation of 2 weeks (I-2008) → *R.Schleichert*

► **New Proposal + Beam Request: pp → $(pp)_s\pi^o$**

(Aut. 2007, PAC#34: approval+allocation of 4 weeks (II-2008)

► **New Proposal + Beam Request: dp → ^{3}He η**

(Spr. 2008, PAC#35: approval+allocation of 4 weeks (I-2009)

► **New Proposal + Beam Request: pd → pd (polarimetry, "n"-target)**

(Spr. 2008, PAC#35: approval+allocation of 1+1 weeks (I-2009)

test measurements: **pd → (2p)n CE, pd → $p_{sp}pp\pi^-$**

► **New Proposal + Beam Request: pd → (2p)n CE (1.1 – 2.5 GeV)**

(Aut. 2008, PAC#36: approval+allocation of 3 weeks (II-2009)

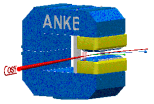
► **New Proposal + Beam Request: pd → $p_{sp}pp\pi^-$ (350 MeV)**

(Aut. 2008, PAC#36: approval+allocation of 3 weeks (II-2009)

► **New Proposal + Beam Request: pd → $nK^+\lambda$ (exploratory run)**

(Spr. 2009, PAC#37: approval+allocation of 2 weeks (I-2010)

Outlook: experiments in 2010–2014 (POF-II)



Preparation of double-polarized experiments which requires:

High Luminosity ► Openable cell + 4 STT modules (!)

► **New Proposal + Beam Request: pd → nK⁺Λ**

(Aut. 2009, PAC#38: approval+allocation of ?? weeks

► **New Proposal + Beam Request: pp → pK⁺Λ**

(Aut. 2009, PAC#38: approval+allocation of ?? weeks

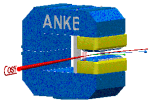
► **New Proposal + Beam Request: pn → dX (X=ω,φ) (exploratory run)**

(Spr. 2010, PAC#39: approval+allocation of ?? weeks

► **New Proposal + Beam Request: pp → ppX (X=ω,φ) (exploratory run)**

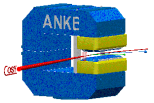
(Spr. 2010, PAC#39: approval+allocation of ?? weeks

Outlook: Publications



2. CE cross section - (D. Chiladze et al.) *in progress*
3. $pp \rightarrow (pp)_s\pi$ - (V. Kurbatov et al.) *in progress*
4. $pd \rightarrow (pp)n$ - (V. Komarov et al.) *in progress*
5. $^3He\ \eta$ - (T. Mersmann et al.) *PRL (in press)*
6. $\sum^+$ production - (Yu. Valdau et al.) *PLB (resubmitted)*
7. K^+K^- pair production (I) - (A. Dzyuba et al.) *draft preparation*
8. K^+K^- pair production (II) - (M. Hartmann, Y. Maeda) *draft preparation*
9. PIT commissioning results - (NIM, K. Grigoriev et al.) *not yet*
10. Λ (1405) - (I. Zychor et al.) *PRL (evaluation)*
11. $pp \rightarrow pp\Phi$ at higher ε - (I. Keshelashvili, M. Hartmann) *not yet*
12. $pd \rightarrow K^+ X$ cross section - (Yu. Valdau et al.) *in progress*
13. $dd \rightarrow \alpha K^+K^-$ cross section - (X. Yuan et al.) *in progress*
14. Target density by Schottky - (NIM, IK, MH, et al.) *draft preparation*
15. ....

Outlook: experiments in 2007–2009 (POF-I)



-

► **Proposal + Beam Request #169.2 : pd → pd (Spin Filtering)**

(Aut. 2007, PAC#34: approval+allocation of 2 + 2 weeks (I-2008)→ *D.Oellers*

► **Beam Request #175.1: pd → p_{sp}d ω**

(Aut. 2007, PAC#34: allocation of 2 weeks (I-2008) → *R.Schleichert*

► **New Proposal + Beam Request: pp → $(pp)_s\pi^o$**

(Aut. 2007, PAC#34: approval+allocation of 4 weeks (II-2008) → *S.Dymov*

► **New Proposal + Beam Request: dp → ^{3}He η**

(Spr. 2008, PAC#35: approval+allocation of 4 weeks (I-2009)→ *M.Papenbrock*

► **New Proposal + Beam Request: pd → pd (polarimetry, "n"-target)**

(Spr. 2008, PAC#35: approval+allocation of 1+1 weeks (I-2009) → *R.Engels, I.Keshelashvili*

test measurements: **pd → (2p)n CE, pd → $p_{sp}pp\pi^-$**

► **New Proposal + Beam Request: pd → (2p)n CE (1.1 – 2.5 GeV)**

(Aut. 2008, PAC#36: approval+allocation of 3 weeks (II-2009) → *I.Keshelashvili*

► **New Proposal + Beam Request: pd → $p_{sp}pp\pi^-$ (350 MeV)**

(Aut. 2008, PAC#36: approval+allocation of 3 weeks (II-2009) → *D.Chiladze*

► **New Proposal + Beam Request: pd → $nK^+\lambda$ (exploratory run)**

(Spr. 2009, PAC#37: approval+allocation of 2 weeks (I-2010) → *Gatchina*