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JÜLICH
FORSCHUNGSZENTRUM

COSY-Experiments:

A general overview and selected results

February 11, 2014 | Michael Hartmann (FZ Jülich)

Content

Physics program

(ANKE, PAX, TOF, WASA)

Preparatory work for FAIR

(HESR and PANDA, CBM, NUSTAR, …)

Future plans

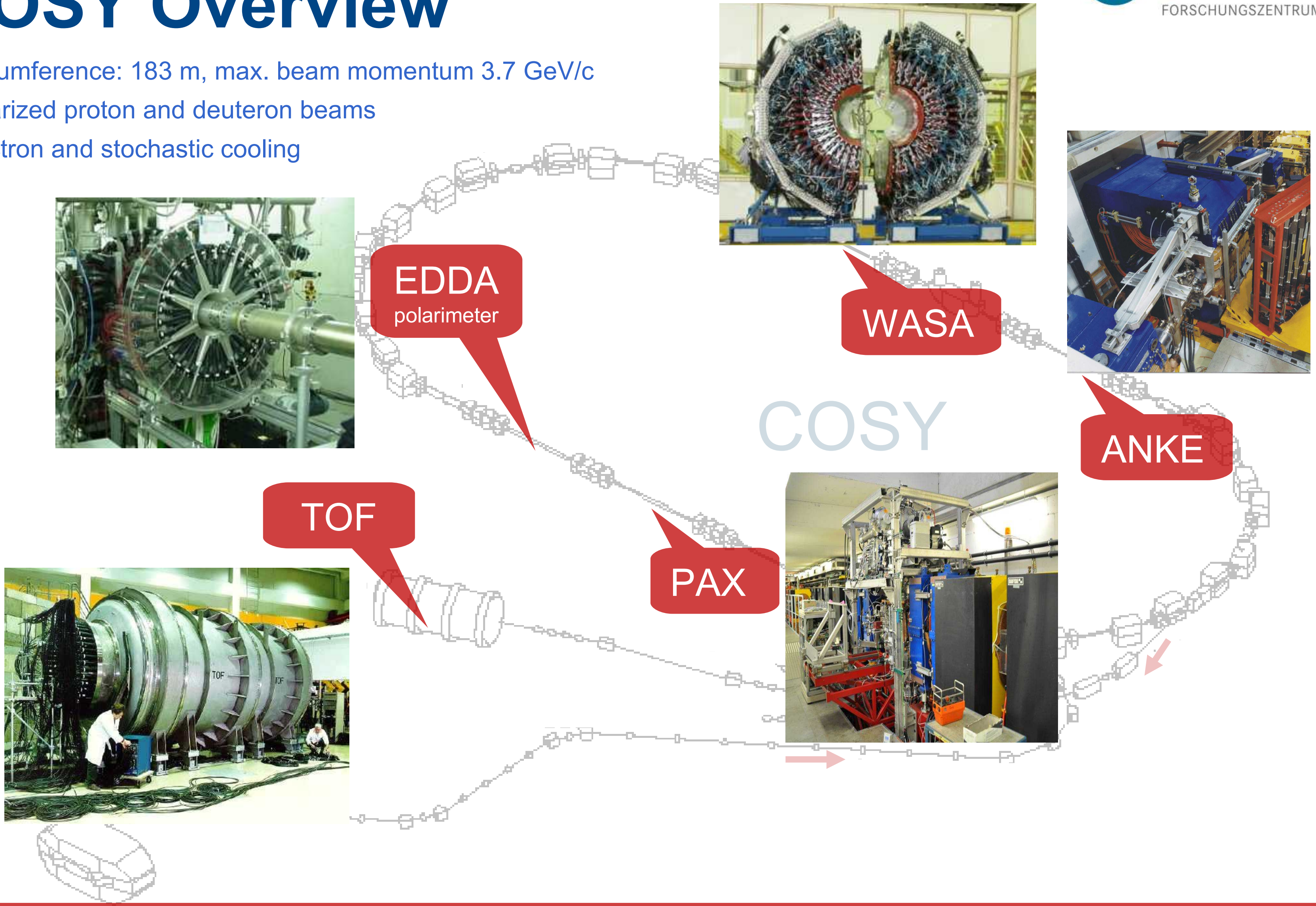
(EDM)

COSY Overview

Circumference: 183 m, max. beam momentum 3.7 GeV/c

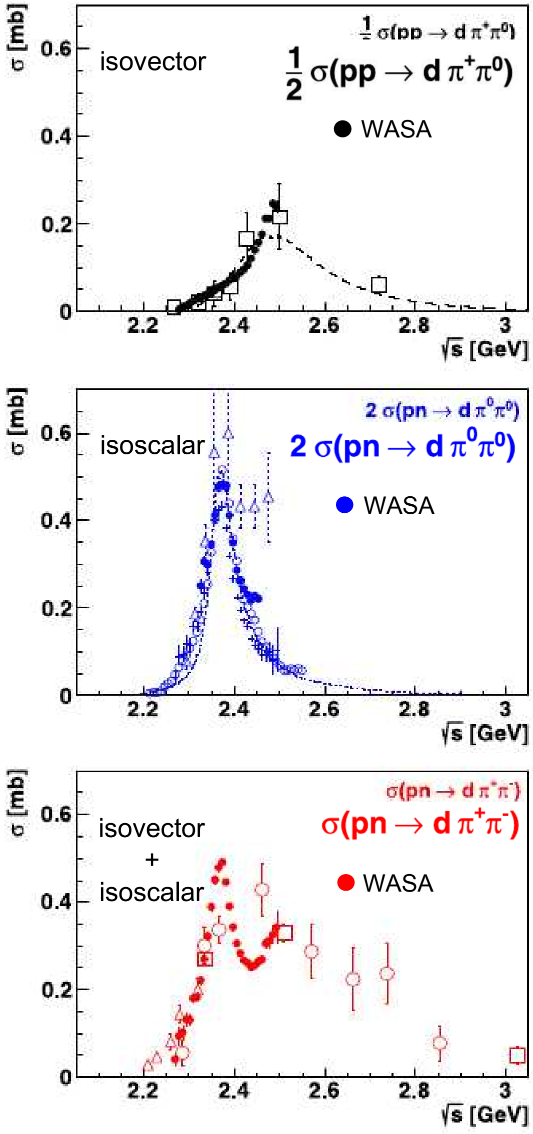
Polarized proton and deuteron beams

Electron and stochastic cooling



… *the* machine for hadron spin physics

WASA: ABC structure



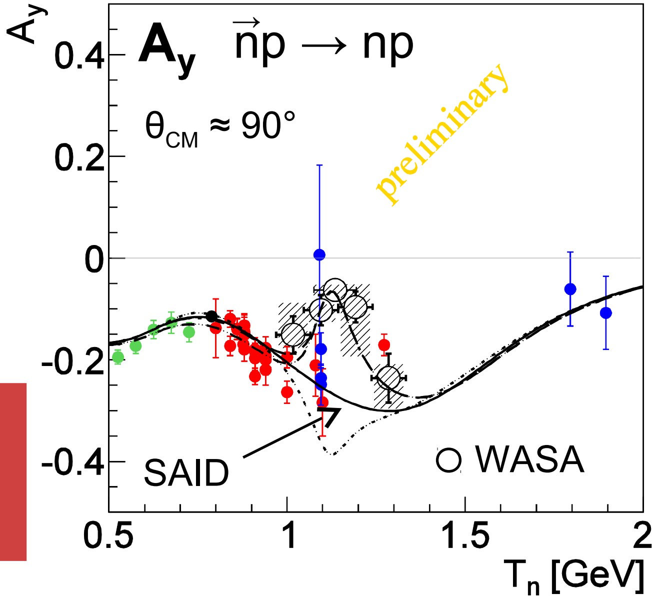
Isospin decomposition of ABC resonance structure
Phys. Lett. B 721 (2013) 229
→ pure isoscalar effect

If resonance in np system:
→ effect should be present in np scattering

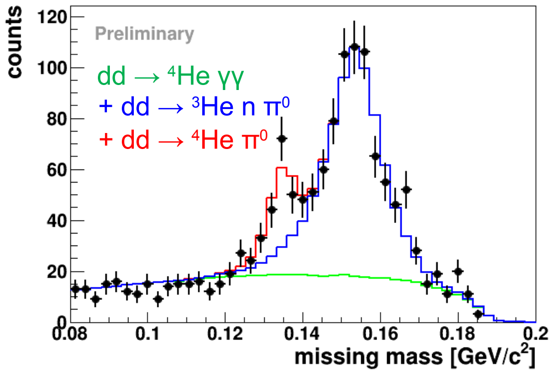
Most sensitive observable in np scattering:
analyzing power A_y and its energy dependence
near $\theta_{CM} \approx 90°$

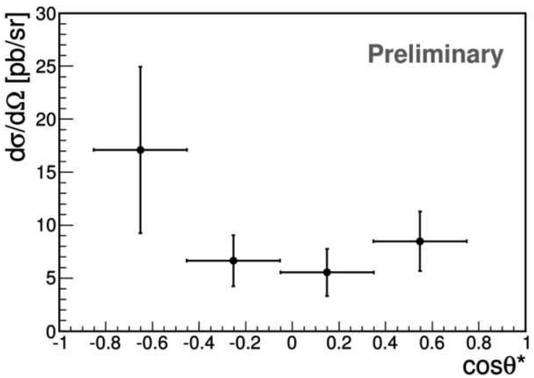
First result:
corresponding signal
at resonance position

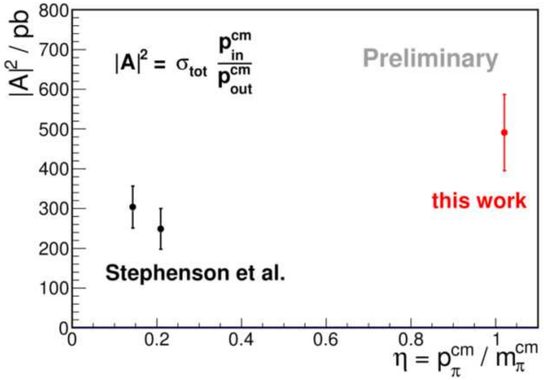
Further analysis needed



WASA: CSB in dd → ^{4}He π^0







Probing hadronic effects of the u- and d-quark mass difference

Charge Symmetry: u ↔ d, subgroup of Isospin Symmetry insensitive to charge difference

dd → ^{4}He π^0 : CS: $\sigma = 0$ $\cancel{CS}$: $\sigma \sim |M_{CSB}|^2 \neq 0$

Stephenson et al.: $\sigma_{tot}(Q = 1.4\text{ MeV}) = 12.7 \pm 2.2$ pb

(PRL 91 (2003) 142302) $\sigma_{tot}(Q = 3.0\text{ MeV}) = 15.1 \pm 3.1$ pb

→ consistent with *s*-wave π-production

↓ **theoretical analysis & prediction** ↓

Contribution of p-wave at higher energies (Q = 60 MeV)

Experimental challenges: ^{3}He/^{4}He separation

$\sigma_{tot}(^3\text{He n } \pi^0) \approx 3 \cdot 10^4\ \sigma_{tot}(^4\text{He } \pi^0)$

Pilot run: $\sigma_{tot,\ prelim.} = (118 \pm 18_{stat} \pm 13_{sys} \pm 8_{norm})$ pb

first differential cross section

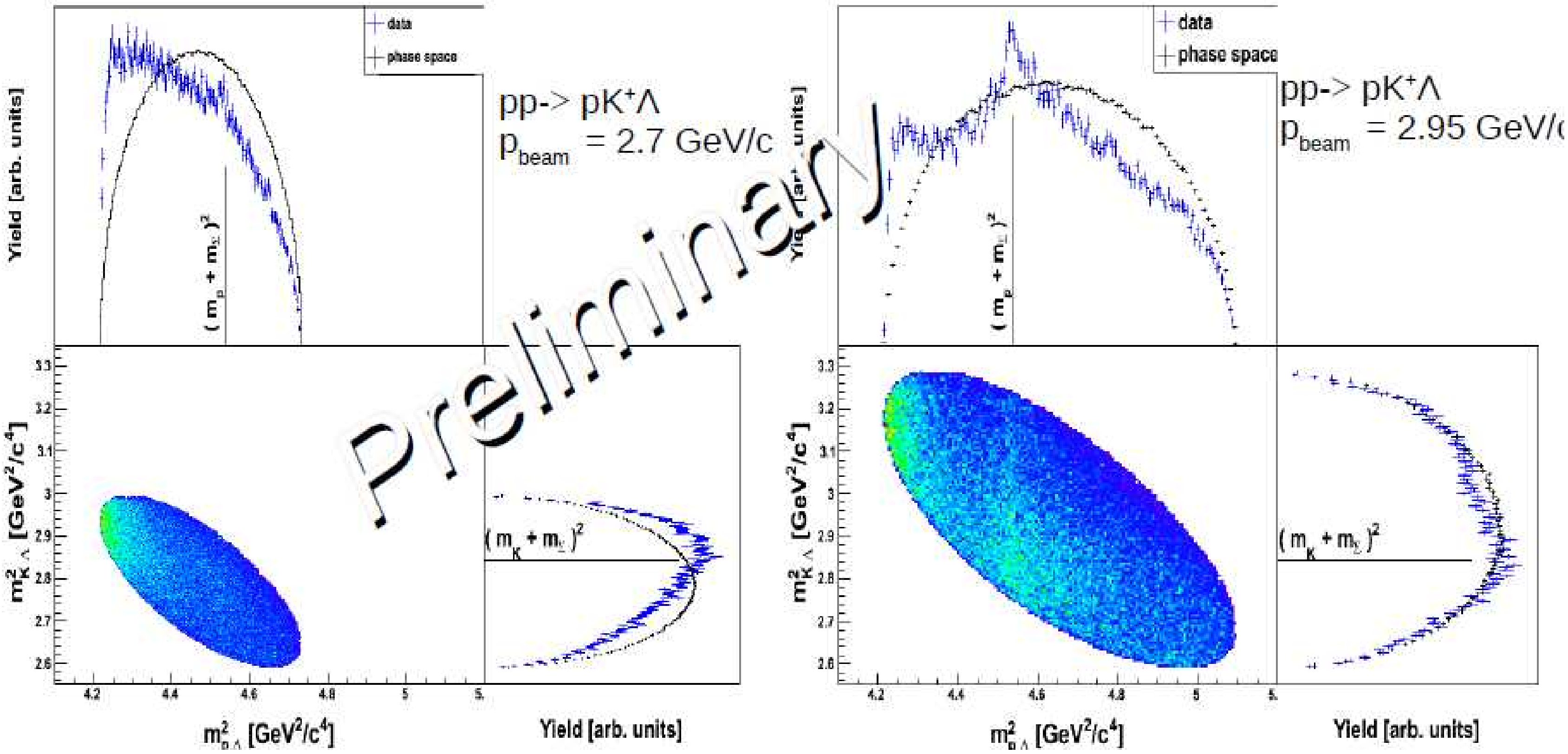
→ more precise data needed:

8 week production run with optimized setup (Feb/Mar 2014)

TOF: Hyperon production

COSY-TOF high statistic data of pN -> pKΛ – exclusive and kinematically complete - allow examination of influence of N* resonances, coupled channel effects, and N – hyperon interactions.

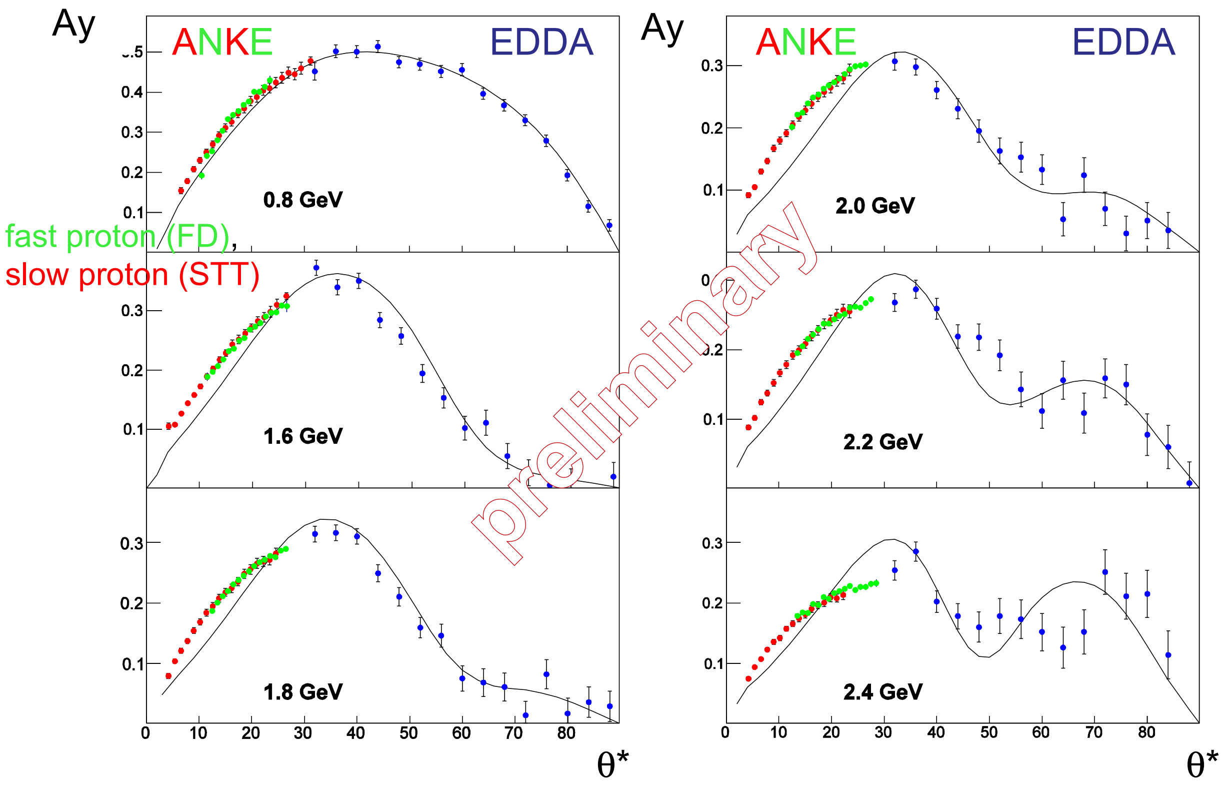
(see e.g.: EPJA 49 (2013)157, PLB 688 (2010) 142

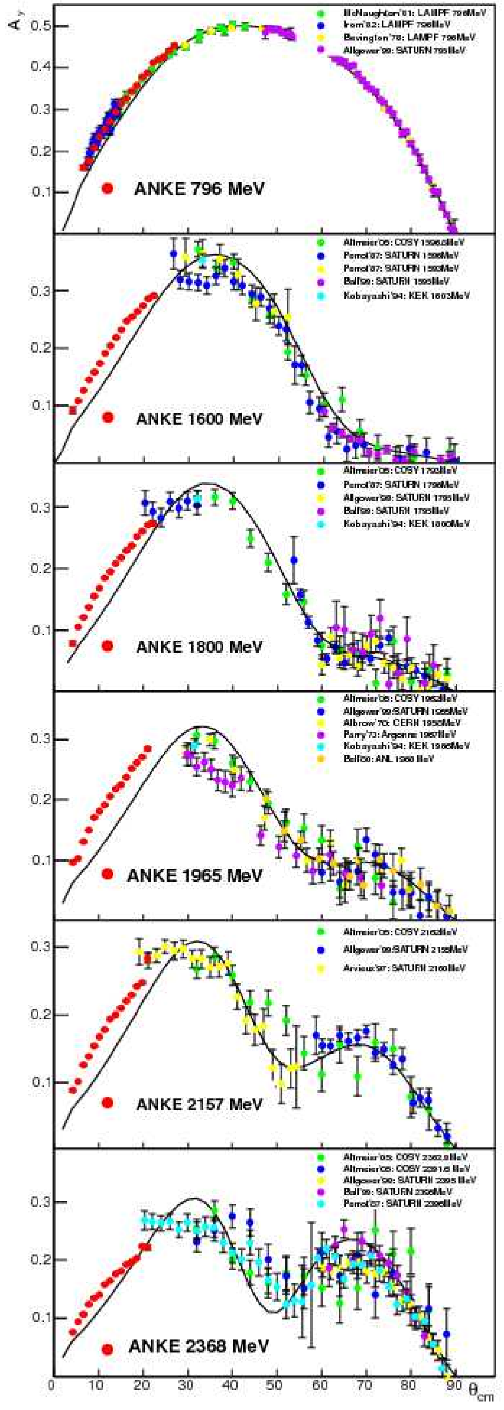


Separation of singlet and triplet scattering length

EDDA → ANKE: NN-scattering

Recent precision data ($\vec{p}p$ elastic scattering; A_y)





great impact on NN phase shifts (SAID group)
fundamental quantities for nuclear physics
Ongoing: double polarized measurements (np system)

ANKE: Double-polarized experiments

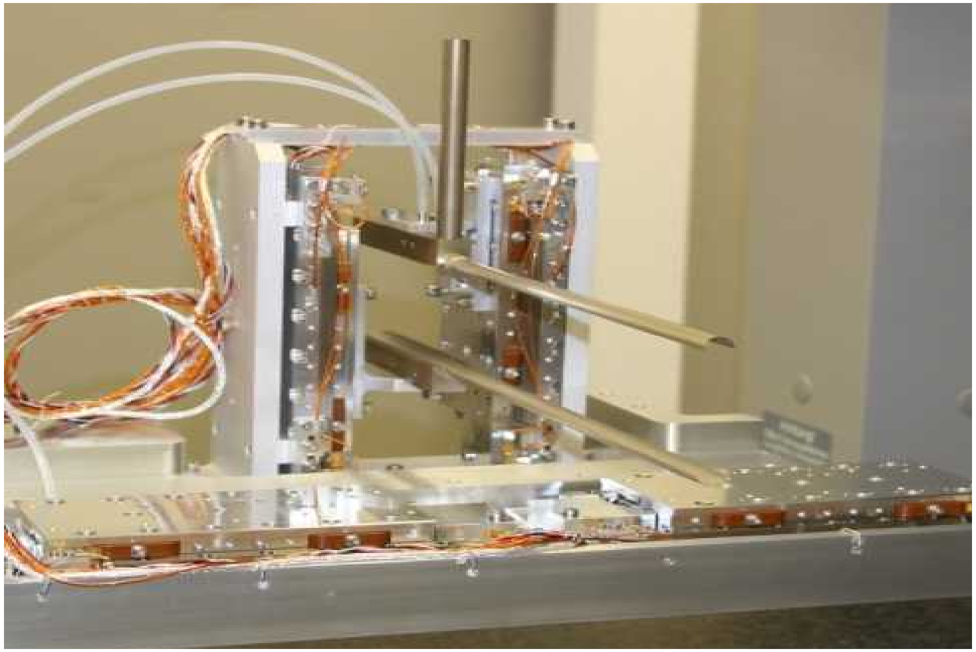
ABS: Openable storage cell
(luminosity factor 5 more)

(i) $\vec{p}\,\vec{n} \rightarrow n\,p$ (A_I, $A_{I,J}$)

(ii) $\vec{p}\,\vec{n} \rightarrow \{pp\}_s\,\pi^-$ (A_{xz} parameter)

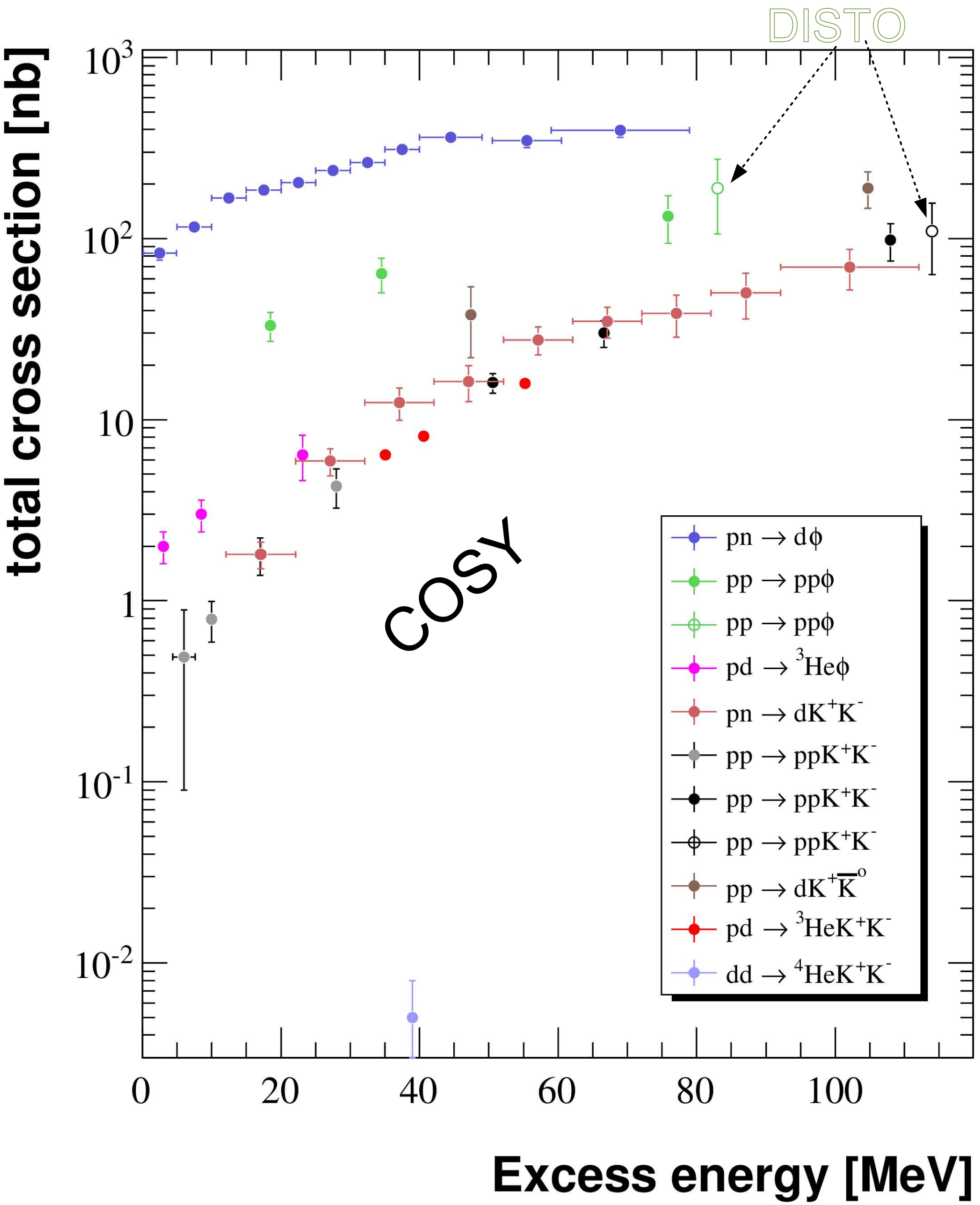
(iii) $\vec{p}\,\vec{p} \rightarrow K^+\,\Lambda\,p$ (C_{YY} coefficient)

http://collaborations.fz-juelich.de/ikp/anke/proposals.shtml



down to 10 mm diameter,
about 85% polarization

Double-polarized experiments approved



COSY: $K\bar{K}$/Φ production (ANKE, ...)

(www.fz-juelich.de/ikp or MH, PoS 057 (2011))

$K\bar{K}$ & Φ production in pp, pd & dd (world data)

ANKE: $pp \rightarrow ppK^+K^-$ at ε_{KK} = 51 MeV

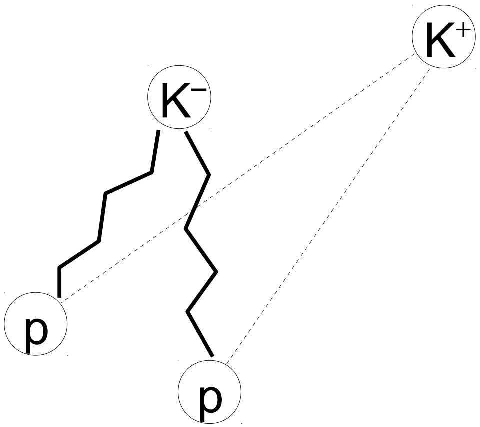
Assumption: K^-p FSI effect

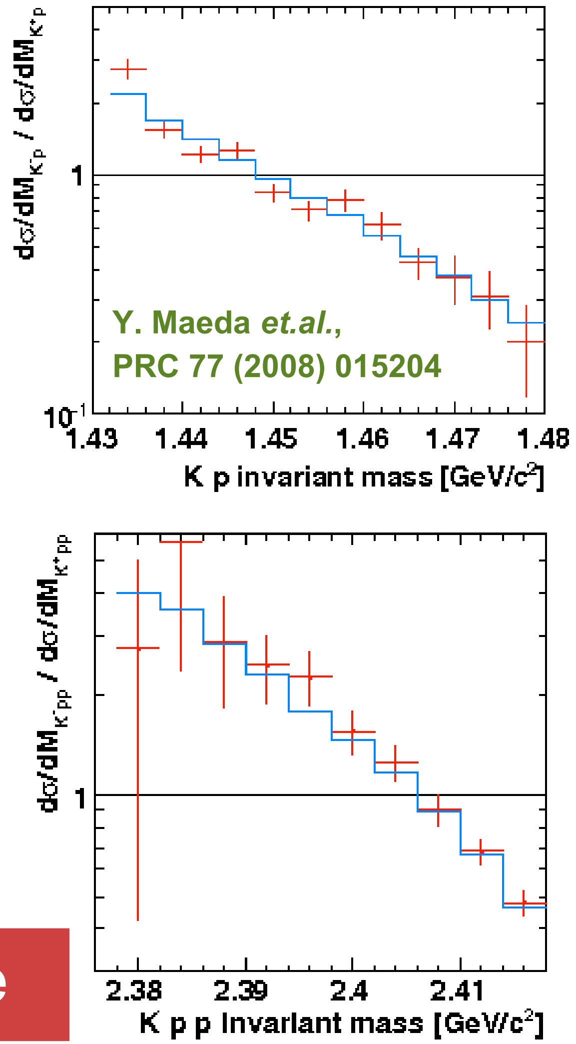
$f(q) = 1/(1-iaq)$, q: relative momentum

a: scattering length

"3-body-FSI" ↔ $f(q_1) \times f(q_2)$,

$|a| \approx 1.5$ fm

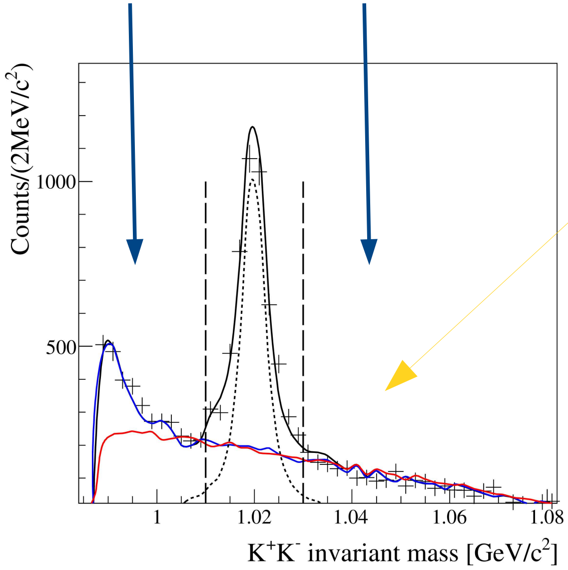




Y. Maeda *et.al.*, PRC 77 (2008) 015204

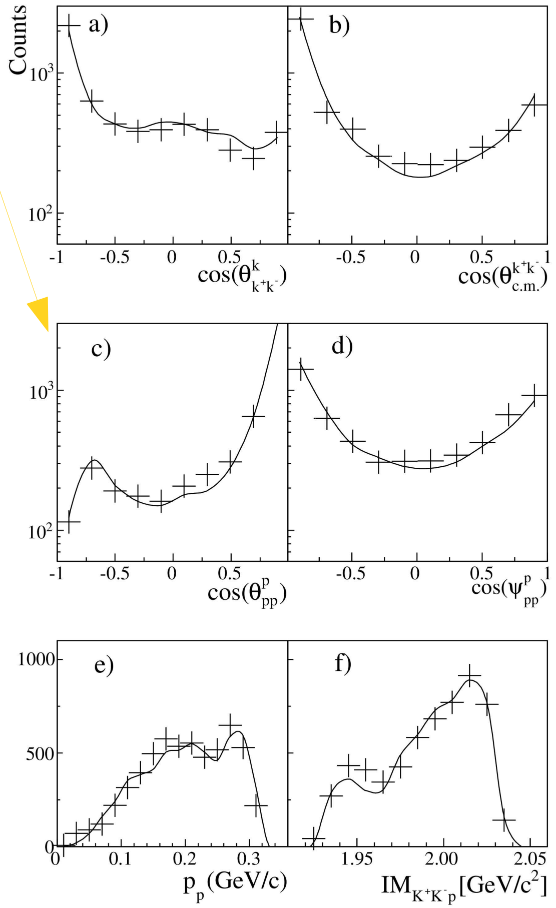
strong K^-p and/or K^-pp FSI is visible

ANKE: ppK$^+$K$^-$ production at ε_{KK} = 108 MeV

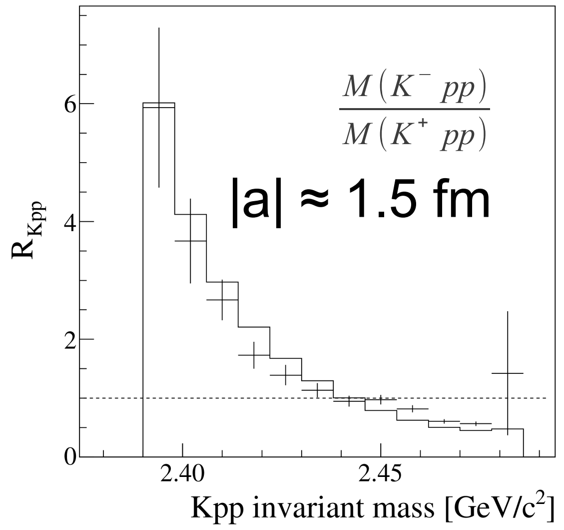


no acceptance correction

“outside Φ”



Q.J. Ye *et.al.*, PRC 85 (2012) 035211

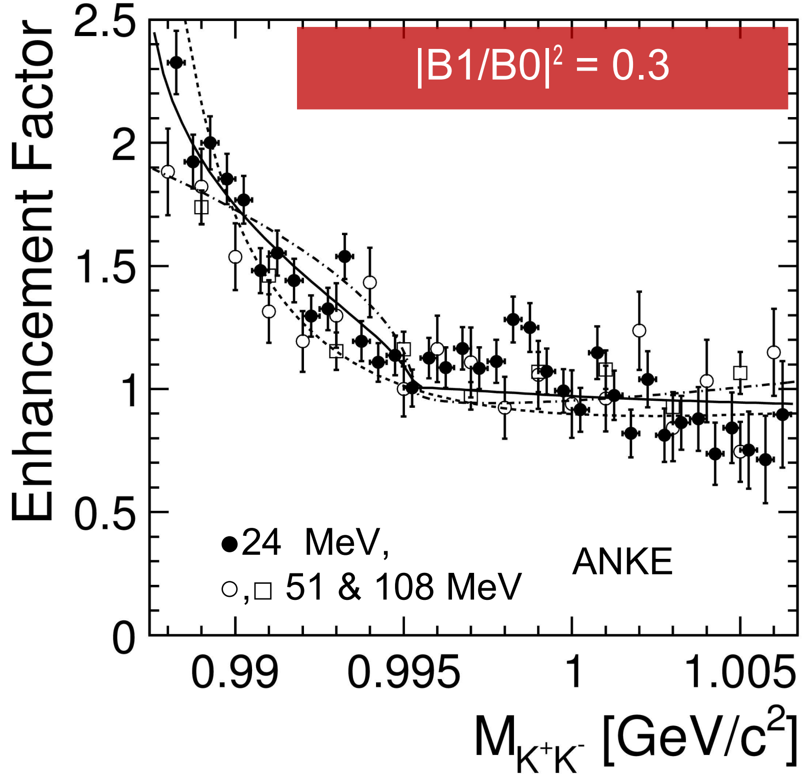


|a| ≈ 1.5 fm

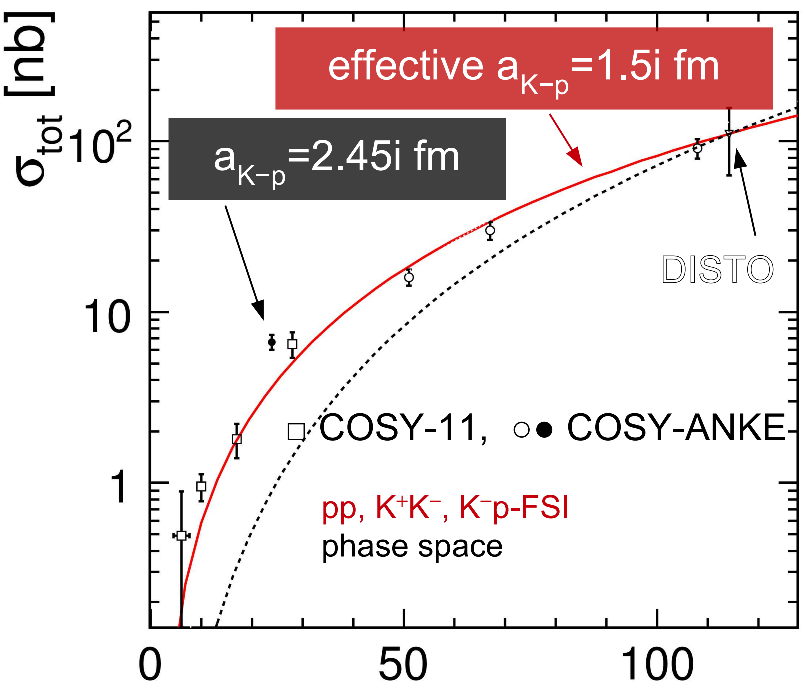
$$\boxed{\begin{aligned} F = F_{pp}(q_{pp}) &\times \\ F_{\bar{K}p}(q_{\bar{K}p_1}) &\times \\ F_{\bar{K}p}(q_{\bar{K}p_2}) &\times \\ F_{K\bar{K}}(q_{K\bar{K}}) & \end{aligned}}$$

ratio of exp. K^+K^- inv. mass to MC (without $K\bar{K}$ interaction)

$pp \to ppK^+K^-$ (total cross section)



$K\bar{K}$ production amplitudes (I=0,1)



Y. Maeda *et.al.*, PRC 77 (2008) 015204

A. Dzyuba *et.al.*, PLB 668 (2008) 315

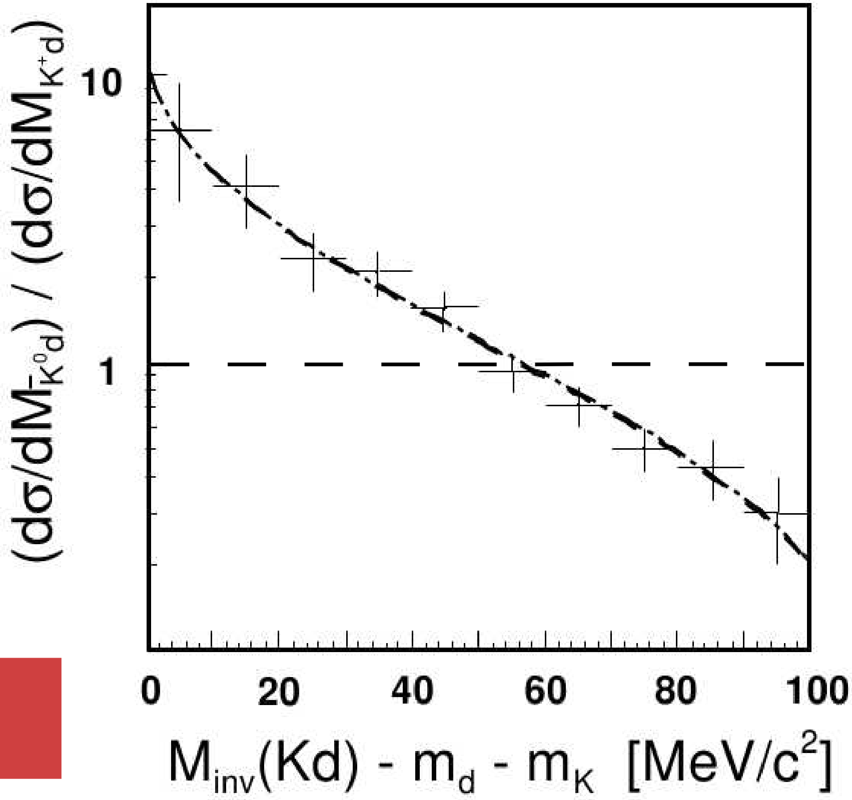
M. Silarski *et.al.*, PRC 80 (2009) 045202, 88 (2013) 025205

Q.J. Ye *et.al.*, PRC 85 (2012) 035211

Q.J. Ye *et.al.*, PRC 87 (2013) 065203

ANKE: $pp \to dK^+\bar{K}^0$

$$a = (-1.0 + i1.2)\ \mathrm{fm}$$

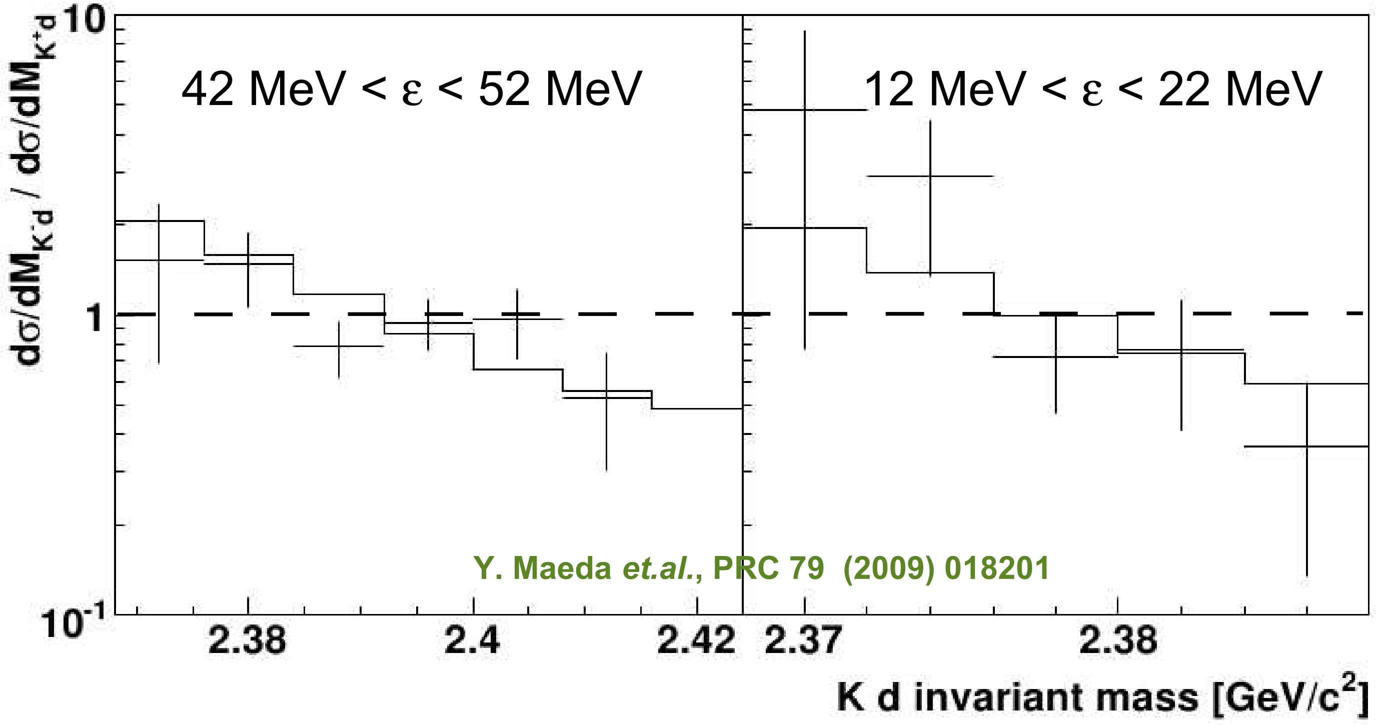


$d\bar{K}^0$ FSI is visible

A. Dzyuba *et.al.*, EPJ A 38 (2008) 1

ANKE: pn→dK⁺K⁻

$$a = (-1.0 + i1.2)\ \text{fm}$$



Y. Maeda *et.al.*, PRC 79 (2009) 018201

dK⁻ FSI is visible

Proton & deuteron induced $K\bar{K}$ production (world data)

$pp \rightarrow ppK^+K^-$

$pp \rightarrow dK^+\bar{K}^0$

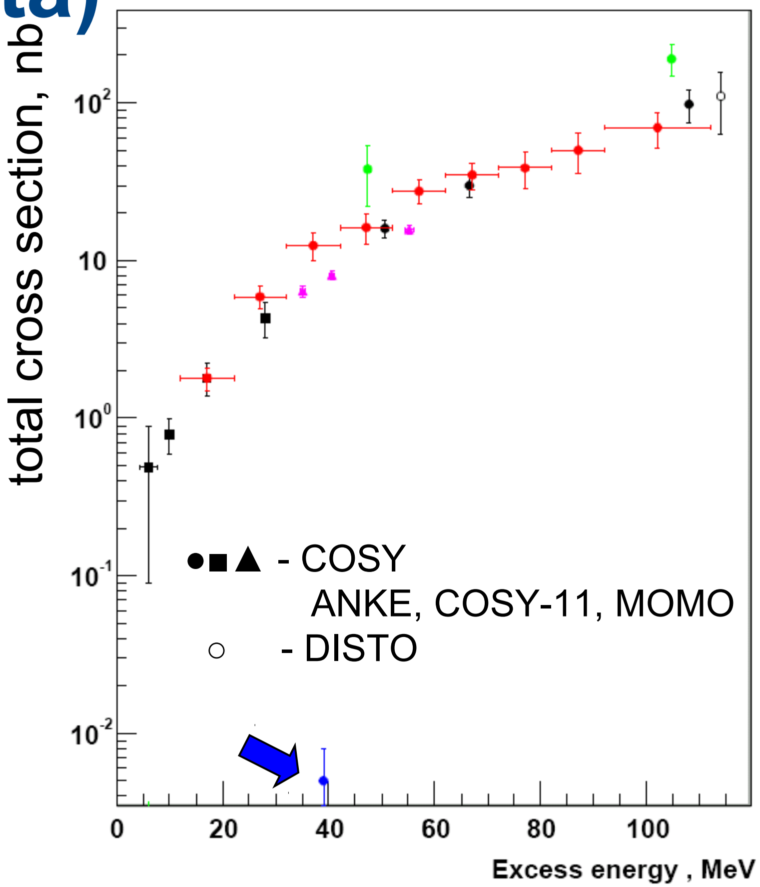
$pn \rightarrow dK^+K^-$

$pd \rightarrow {}^3HeK^+K^-$

PRC 75 (2007) 015204

$dd \rightarrow {}^4HeK^+K^-$

EPJ A 42 (2009) 1



$pd \rightarrow {}^3He\ a_0(980)$, WASA-COSY

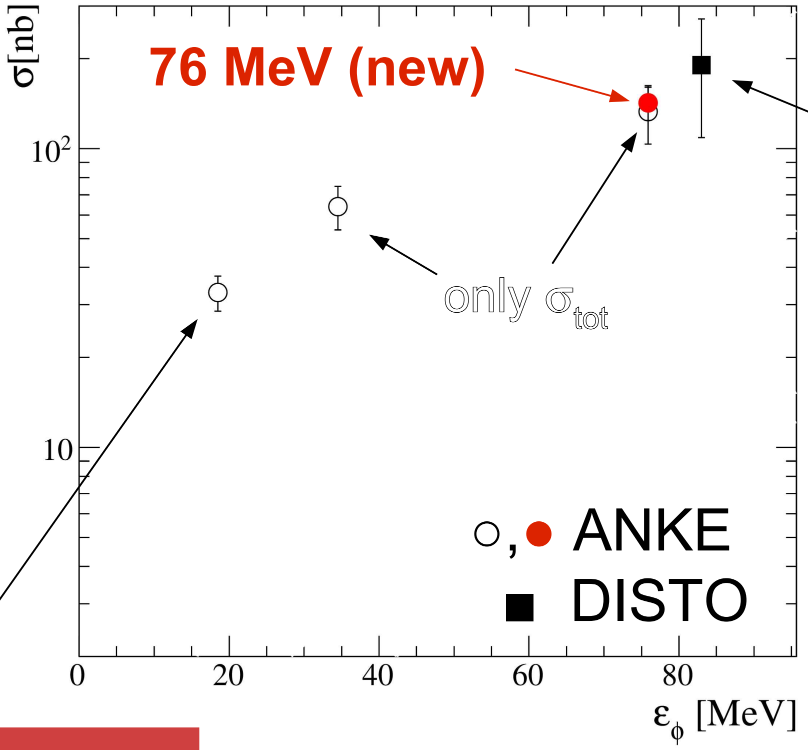
↳ $\pi^0\eta$ BR≅90%, weak signal (~1nb @ ε=256 MeV, preliminary)

Chuan Zheng, PhD INP

↳ K^+K^- BR≅10%,

~~a_0 / f_0~~

ANKE: pp→ppΦ total cross sections



DISTO:
higher PW,
no pp-FSI ?

“Ss” + pp-FSI

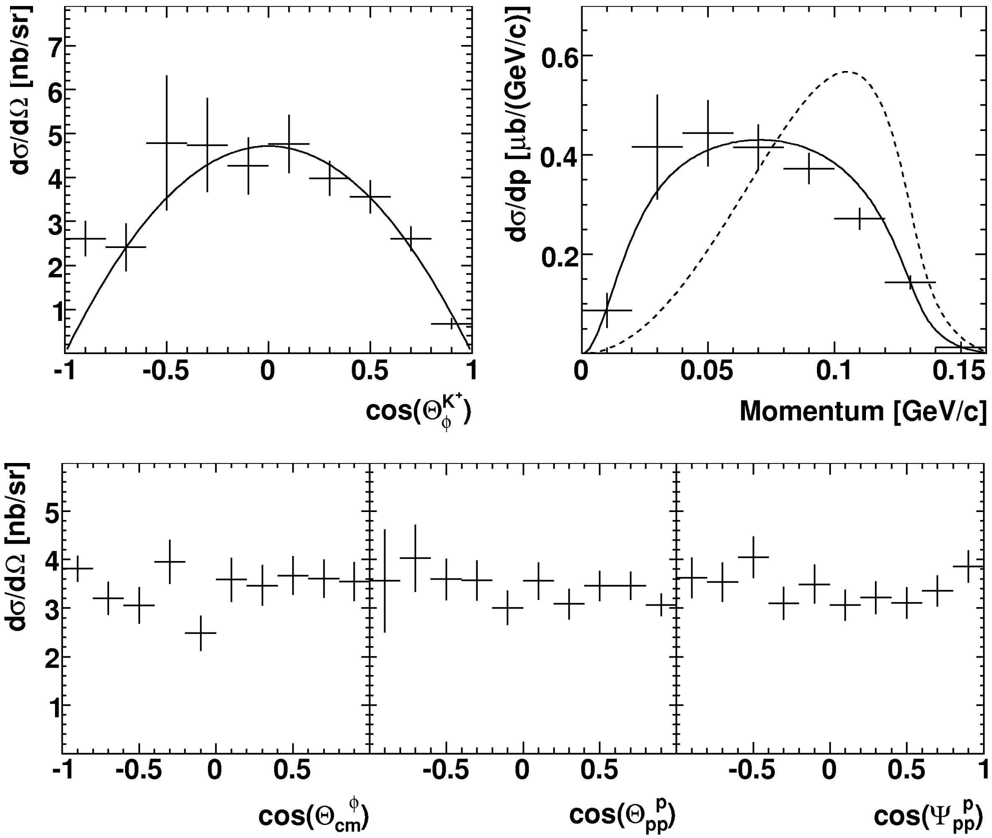
ANKE: pp→ppΦ (differential cross sections) at ε_Φ = 18.5 MeV

close to threshold the angular decay distribution must display a $\sin^2\theta_\phi^{K^+}$

Φ in relative S-wave

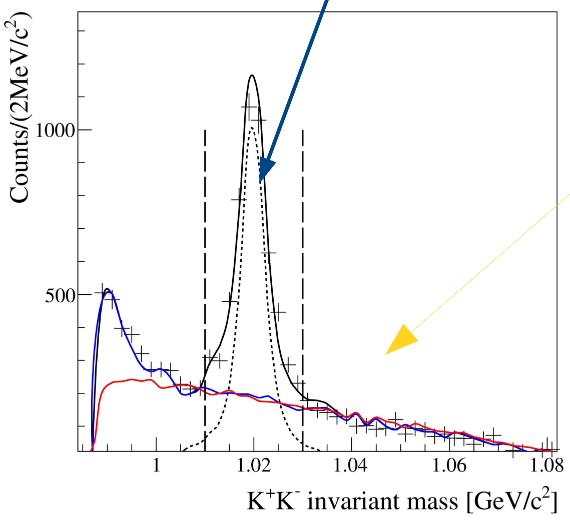
transition from $^3P_1$ (pp)-entrance channel to $^1S_0$ (pp) final-state

clear effect of pp-FSI



MH *et.al.* PRL 96 (2006) 242301

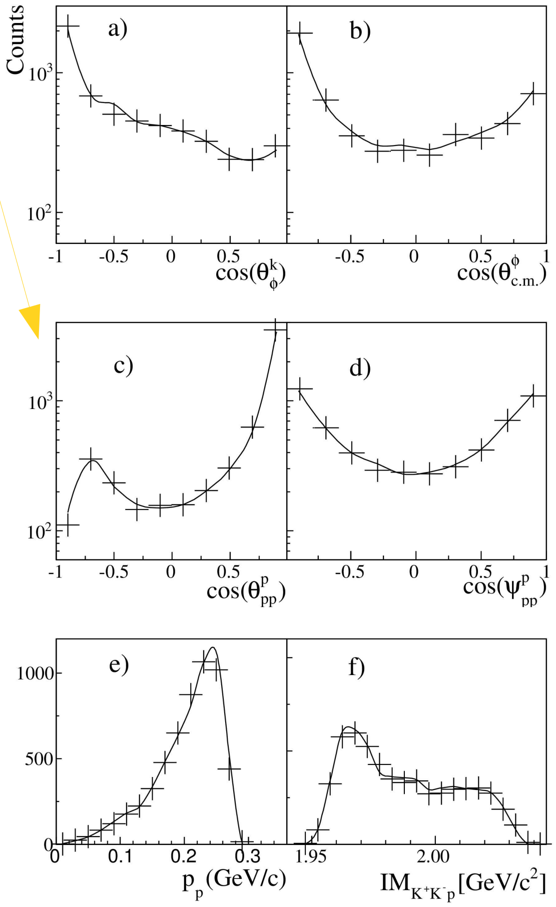
ANKE: pp→ppΦ production at ε_Φ = 76 MeV ...



no acceptance correction

Q.J. Ye *et.al.*, PRC 85 (2012) 035211

“inside Φ”

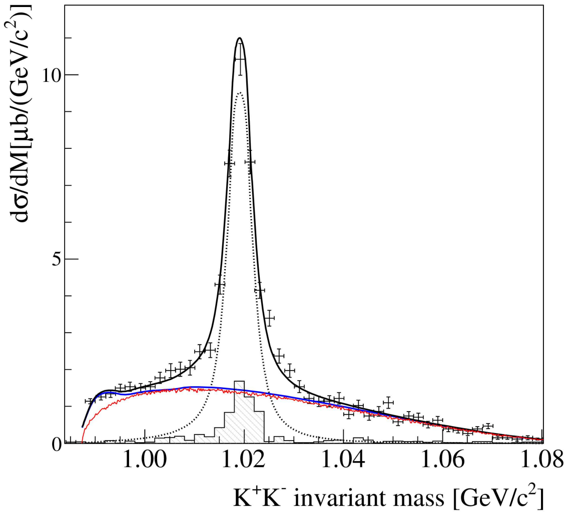


spin-averaged squared transition matrix element

$$\overline{|M|^2} = A_{Ss}\,(\hat{k}\times\hat{K})^2 + A_{Ps}\,\vec{p}^{\,2} + A_{Pp}(\vec{q}\cdot\vec{p})^2 + A_{Sp}\left[3(\vec{q}\cdot\hat{K})^2 - \vec{q}^{\,2}\right].$$

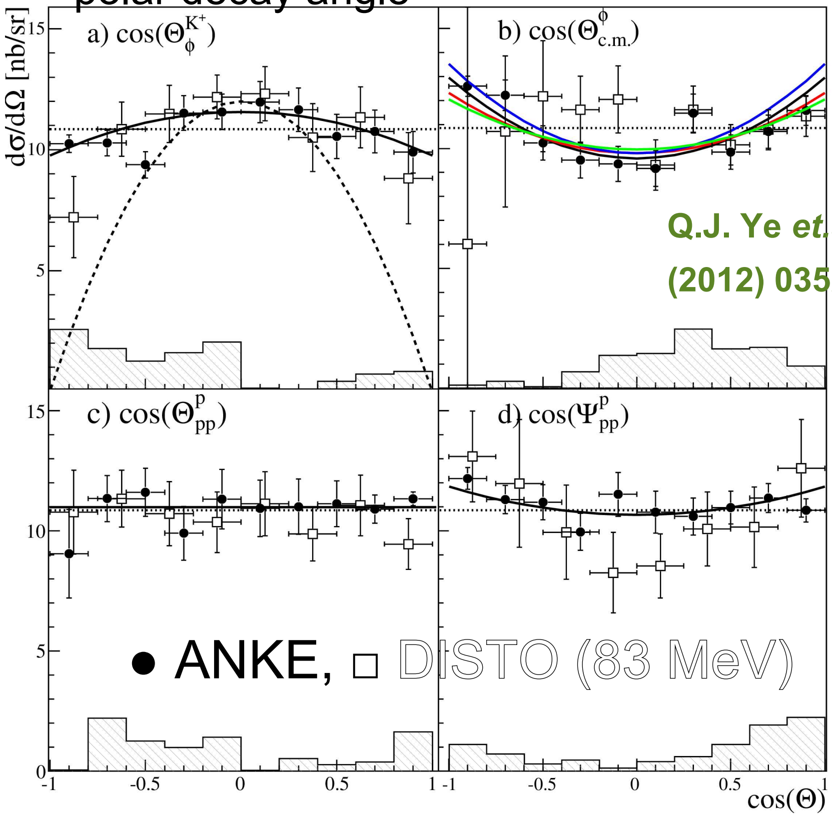
multiplied by pp-FSI (Jost function)

… and final differential distributions at 76 MeV



$$\frac{d\sigma}{d\Omega} \propto \left[(1-\rho_{00})\sin^2\theta_\phi^K + 2\rho_{00}\cos^2\theta_\phi^K\right],$$

polar decay angle



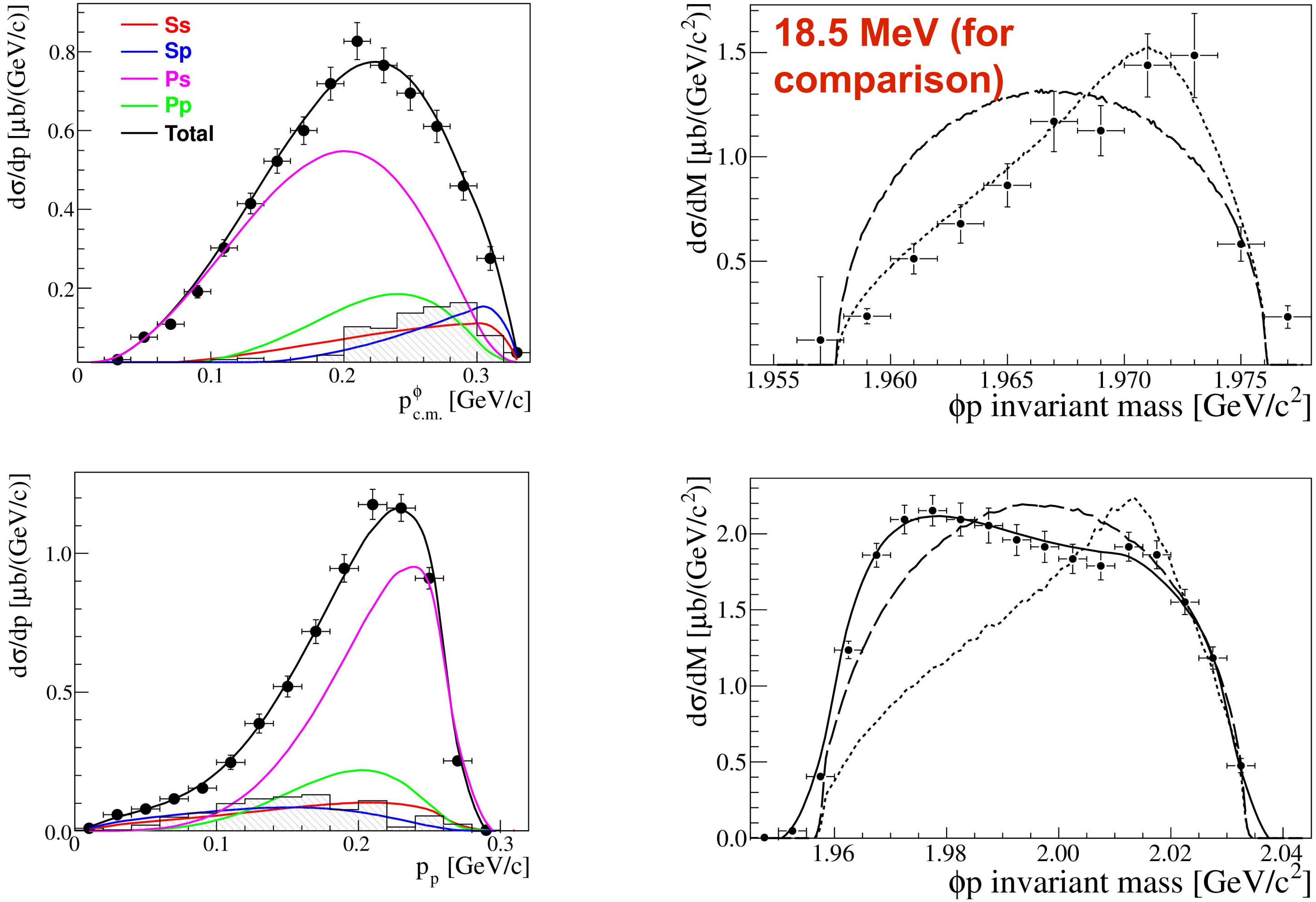
● ANKE, □ DISTO (83 MeV)

Q.J. Ye *et.al.*, PRC 85 (2012) 035211

angular distributions (symmetric about cos θ = 0)

$$\frac{d\sigma}{d\Omega} = a\left[1 + b\,P_2(\cos\theta)\right].$$

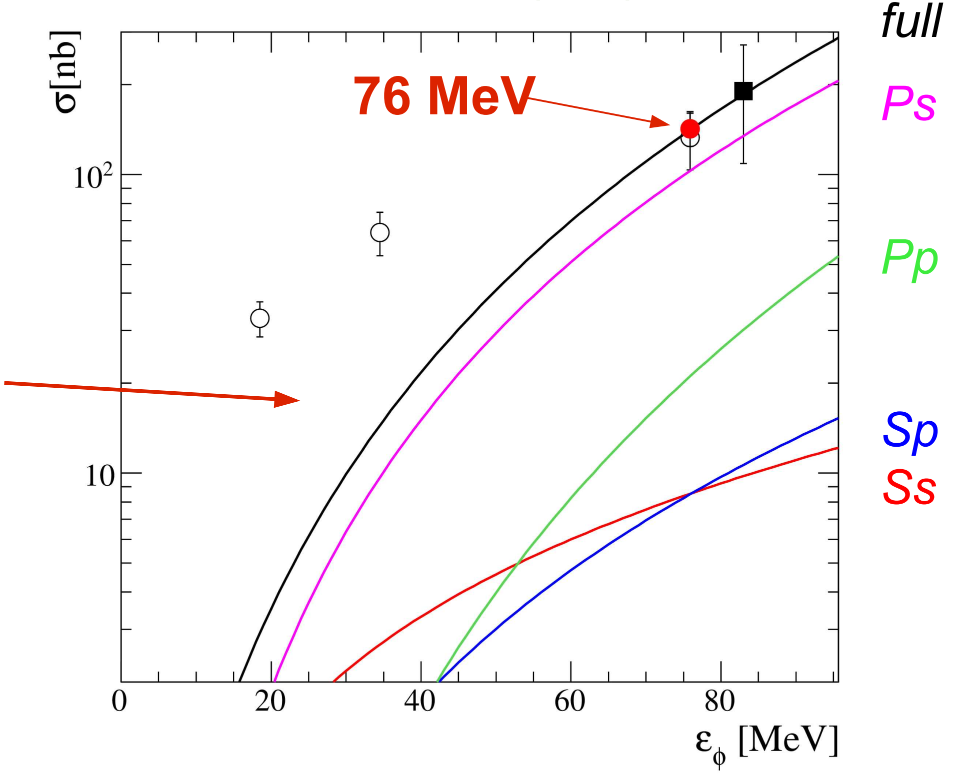
… and final differential distributions at 76 MeV



Q.J. Ye *et.al.*, PRC 85 (2012) 035211

… and ppΦ total cross section dilemma

Q.J. Ye *et.al.*, PRC 85 (2012) 035211



76 MeV

?

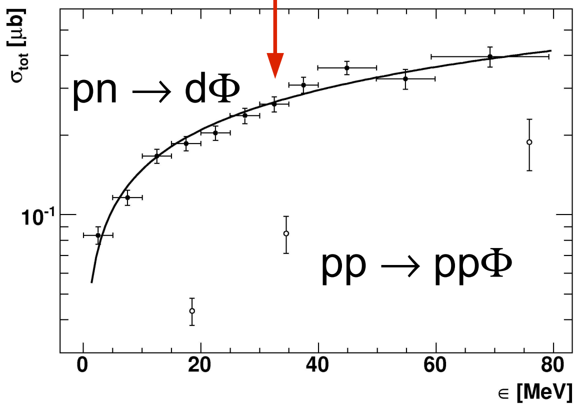
Simplest way out: A Φp threshold enhancement leads to a significant energy dependence of some of the A_{Ll} coefficients.

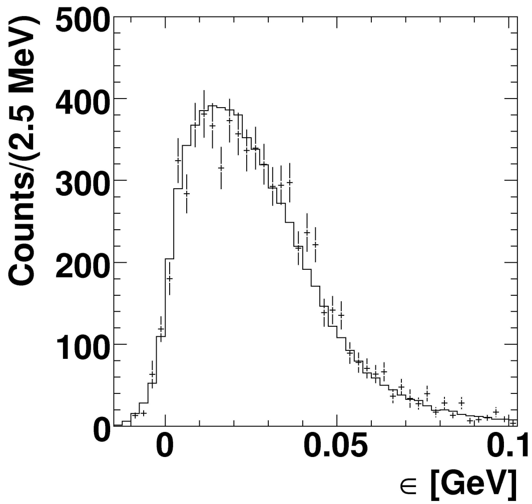
ANKE: pn→dΦ (differential & total cross sections)

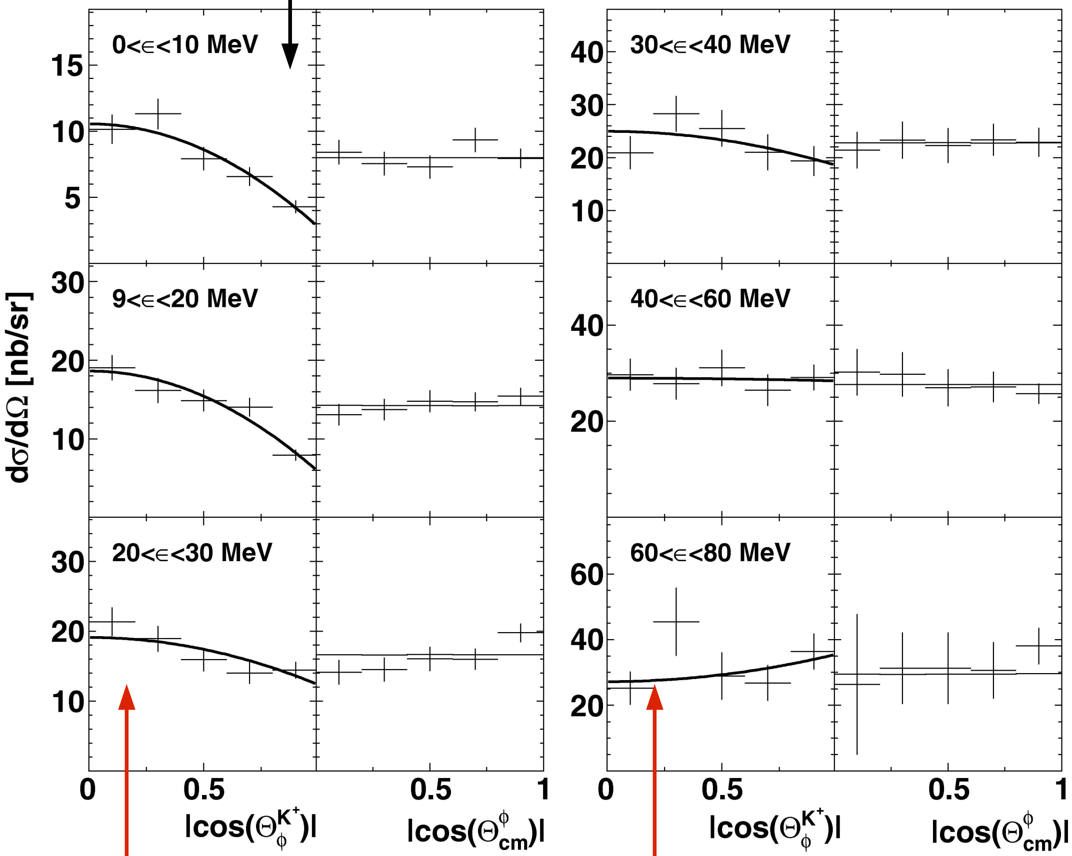
σ_{tot} follows phase space

Y. Maeda *et.al.*, PRL 97 (2006) 142301

$d\sigma/d\Omega_\Phi^{K^+} = 3(a\cdot\sin^2\Theta_\Phi^{K^+}+2b\cdot\cos^2\Theta_\Phi^{K^+})/8\pi,\ \sigma_{tot} = a+b$







higher PW

ANKE: Φ(→K⁺K⁻) production in pA - Φ-width measurement

Method: Attenuation measurements of the Φ flux

SPring-8 photo-production, later also by CLAS.

$$D = \exp\left(-\int_z^{\infty} dl \, \frac{\Gamma^*(\rho(r))M_0}{p_\Phi}\right), \rho(r) - local\ nuclear\ density$$

Φ survival probability in the nucleus matter rest frame:
In-medium width deduced from the target mass dependence.

dominate K^+K^- BR =0.49

We present the A-dependence of the Φ production in the following form:

$$R = \frac{T_A}{T_C} = \frac{12}{A}\frac{\sigma_\phi^A}{\sigma_\phi^C}, \quad T_A = \frac{\sigma_\phi^A}{A\sigma_\phi^N}$$

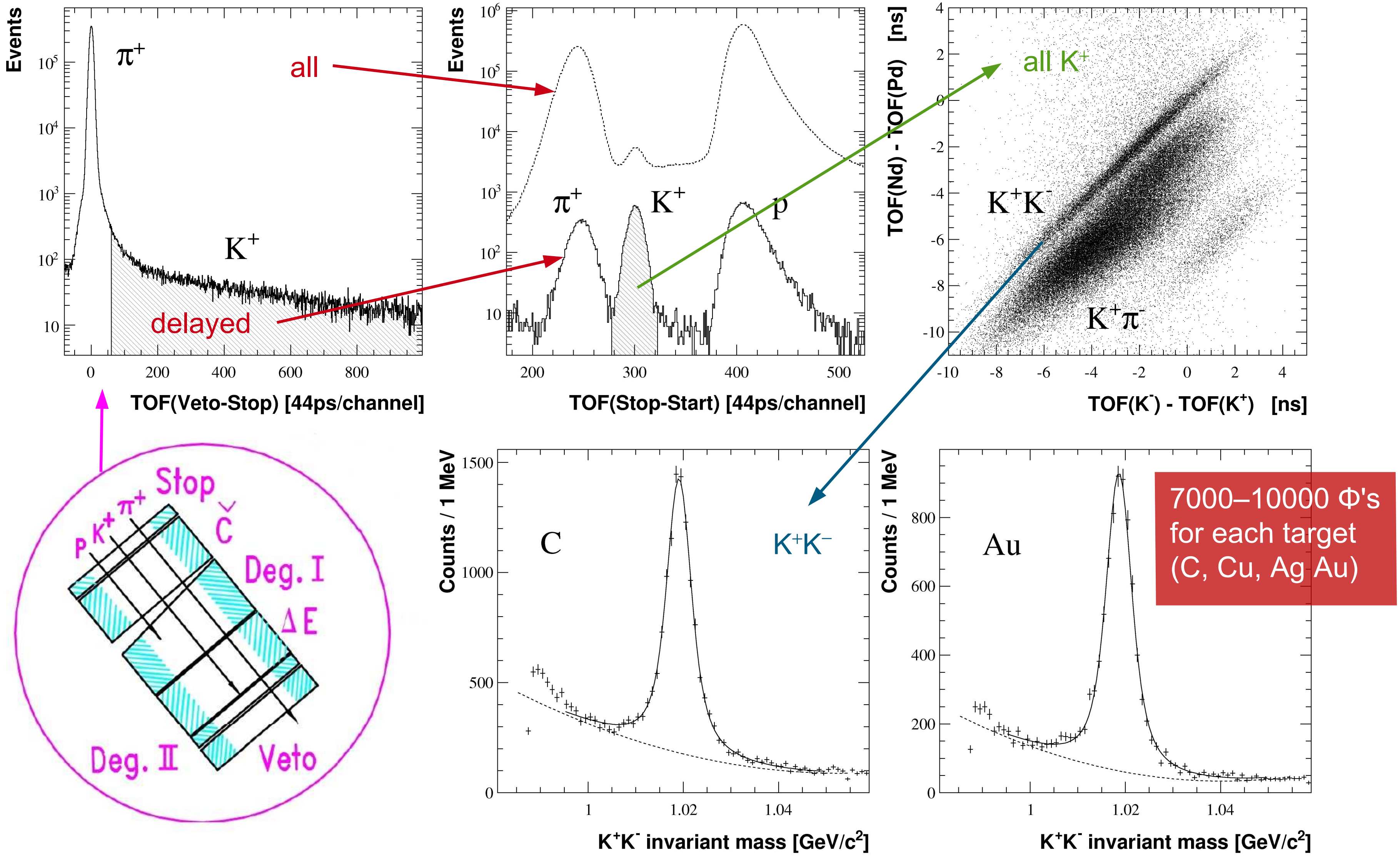
nuclear transparency ratio

experiment at ANKE

Reaction: pA → Φ X , via K^+K^- decay
p-Energy: 2.83 GeV ($\varepsilon_{\text{free NN}}$≈ 76MeV)
Targets: C, Cu, Ag, Au

Momentum and angular range: (0.6 — 1.6) GeV/c, $0^o \leq \Theta_\Phi \leq 8^o$

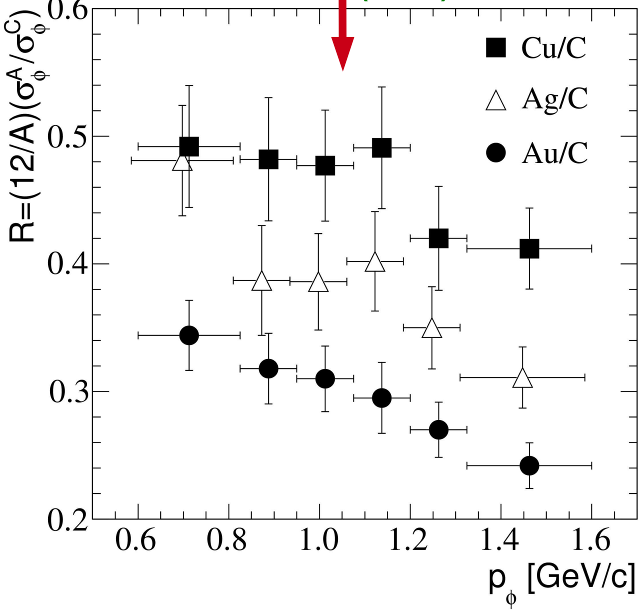
Φ / K^+K^- selection



7000–10000 Φ's for each target (C, Cu, Ag Au)

Transparency ratios:
experiment and models

MH *et.al.*, PRC 85 (2012) 035206.



Relevant features for models:

forward acceptance

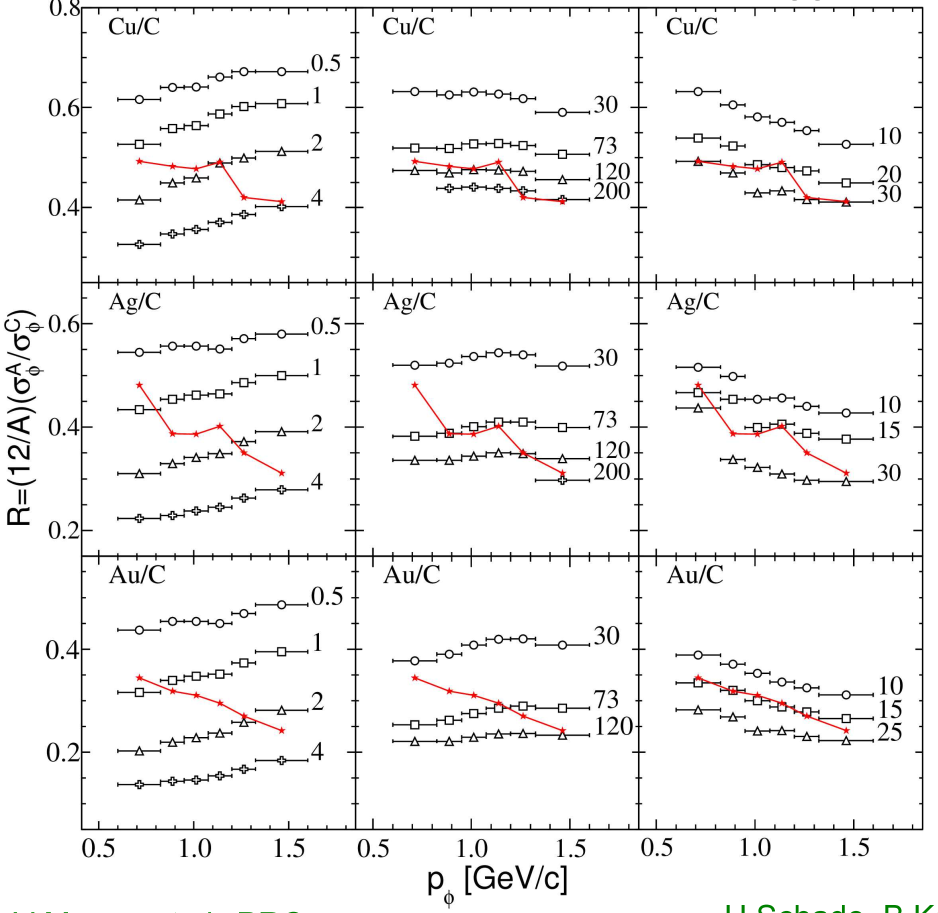
two-step production processes

$\sigma_{pn\to pn\Phi}/\sigma_{pp\to pp\Phi} \approx 4$

Valencia/E.Oset *et al.*
MC & Chiral Unitary Approach

Moscow/E.Paryev
Nuclear Spectral Function Approach

Rossendorf/ B.Kämpfer *et al.*
BUU



V.Magas *et al.*, PRC 71 (2005) 065202; L.Roca (private communication)

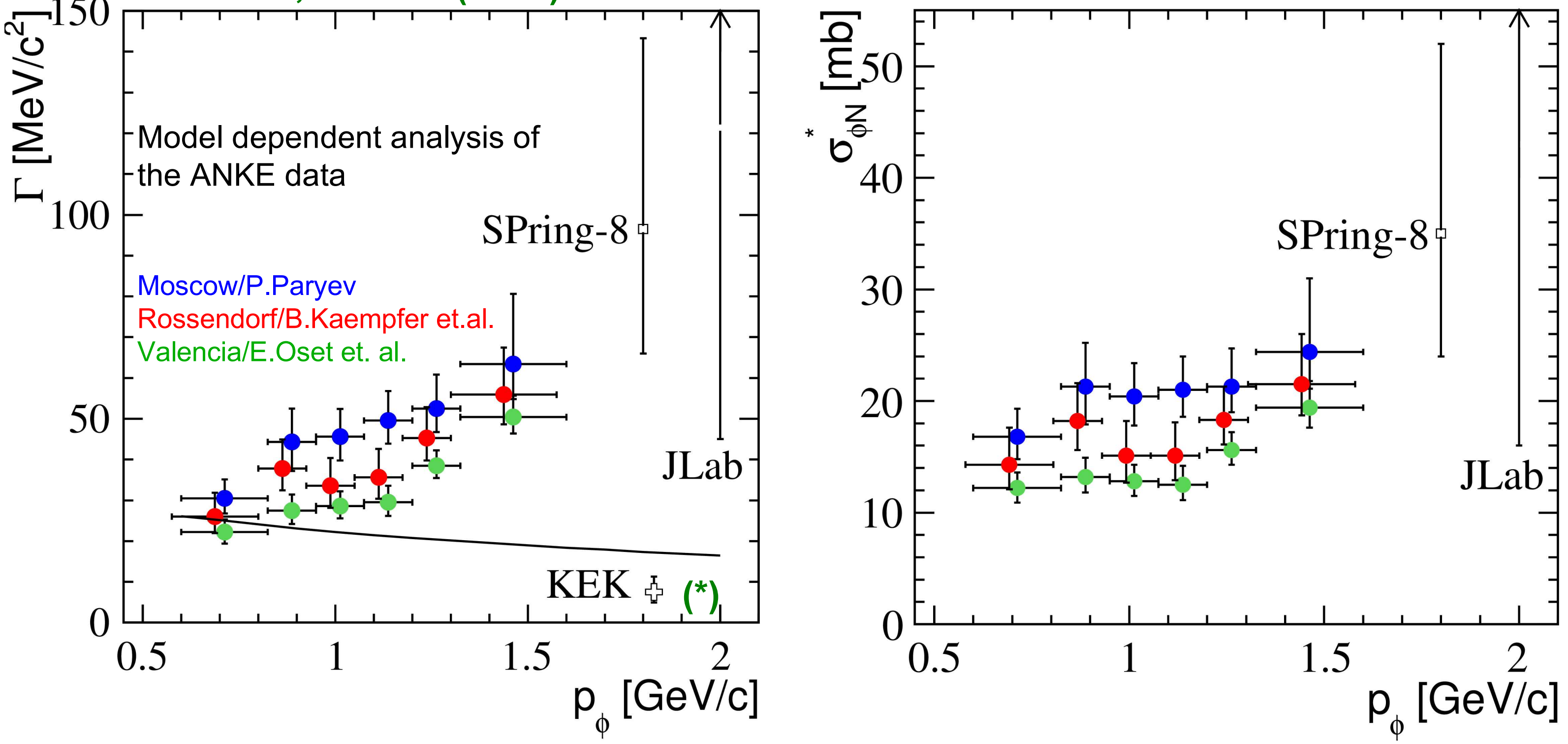
E.Paryev, J.Phys. G 36 (2009) 015103

H.Schade, B.Kämpfer (private communication); cf. PRC 81 (2010) 034902:

In-medium width Γ_Φ and $\sigma^*_{\Phi N}$ cross section

LDA: $$\Gamma_\Phi^{lab}(\rho_0) = \frac{p_\Phi}{E}\sigma^*_{\Phi N}\rho_0$$

MH *et.al.*, PRC 85 (2012) 035206



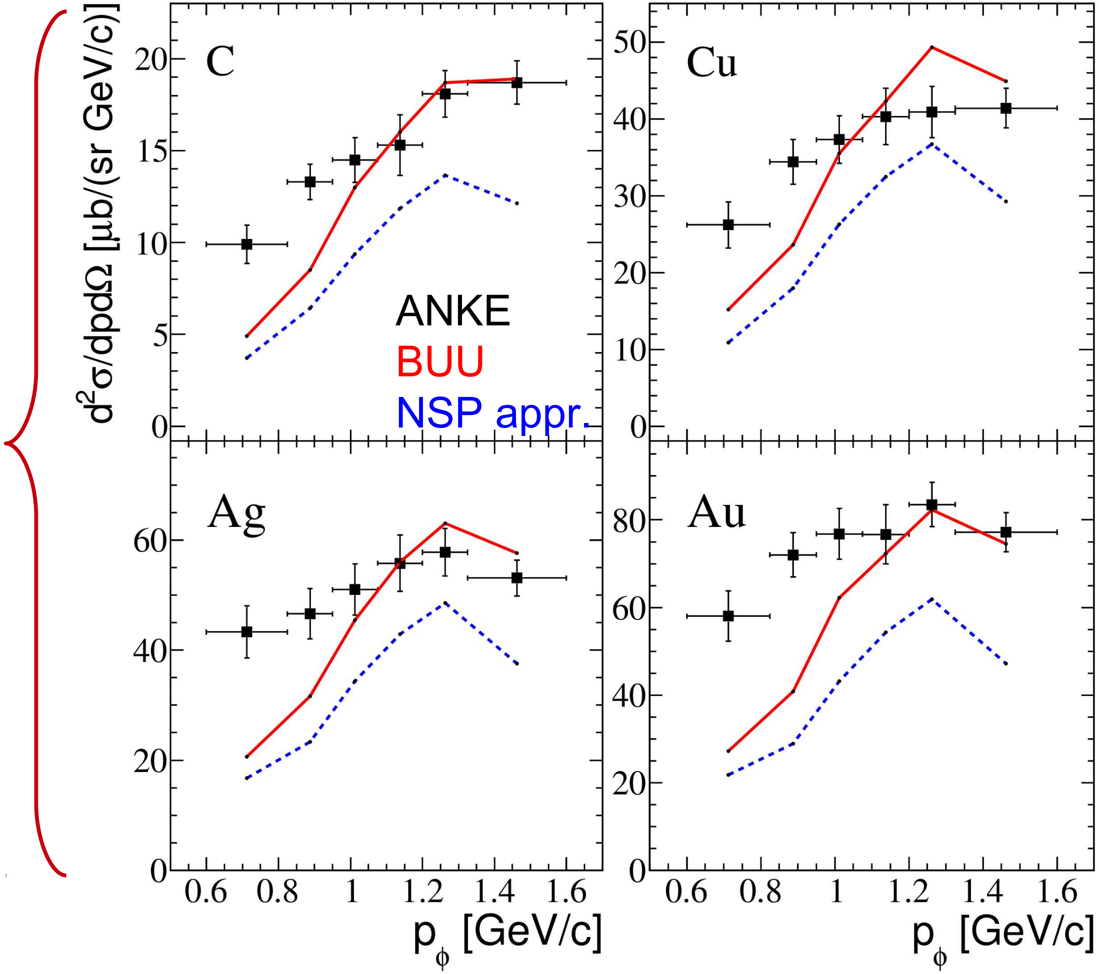
significant momentum dependence

cf. A. Polyanskiy *et.al.*, PLB 695 (2011) 74, (*) MH et.al., EPJ Web Conf. 36 (2012) 00011

Double differential cross section of Φ production

MH *et.al.*, PRC 85, 035206 (2012).

Excess in low momentum part

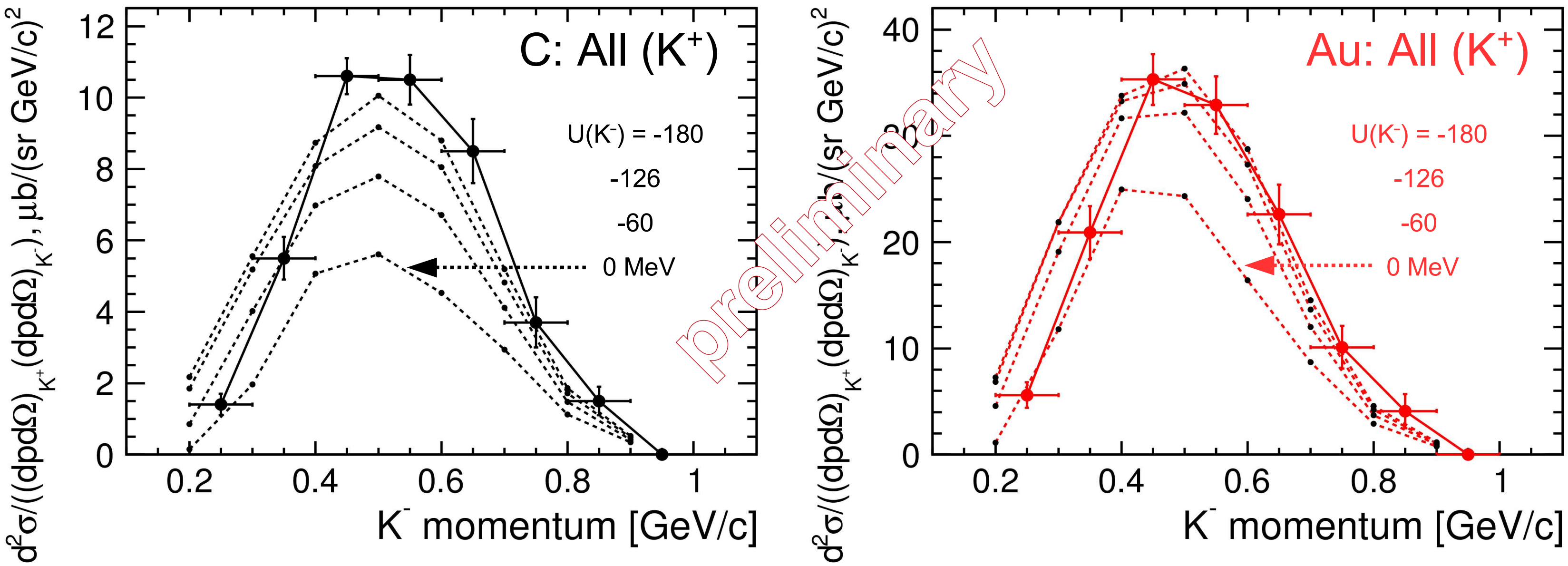


+ common systematics ~ 20 %

ANKE: (non-Φ) K^+K^- production in pA - first look/preliminary!

0.2 < p(K^+) < 0.6 GeV/c, θ(K^+,K^-) < 12°, IM(K^+,K^-) < 1.005 GeV

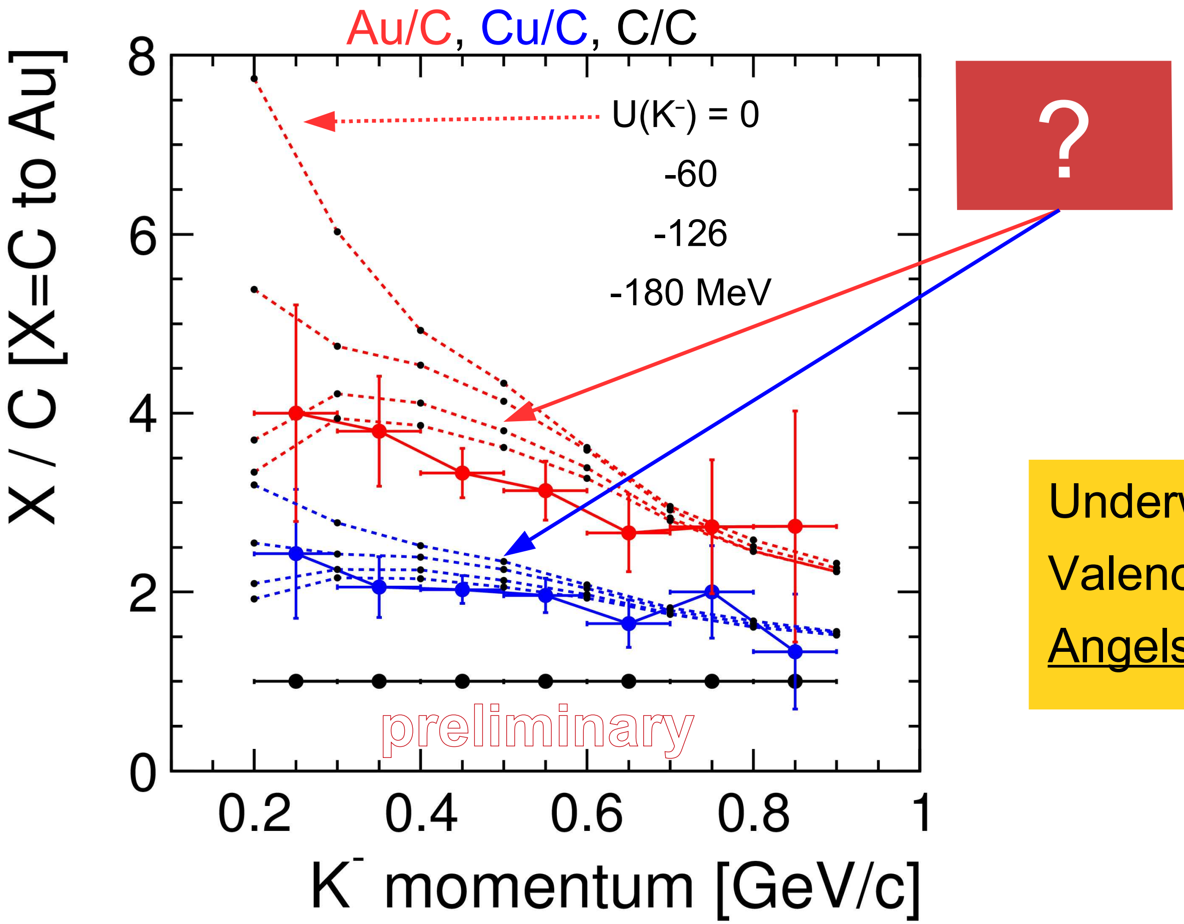
model calculation (NSP appr. / E. Paryev), absorption from KN scatt. data



?

go to ratios

ANKE: (non-Φ) K^+K^- production in pA
- first look/preliminary!

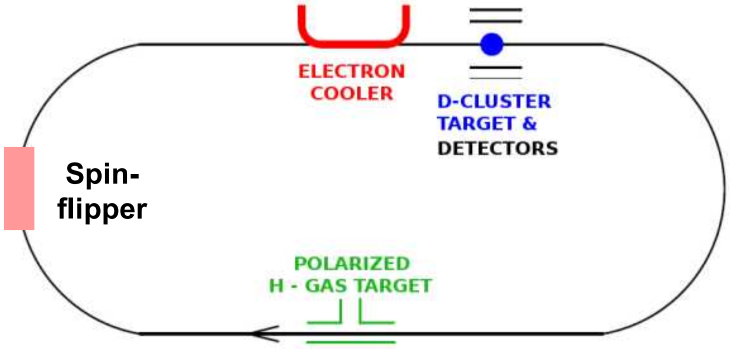


Underway / calculations from Valencia group (Eulogio Oset): Angels Ramos & Luis Roca

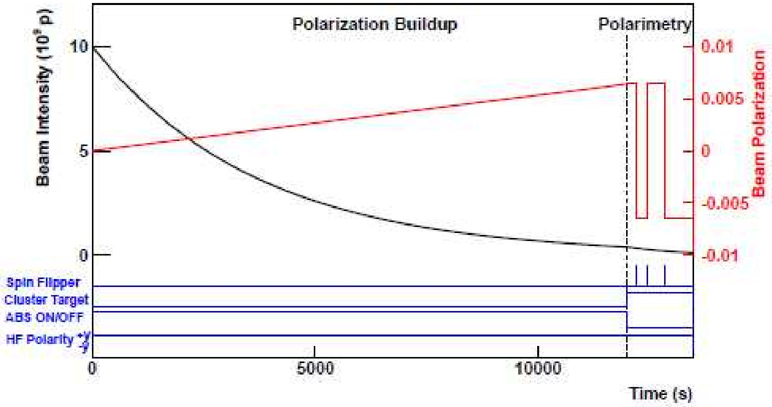
finalization of exp. data; in-depth model analysis needed

PAX: Transverse polarization buildup of a stored beam by Spin-Filtering

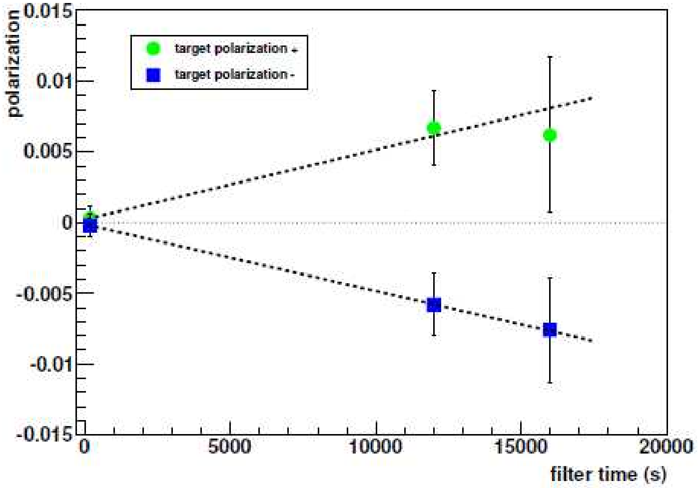
Experiment with COSY / schematic

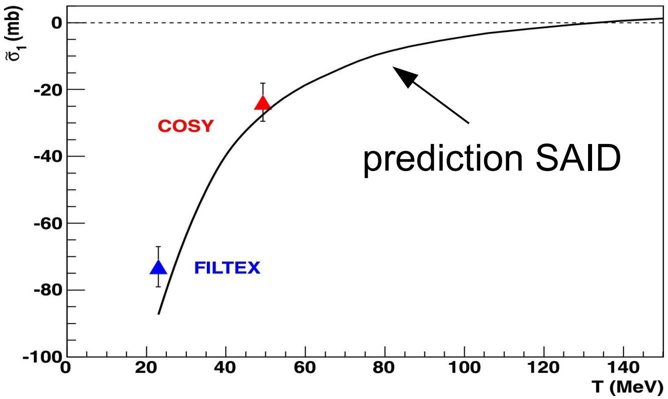


COSY Cycle / schematic



Results

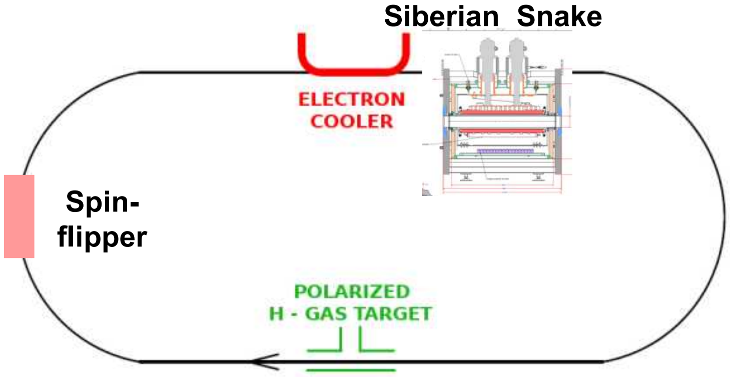




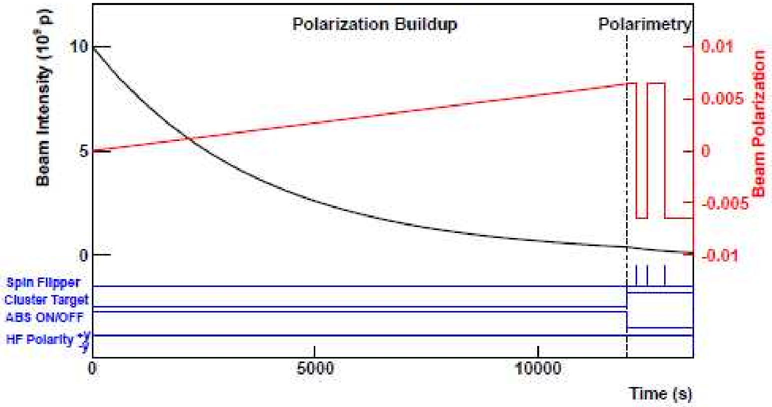
W. Augustyniak *et.al.*, PLB 718 (2012) 64

PAX: Transverse polarization buildup of a stored beam by Spin-Filtering

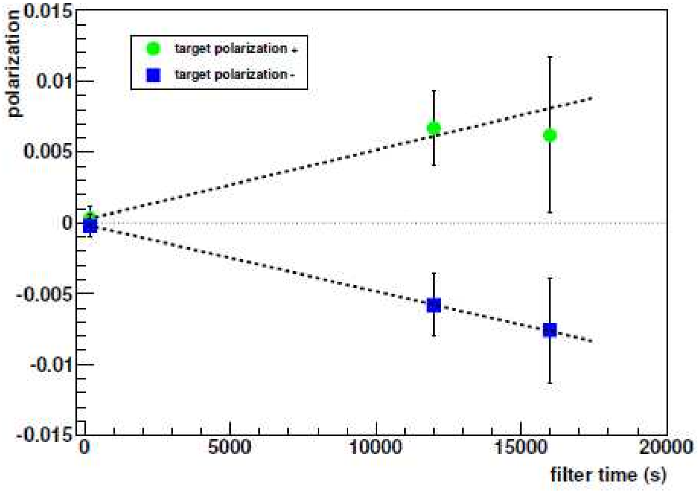
Experiment with COSY / schematic

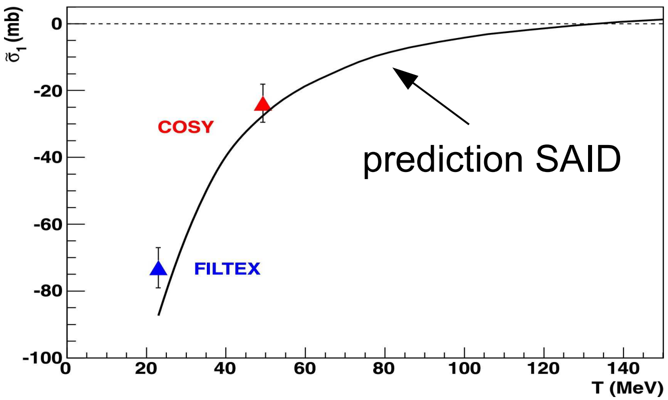


COSY Cycle / schematic



Results

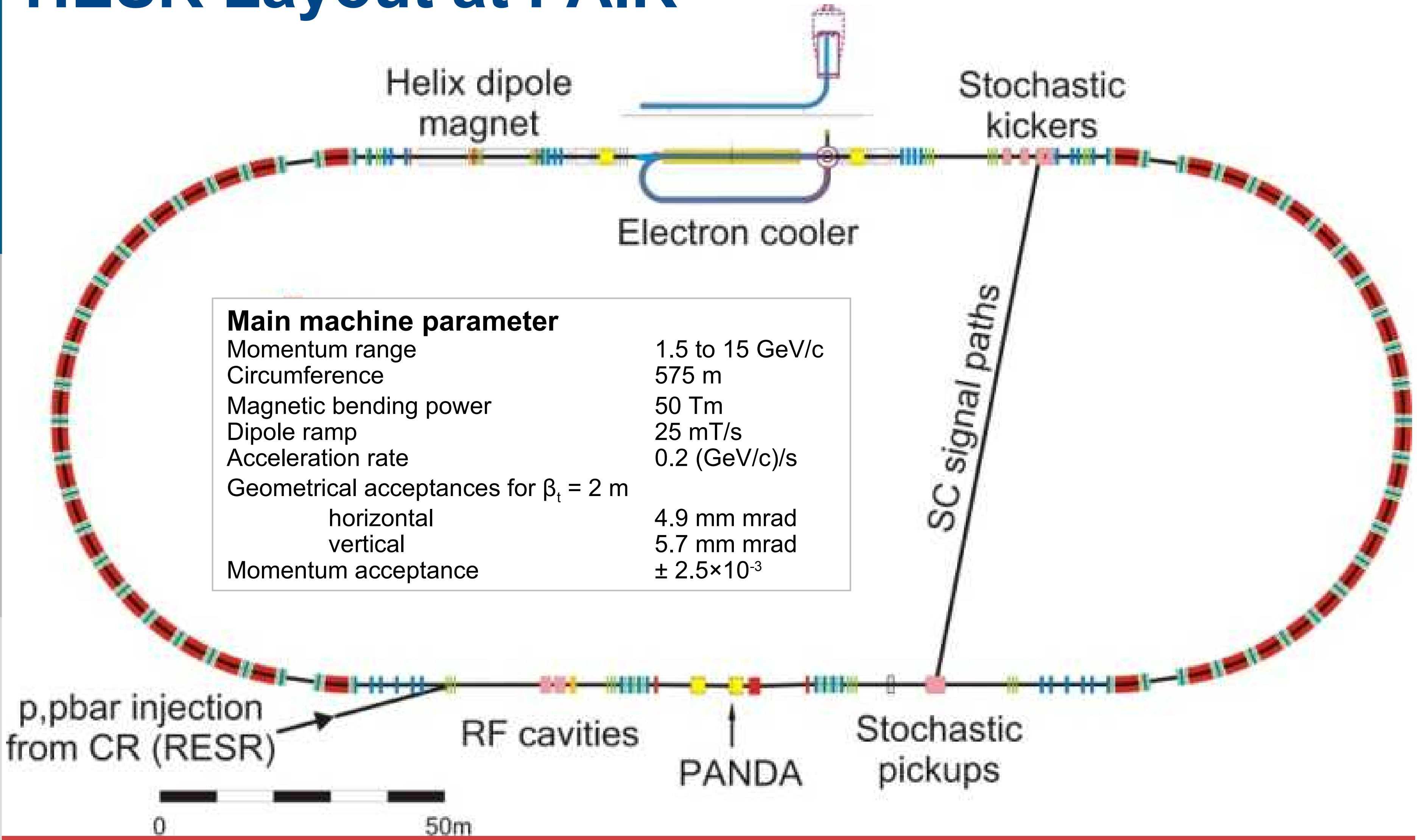




W. Augustyniak *et.al.*, PLB 718 (2012) 64

Preparation for longitudinal polarization build-up at COSY and PAX-at-CERN/AD

HESR Layout at FAIR

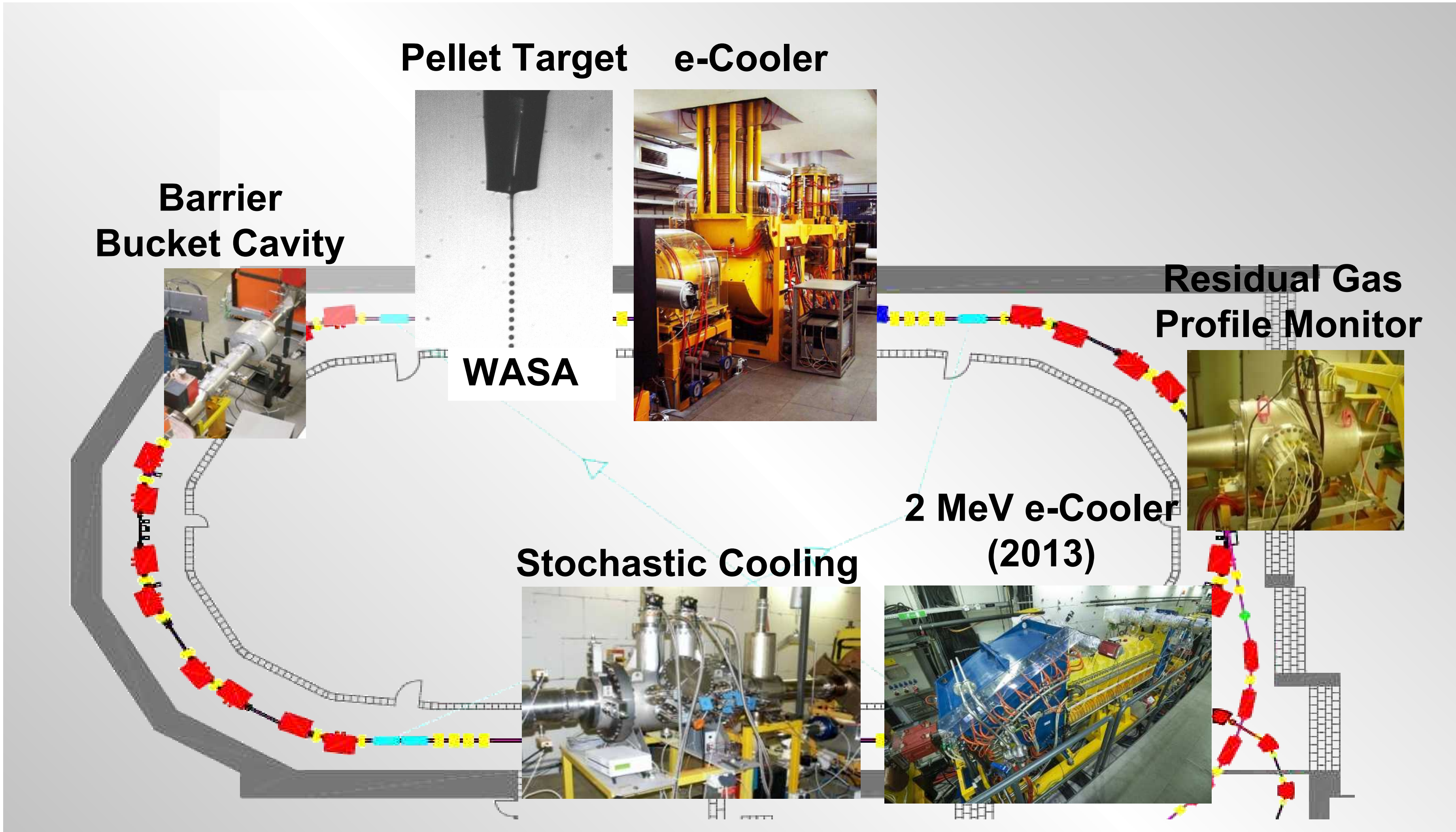


Main machine parameter

Momentum range	1.5 to 15 GeV/c
Circumference	575 m
Magnetic bending power	50 Tm
Dipole ramp	25 mT/s
Acceleration rate	0.2 (GeV/c)/s
Geometrical acceptances for β_t = 2 m	
horizontal	4.9 mm mrad
vertical	5.7 mm mrad
Momentum acceptance	$\pm 2.5\times10^{-3}$

Jülich is leading lab for design and construction

HESR Prototyping and Beam Physics



Pellet Target

e-Cooler

Barrier Bucket Cavity

WASA

Residual Gas Profile Monitor

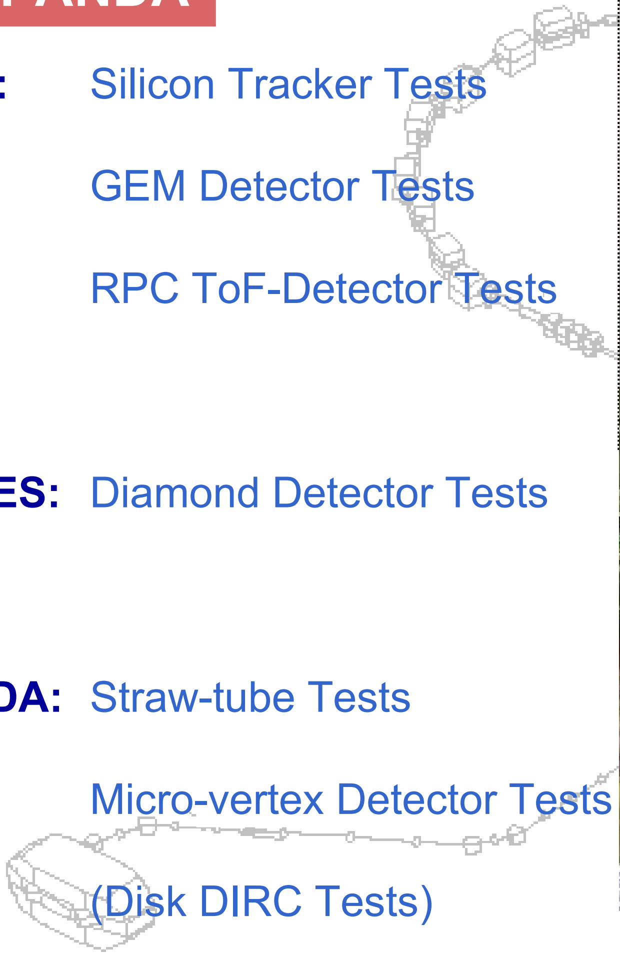
2 MeV e-Cooler (2013)

Stochastic Cooling

HESR accelerator component tests

Preparatory Work for FAIR Detectors

CBM, PANDA



CBM: Silicon Tracker Tests

GEM Detector Tests

RPC ToF-Detector Tests

HADES: Diamond Detector Tests

PANDA: Straw-tube Tests

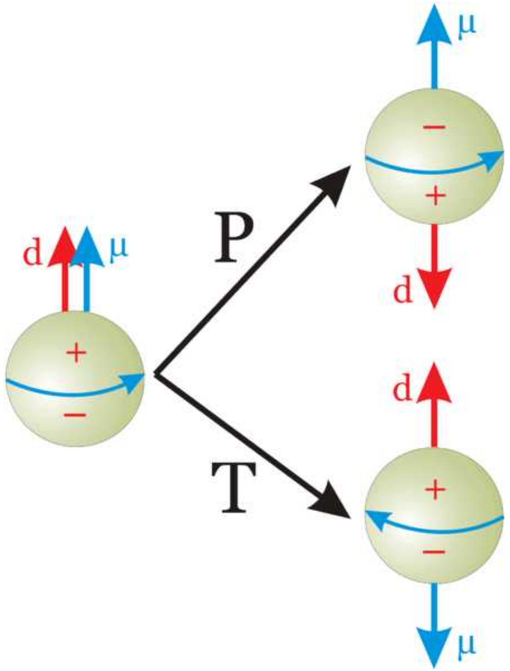
Micro-vertex Detector Tests

(Disk DIRC Tests)

„Preassembly“ of PANDA parts (TOF area)

Electric Dipole Moments

EDM: Permanent spatial separation of positive an negative charges

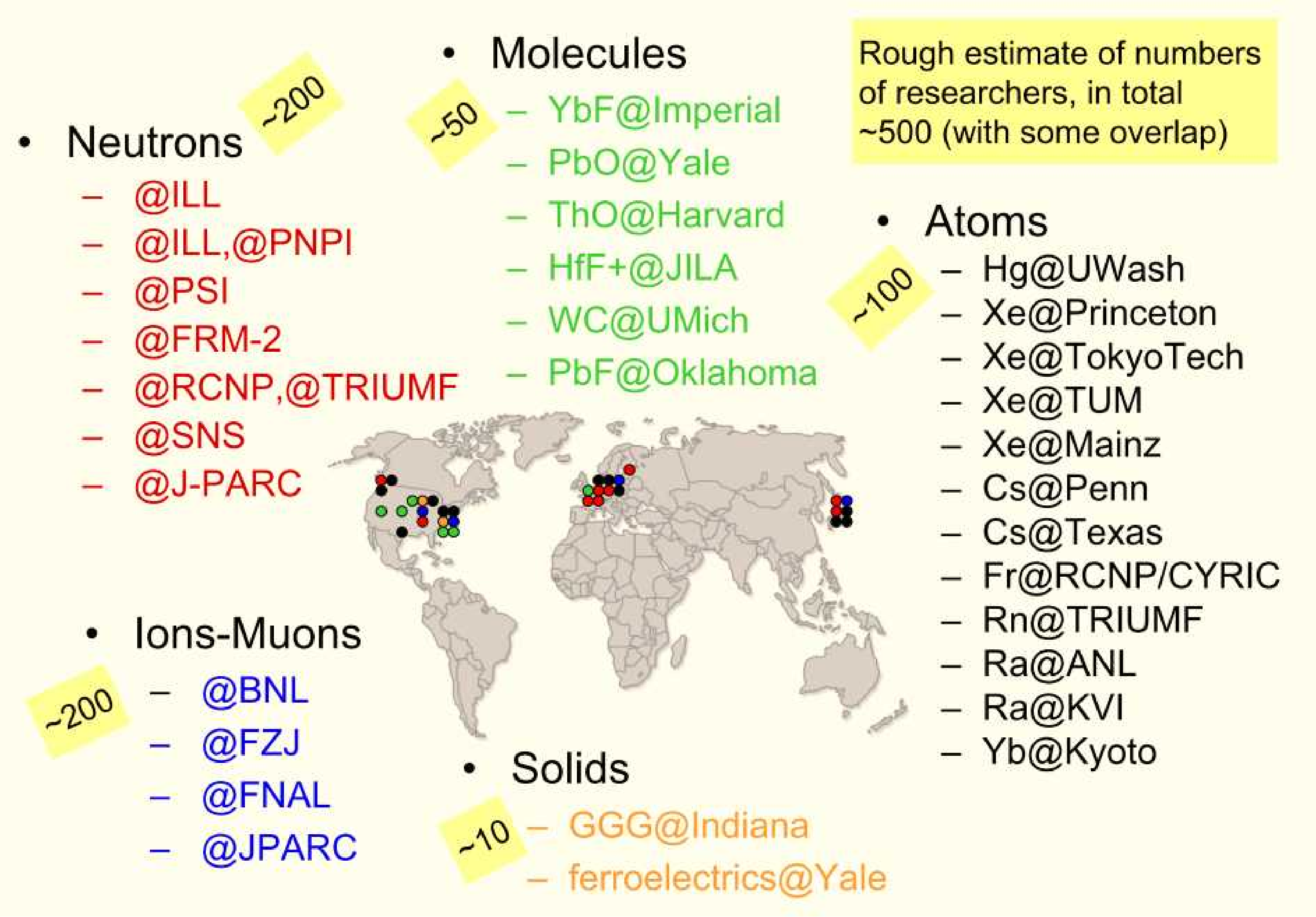


Permanent EDMs violate parity P and time reversal symmetry T

Assuming CPT to hold,
combined symmetry CP violated as well.

EDMs are candidates to solve mystery of matter-antimatter asymmetry

EDMs – Ongoing / Planned



- Neutrons
  - @ILL
  - @ILL,@PNPI
  - @PSI
  - @FRM-2
  - @RCNP,@TRIUMF
  - @SNS
  - @J-PARC

~200

- Molecules
  - YbF@Imperial
  - PbO@Yale
  - ThO@Harvard
  - HfF+@JILA
  - WC@UMich
  - PbF@Oklahoma

~50

Rough estimate of numbers of researchers, in total ~500 (with some overlap)

- Atoms
  - Hg@UWash
  - Xe@Princeton
  - Xe@TokyoTech
  - Xe@TUM
  - Xe@Mainz
  - Cs@Penn
  - Cs@Texas
  - Fr@RCNP/CYRIC
  - Rn@TRIUMF
  - Ra@ANL
  - Ra@KVI
  - Yb@Kyoto

~100

- Ions-Muons
  - @BNL
  - @FZJ
  - @FNAL
  - @JPARC

~200

- Solids
  - GGG@Indiana
  - ferroelectrics@Yale

~10

P. Harris, K. Kirch … A huge worldwide effort

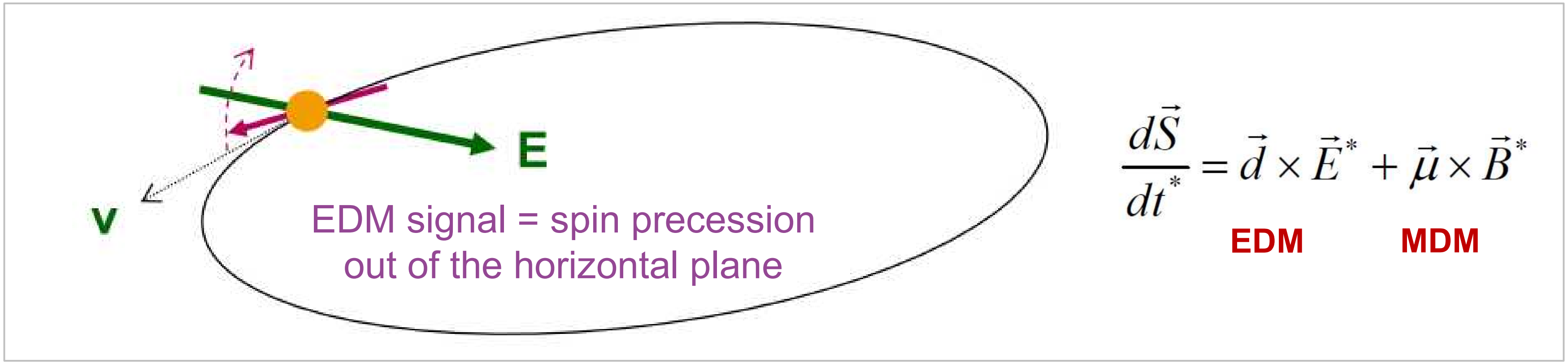
EDM – Charged particles (p,d, …)

Why? (**charged particles**)

- Identification of the CPV-source
- Highest sensitivity (goal 10^{-29} e cm)

How? (**spin tracking in E-, B-fields**)

- Polarized particles
- Precision storage ring



EDM signal = spin precession out of the horizontal plane

$$\frac{d\vec{S}}{dt^*} = \underbrace{\vec{d} \times \vec{E}^*}_{\text{EDM}} + \underbrace{\vec{\mu} \times \vec{B}^*}_{\text{MDM}}$$

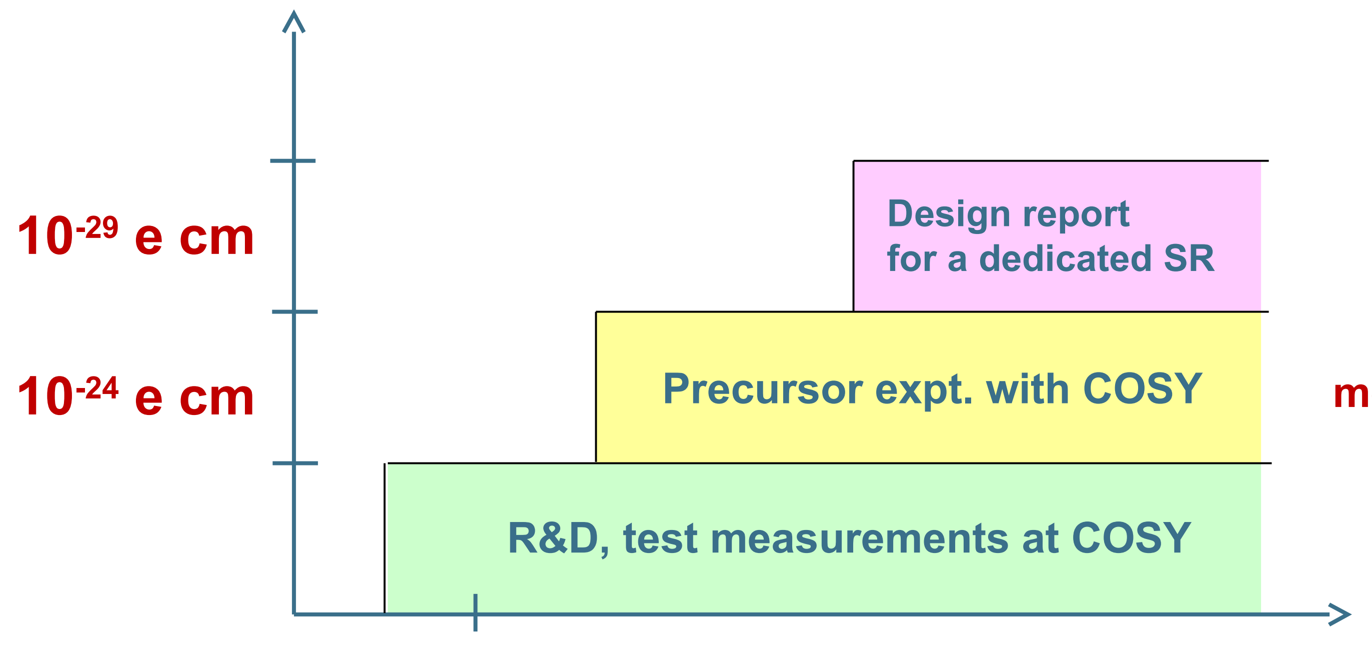
Where? (**COSY at Forschungszentrum Jülich**)

- Storage ring (conventional) and polarized beams
- Accelerator and experimental experience in spin physics
- Strong environment (e.g. FZJ infrastructure, JARA)

EDM – Strategy

Charged-particle EDM searches at storage rings represent **a challenge**!

- Stepwise approach



EDM Sensitivity

10^{-29} e cm

10^{-24} e cm

Design report for a dedicated SR

Precursor expt. with COSY

R&D, test measurements at COSY

First direct measurements for p, d

Time

Now

2018

Spin-off: Accelerators, instrumentation, metrology, …

Summary and Outlook

COSY has a strong physics program:

spin physics and symmetries

COSY is an ideal test machine for FAIR preparatory work:

accelerator and detector components

COSY is the ideal starting place for charged - particle EDMs and precision measurements:

R&D work, first direct measurement and dedicated storage ring

Summary and Outlook

Thank you!

COSY has a strong physics program:
spin physics and symmetries

COSY is an ideal test machine for FAIR preparatory work:
accelerator and detector components

COSY is the ideal starting place for charged - particle EDMs and precision measurements:
R&D work, first direct measurement and dedicated storage ring

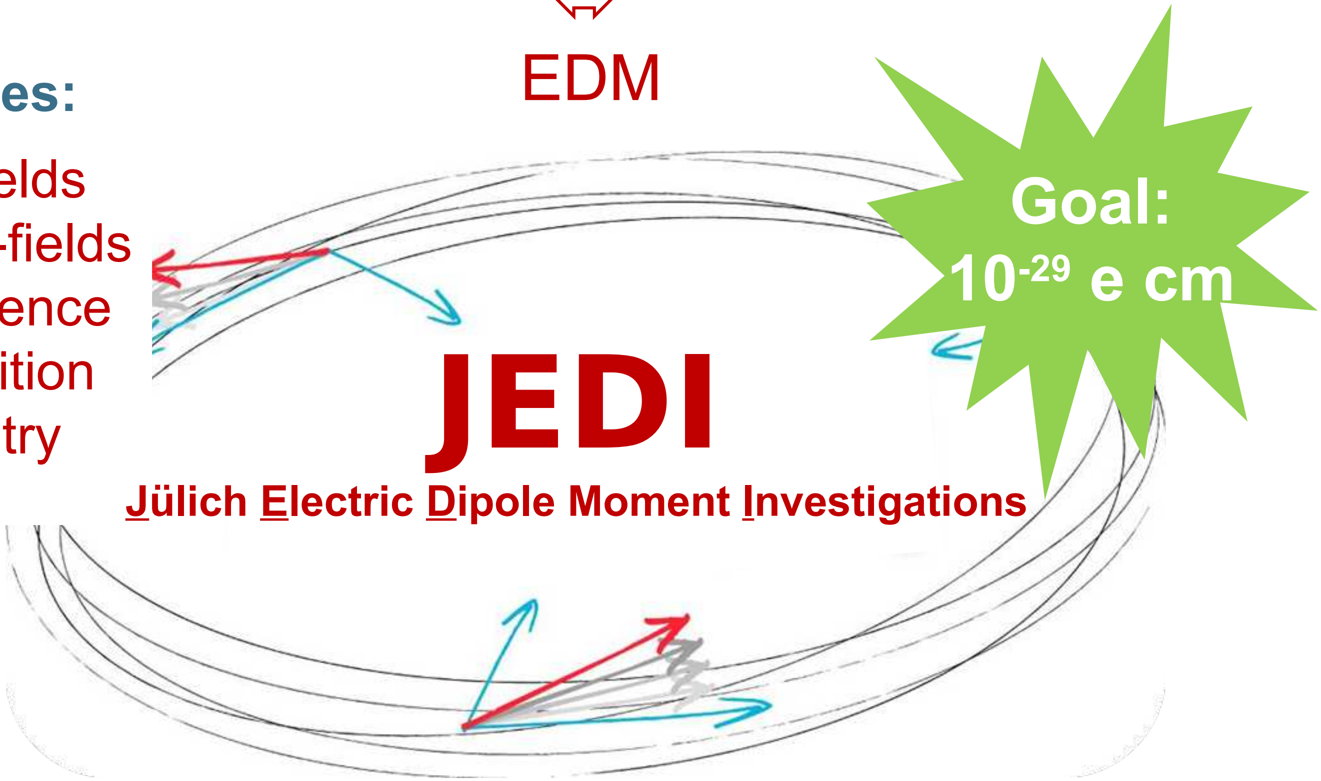
Extra slides

Storage Ring EDM Project

… watch for development of vertical polarization

⬄

EDM



Challenges:

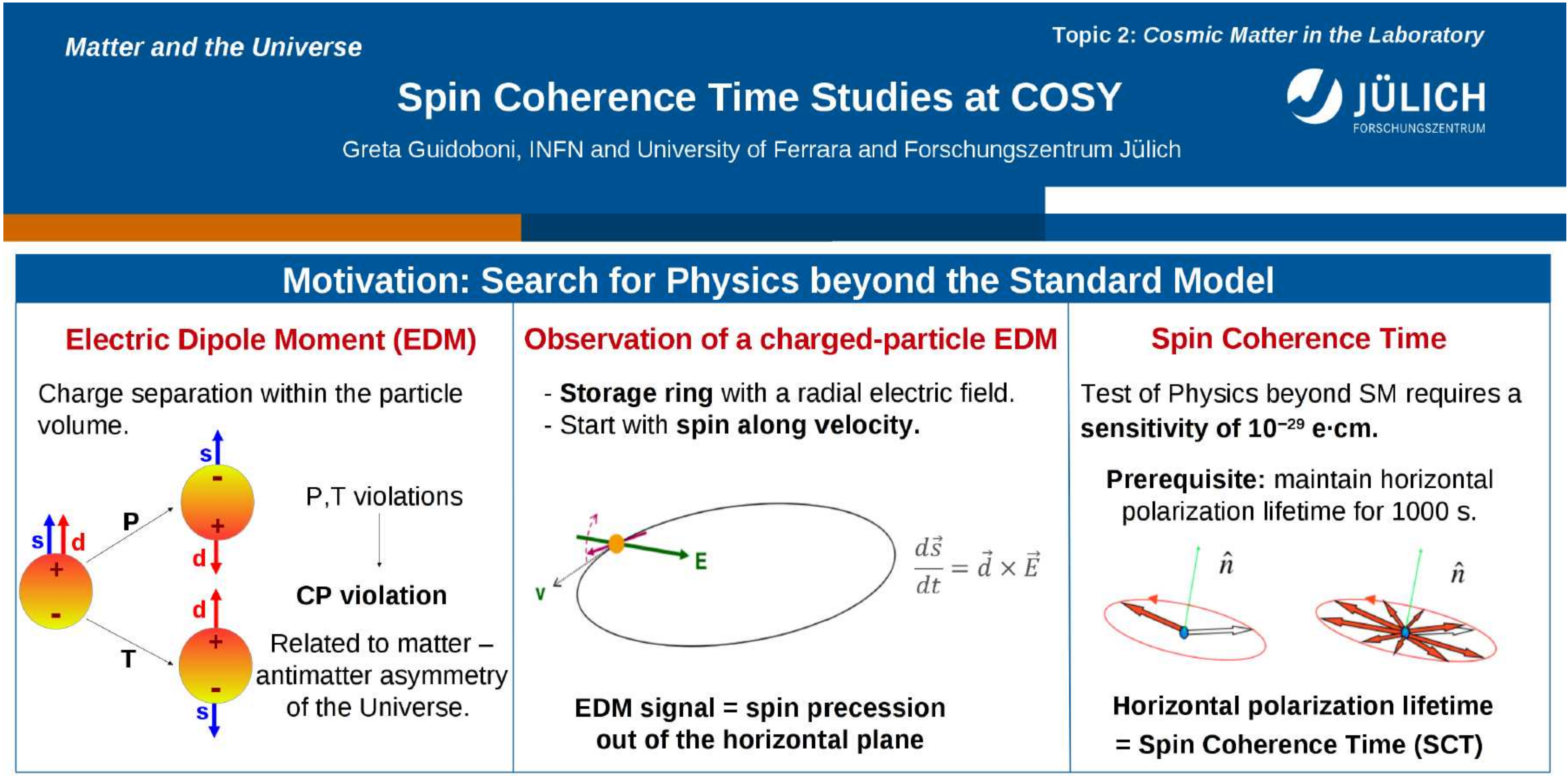
Huge E-fields
Shielding B-fields
Spin coherence
Beam position
Polarimetry
(...)

Goal:
10^{-29} e cm

JEDI

Jülich Electric Dipole Moment Investigations

~ 100 members
(Aachen, Dubna, Ferrara, Cornell, Jülich, Krakow, Michigan, St. Petersburg, Minsk, Novosibirsk, Stockholm, Tbilisi, . . .)
10 PhD students



Matter and the Universe

Topic 2: *Cosmic Matter in the Laboratory*

Spin Coherence Time Studies at COSY

Greta Guidoboni, INFN and University of Ferrara and Forschungszentrum Jülich

Motivation: Search for Physics beyond the Standard Model

Electric Dipole Moment (EDM)

Charge separation within the particle volume.

P,T violations

CP violation

Related to matter – antimatter asymmetry of the Universe.

Observation of a charged-particle EDM

- **Storage ring** with a radial electric field.
- Start with **spin along velocity.**

$$\frac{d\vec{s}}{dt} = \vec{d} \times \vec{E}$$

EDM signal = spin precession out of the horizontal plane

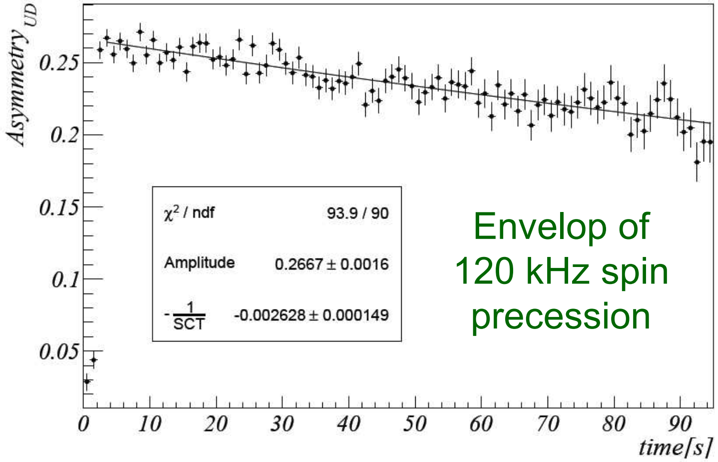
Spin Coherence Time

Test of Physics beyond SM requires a **sensitivity of 10^{-29} e·cm.**

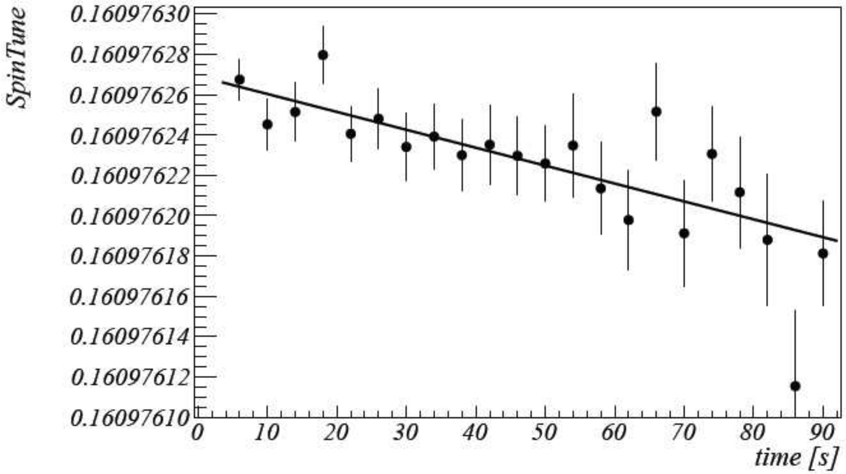
Prerequisite: maintain horizontal polarization lifetime for 1000 s.

Horizontal polarization lifetime = Spin Coherence Time (SCT)

R&D Work at COSY (preliminary)



Up-down asymmetry (~ horizontal polarization) as a function of time



Measured spin tune versus time in cycle

Prerequisites to get long SCT:

Beam bunching
Beam cooling
Sextupole correction
SCT ≈ 400s

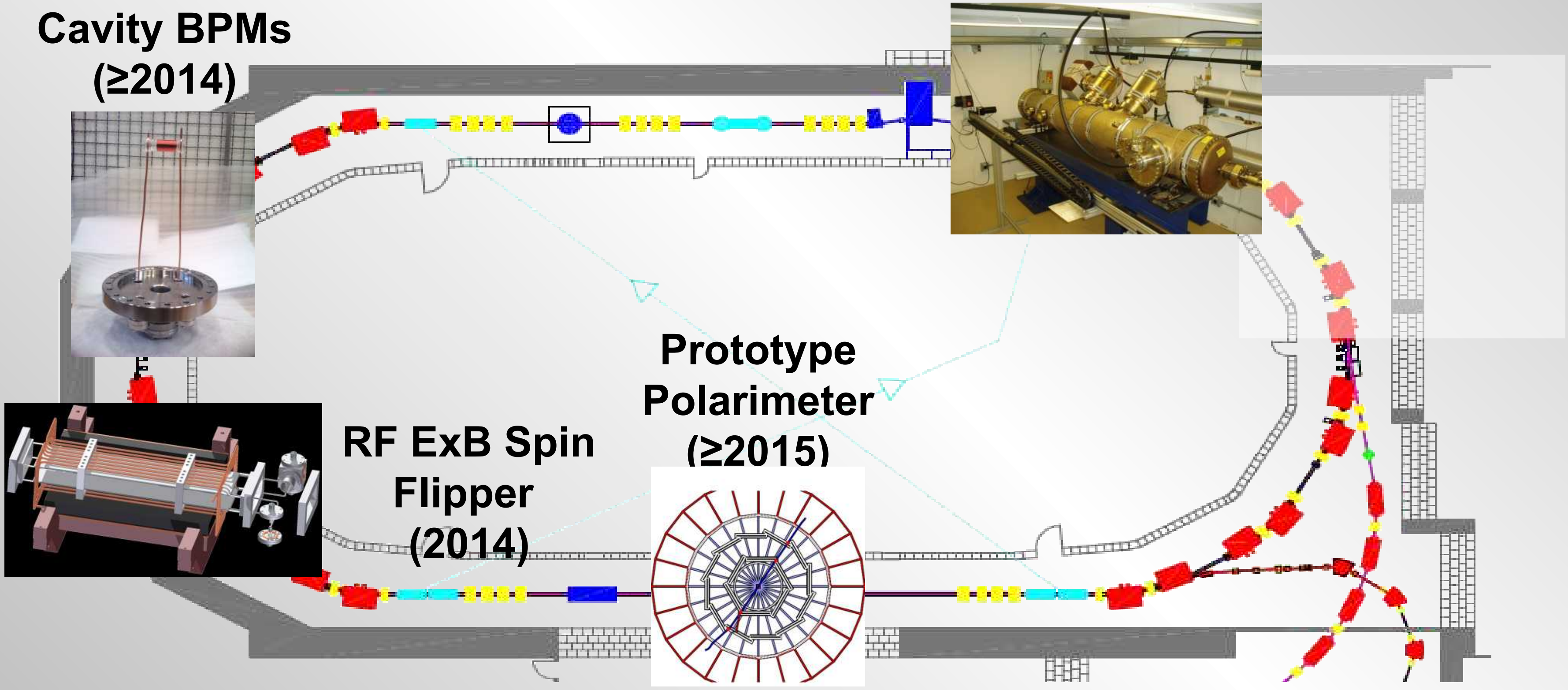
Precision of spin tune measurement:

10^{-8} per 4 seconds

Averaged spin tune can be determined to 10^{-10} in a single 100s cycle

High-precision spin physics !

EDM Prototyping and Spin Physics



Electrostatic Deflector (2017)

SQUID and Cavity BPMs (≥2014)

Prototype Polarimeter (≥2015)

RF ExB Spin Flipper (2014)

EDM accelerator and detector component tests

Method of Φ-width measurement

- Attenuation measurements of the Φ flux SPring-8 photo-production, up-coming CLAS results.

$$D = \exp\left(- \int_z^\infty dl \, \frac{\Gamma^*(\rho(r)) M_0}{p_\Phi} \right), \rho(r) - local\ nuclear\ density$$

Φ survival probability in the nucleus matter rest frame: In-medium width deduced from the target mass dependence.

dominate K^+K^- BR =0.49

SPring-8 / LEPS experiment

Reaction: $\gamma A \rightarrow \Phi X$, via K^+K^- decay
γ-Energy: 1.5 — 2.4 GeV
Targets: Li, C, Al, Cu

Result: large $\sigma_{\Phi N} = 35^{+17}_{-11}$ mb, using Glauber-type multi-scatt. theory (free $\sigma_{\Phi N} \approx$ 8-10 mb)

T. Ishikawa *et al.*, PLB 608 (2005) 215

COSY experiment at ANKE

Reaction: $pA \rightarrow \Phi X$, via K^+K^- decay
p-Energy: 2.83 GeV ($\varepsilon_{\text{free NN}} \approx$ 76MeV)
Targets: C, Cu, Ag, Au

Momentum and angular range: (0.6 — 1.6) GeV/c, $0^o \leq \Theta_\Phi \leq 8^o$

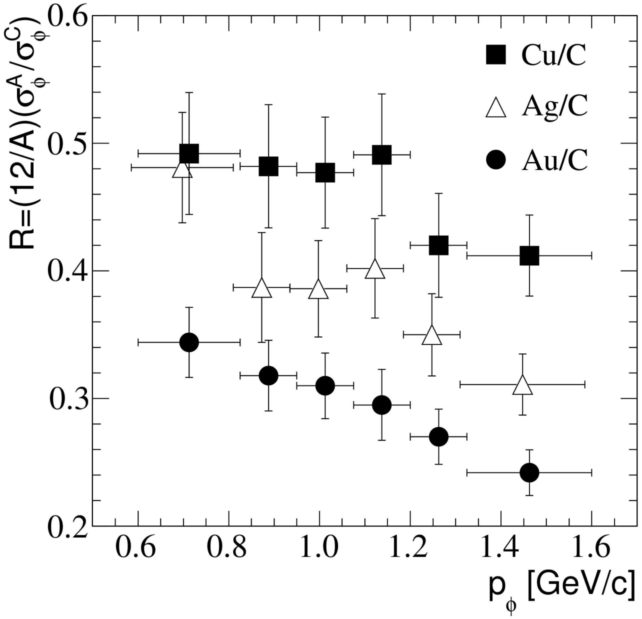
Transparency ratios: experiment

We present the A-dependence of the

Φ production in the following form:

$$R = \frac{T_A}{T_C} = \frac{12}{A}\frac{\sigma_\phi^A}{\sigma_\phi^C}, \qquad T_A = \frac{\sigma_\phi^A}{A\sigma_\phi^N}$$

nuclear transparency ratio



Any interpretation of the transparency ratio has to rely on a detailed theoretical treatment

Limited sensitivity to in-medium signal

$$\underbrace{\frac{d\sigma_{V\rightarrow X_1X_2}}{d\mu}\sim A(\mu)\,\frac{\Gamma_{V\rightarrow X_1X_2}}{\Gamma_{tot}}}_{}=\underbrace{\frac{\mu\Gamma_{tot}}{(\mu^2-m_V^2)^2+\mu^2\Gamma_{tot}^2}\,\frac{\Gamma_{V\rightarrow X_1X_2}}{\Gamma_{tot}}}_{}$$

experimental observed mass distribution = convolution of spectral function with the branching ratio into channel being studied

After integration over all nucleons and parameterizing strength function with Breit Wigner

$$\Gamma_{tot}=\Gamma_{vac}+\Gamma_{med}$$

$$\Gamma_{med}(\rho(r))=\Gamma_{med}(\rho_0)\frac{\rho(r)}{\rho_0}$$

In the low density approximation

3 effects limit sensitivity:

i. yield reduced by increase of in-medium width ($\Gamma_{med}>>\Gamma_{vac}$)

ii. reduced yield spreads out in mass, difficult to distinguish from background

iii. decays occur at low densities ($\rho << \rho_0$) even for low momentum selection

F.Eichstaedt *et al.*,
PTPSuppl. 168 (2007) 495

Mosel/Leupold/Metag, PTP.Suppl. 186 (2010) 260

Limited sensitivity to in-medium signal

$$\underbrace{\frac{d\sigma_{V\to X_1X_2}}{d\mu} \sim A(\mu)\,\frac{\Gamma_{V\to X_1X_2}}{\Gamma_{tot}}}_{} = \underbrace{\frac{\mu\Gamma_{tot}}{(\mu^2-m_V^2)^2+\mu^2\Gamma_{tot}^2}\,\frac{\Gamma_{V\to X_1X_2}}{\Gamma_{tot}}}_{}$$

experimental obs
convolution of s
branching ratio ir

eons and pa-
on with Breit

$$\frac{d\sigma_{V\to X_1X_2}}{d\mu} \sim \frac{1}{\rho^2(r)}$$

$\Gamma_{tot} = \Gamma_{vac}$ $)\,\frac{\rho(r)}{\rho_0}$

In the low density approximation

3 effects limit sensitivity:

i. yield reduced by increase of in-medium width ($\Gamma_{med} >> \Gamma_{vac}$)
ii. reduced yield spreads out in mass, difficult to distinguish from background
iii. decays occur at low densities ($\rho << \rho_0$) even for low momentum selection

F.Eichstaedt *et al.*, PTPSuppl. 168 (2007) 495

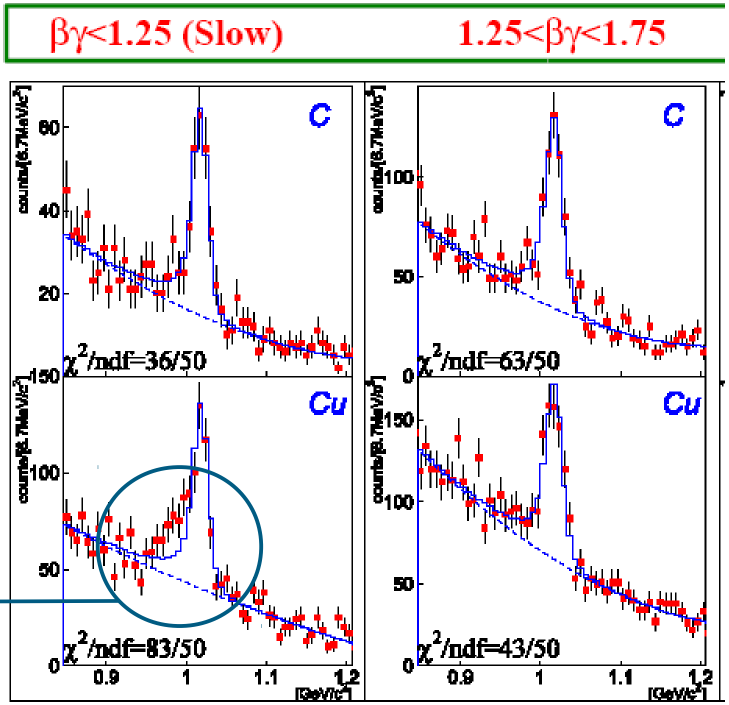
Mosel/Leupold/Metag, PTP.Suppl. 186 (2010) 260

Methods of Φ-width measurement

- Study of the meson spectral function - measure low momentum Φ's via leptonic decays. Not really done yet.

  - $\Phi \to e^+e^-$ (BR = $3 \cdot 10^{-4}$)
  - $\Phi \to K^+K^-$ (BR = 0.49, K^- FSI, hadronic potential)

$\Phi \to e^+e^-$

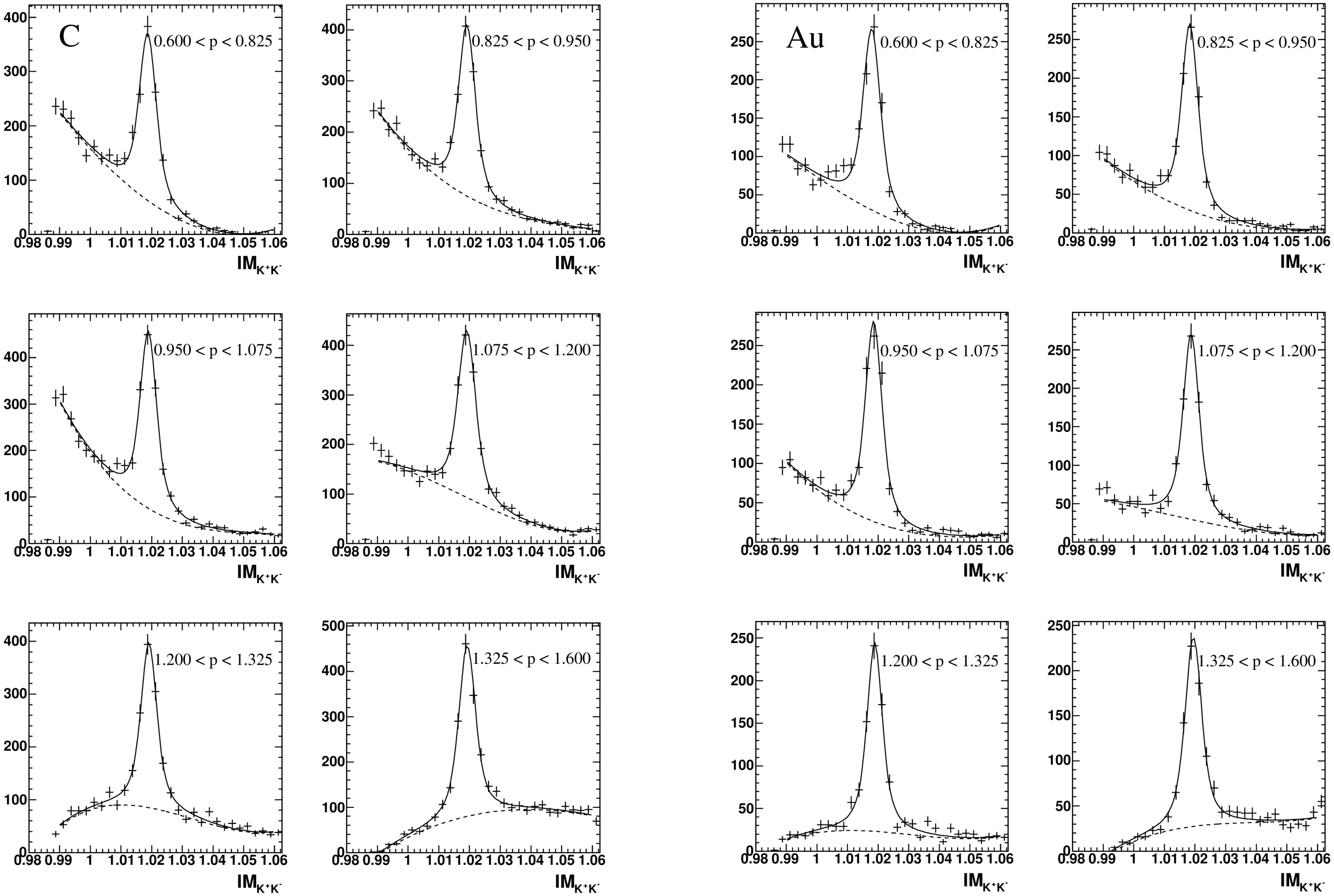


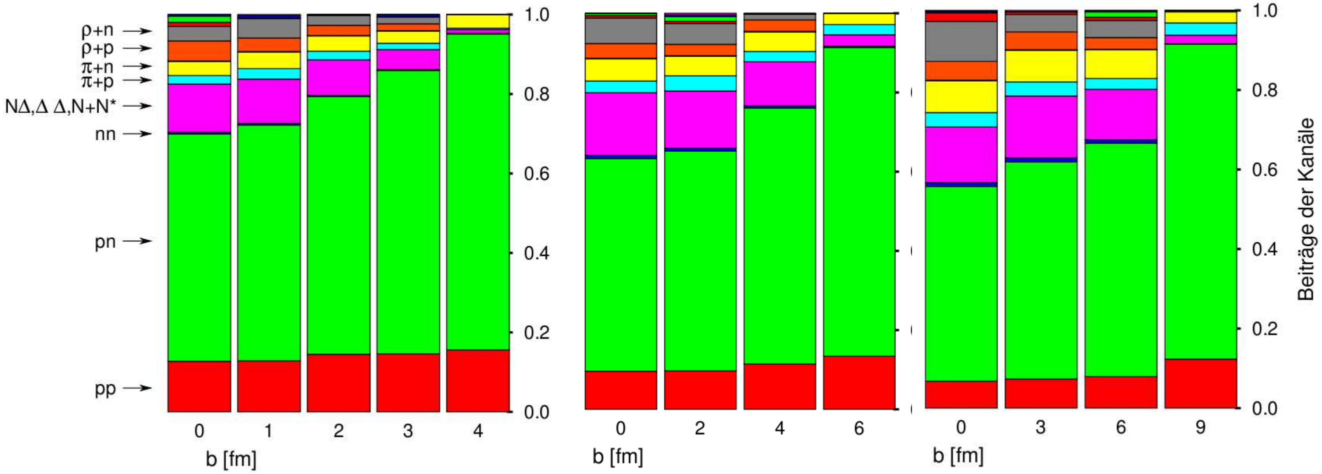
KEK-PS: pA @ 12 GeV

$\Gamma^* \approx 15$ MeV, $m^* \approx -3.4\%$)
for $\langle p_\phi \rangle = 1.8$ GeV/c

R.Muto *et al.*, PRL 98 (2007) 042501

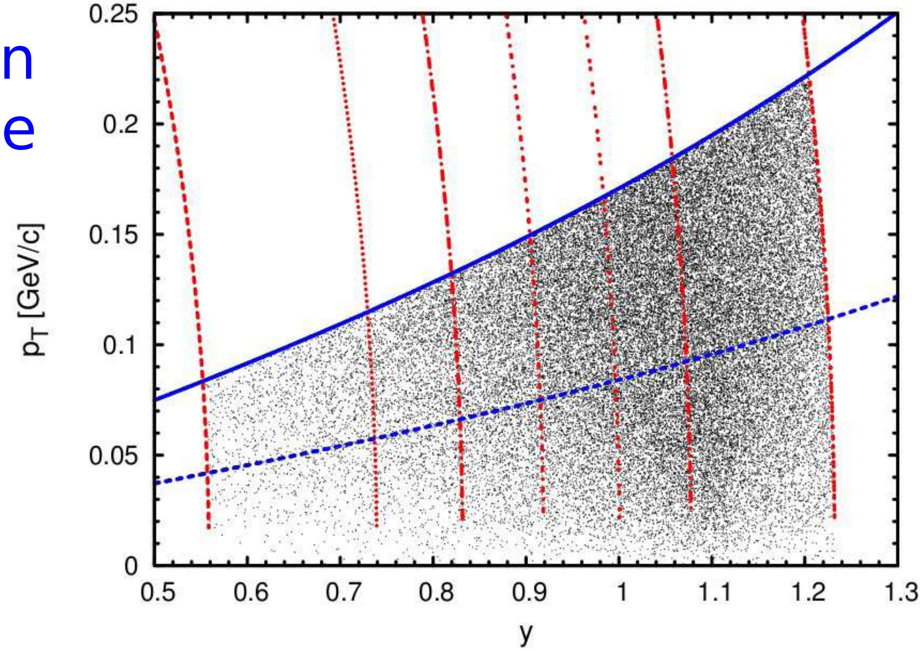
Invariant mass spectra for 6 momentum bins





pA: p+C,Cu,Au
@ 2.83 GeV(ANKE)

phase space distribution
of ϕ in ANKE acceptance



pp→ppΦ (energy dependence)

OZI rule: $4.2 \times 10^{-3} \equiv R_{OZI}$

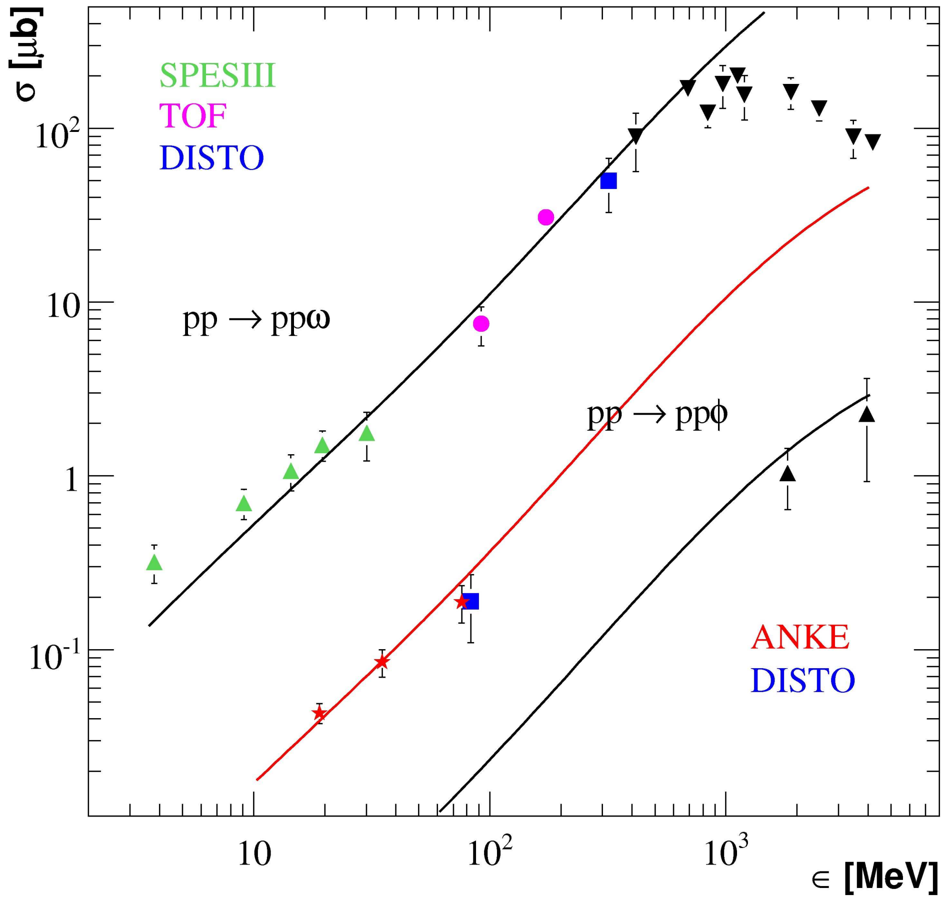
$R_{\Phi/\omega}$(high energy) ≈ (1 - 2.4)×R_{OZI}

(in agreement with πN data and

the Φρπ and ωρπ coupling)

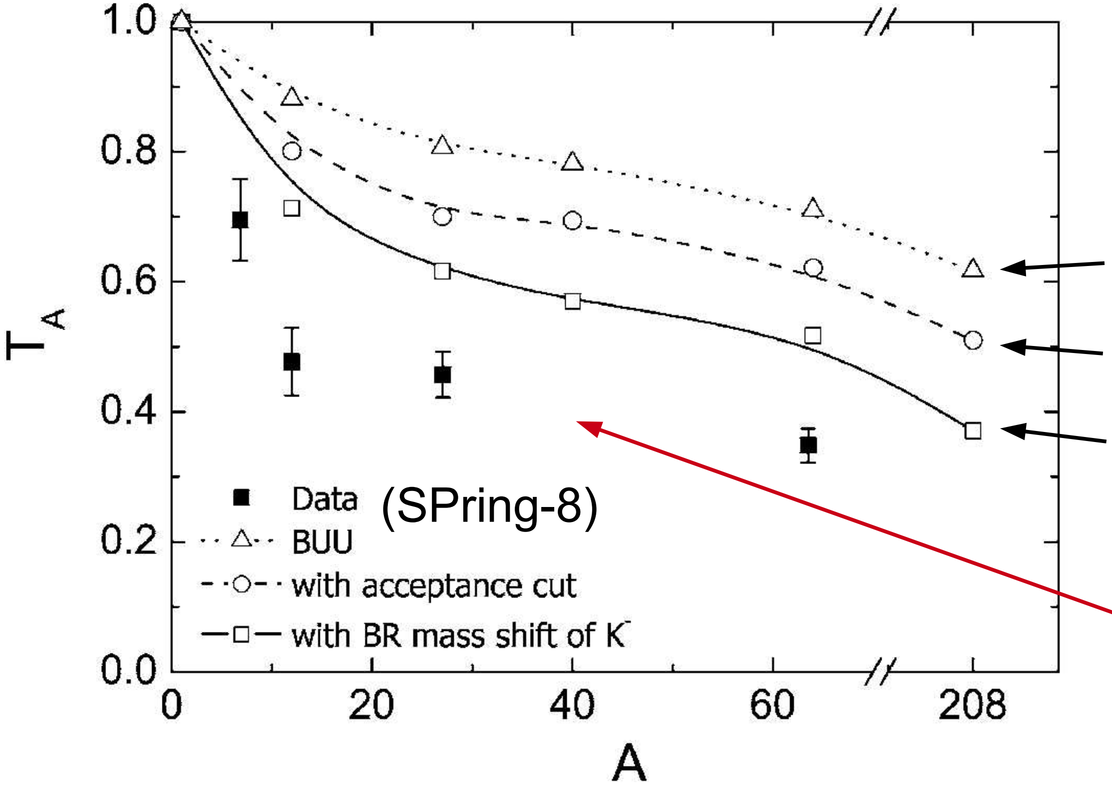
$R_{\Phi/\omega}$(18.5-79.5 MeV, ANKE) ≈ 7×R_{OZI}

PRL 96 (2006) 242301



Giessen-BUU calculations (SPring-8 data)

P. Muelich *et al.*, NPA 765 (2006) 188



(SPring-8)

$\Gamma_{free} + \Gamma_{coll.}$ (~10 mb)

+ acceptance

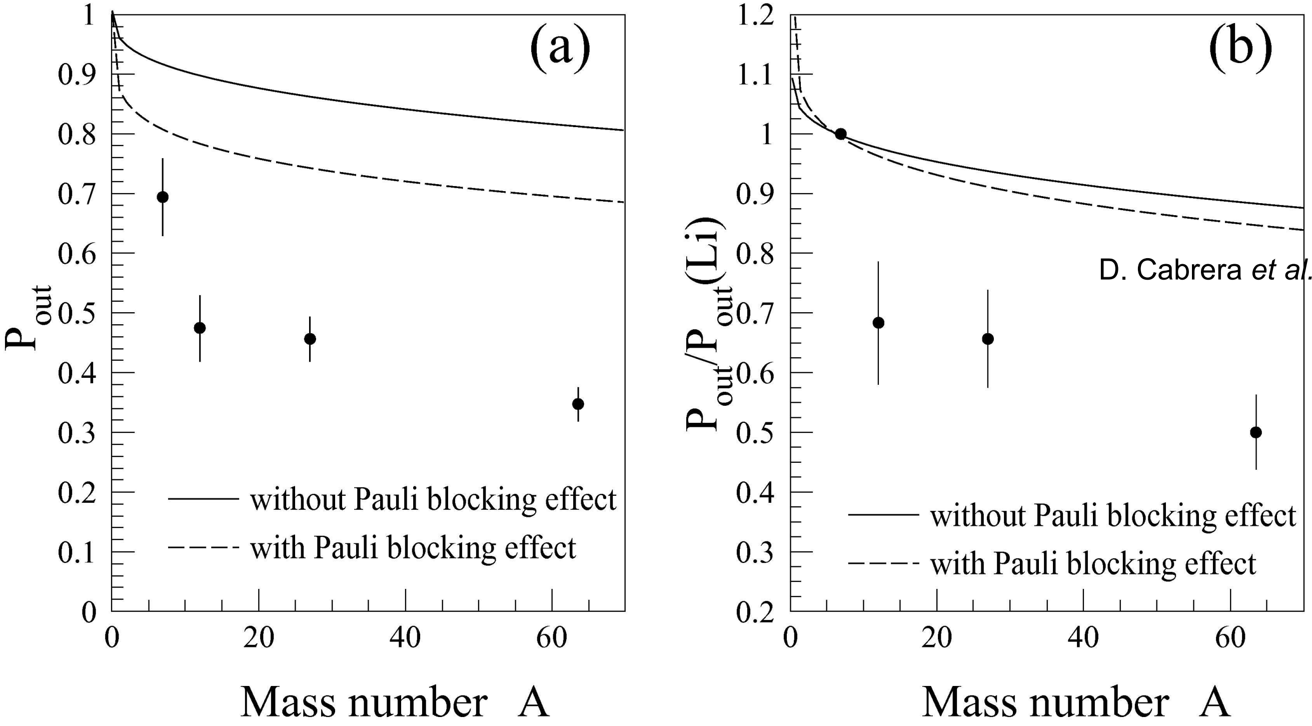
+ Γ_{decay} (K^+K^-: 2 to 20 MeV)

$\Gamma_{coll.}$ (~10 mb) x 2.6

Γ ≈ 80 MeV, 1.8 GeV/c Φ's

Valencia calculations (SPring-8-data)

E. Oset *et al.*, Pramana 66 (2006) 731



D. Cabrera *et al.*, NPA 733 (2004) 130

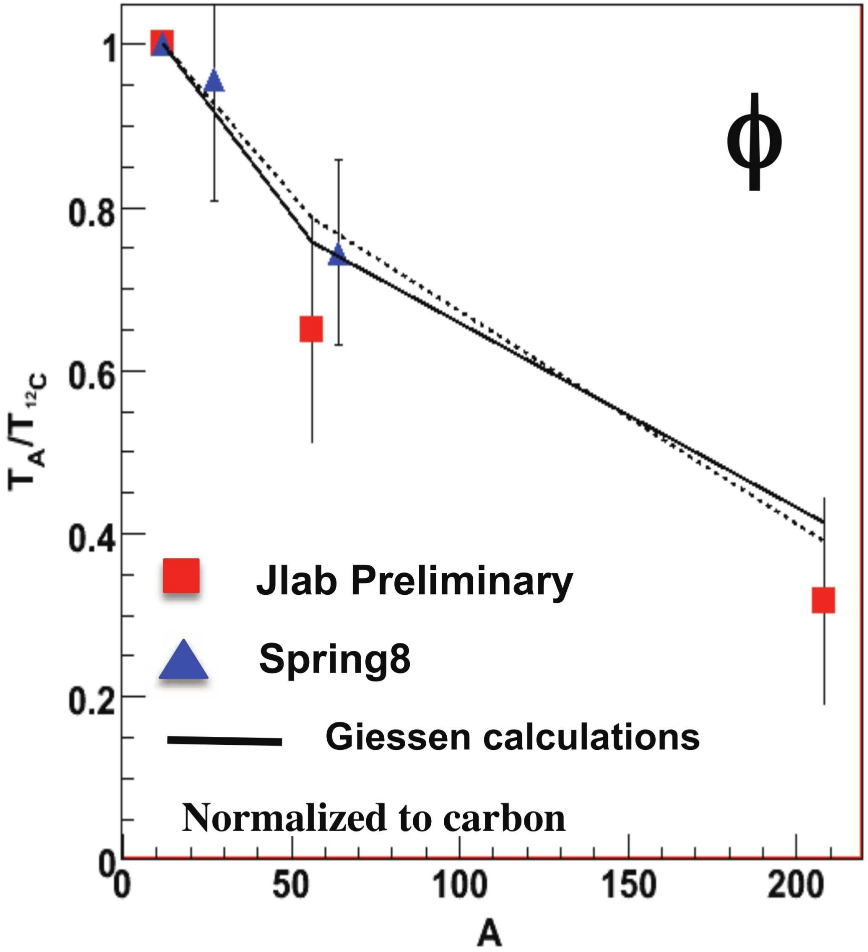
$$P_{out} = \frac{\sigma_\phi^A}{A\,\sigma_\phi^N}$$

SPring-8 and up-coming JLAB-g7 (CLAS) result

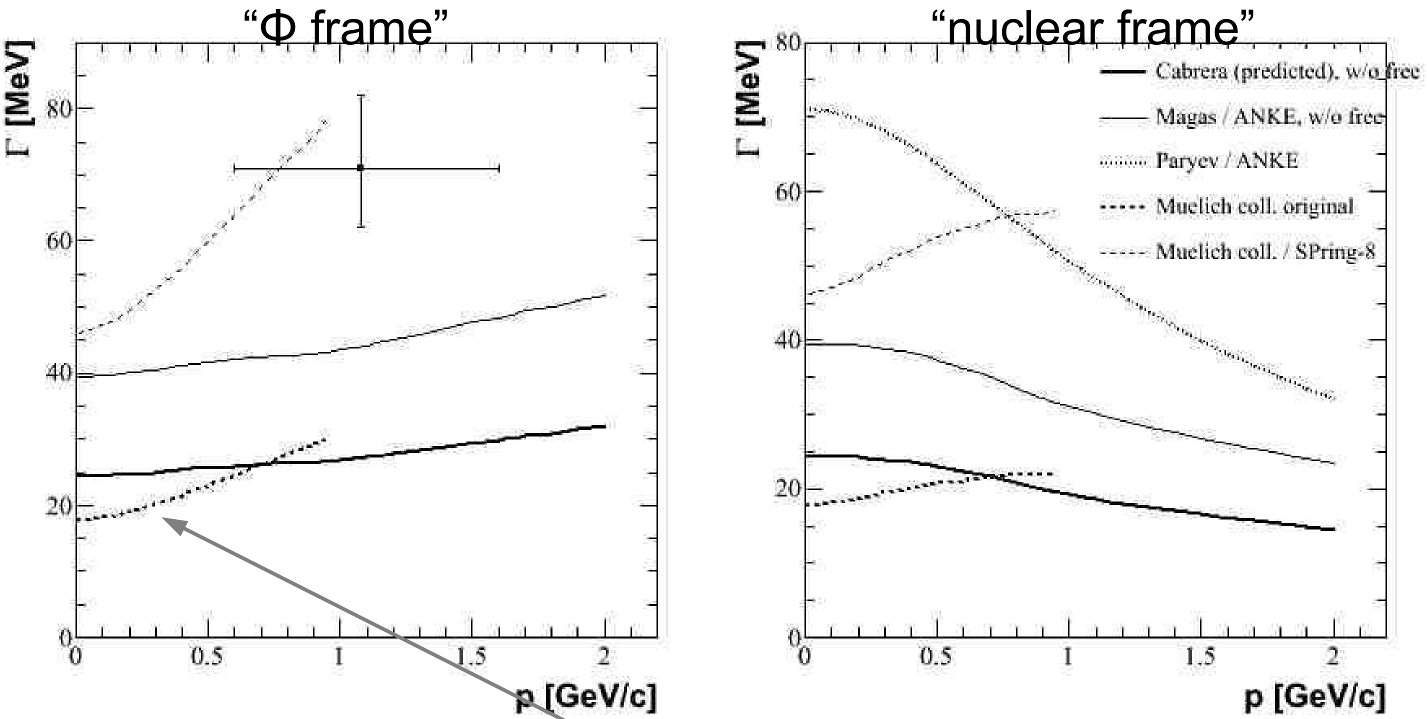
CLAS: γA → Φ(→e^+e^-)X

“agreement”

R. Nasseripour *et al.*, AIP 1056 (2008) 223



Momentum dependence of the in-medium Φ-width



“Φ frame”

“nuclear frame”

$$\mathcal{I}\mathrm{m}\Pi_{\mathrm{coll}}(q_0=\sqrt{m_V^2+\mathbf{q}^2},\mathbf{q},n_N(\mathbf{r})) = -4\int\frac{d^3p}{(2\pi)^3}\Theta(|\mathbf{p}|-p_F)\frac{|\mathbf{k}_{\mathrm{cm}}|\sqrt{s}}{E_N(\mathbf{p})}\sigma_{VN}(s)$$

$$\Gamma_{\mathrm{coll}} = -\frac{\mathcal{I}\mathrm{m}\Pi_{\mathrm{coll}}}{m_\phi}$$

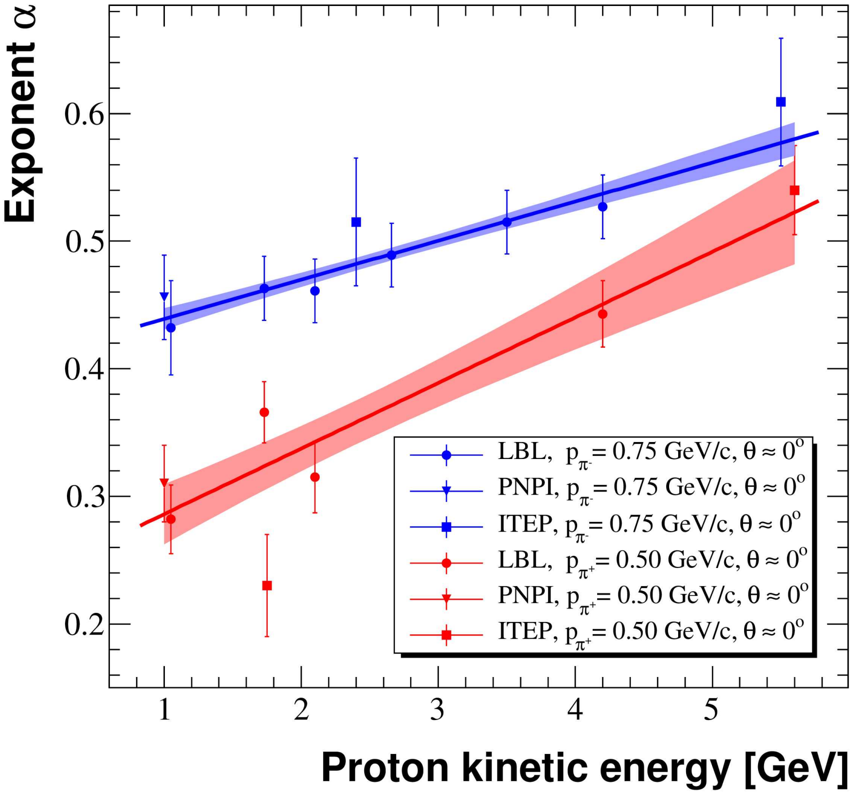
Determination of α for π production

At T_p = 2.83 GeV:

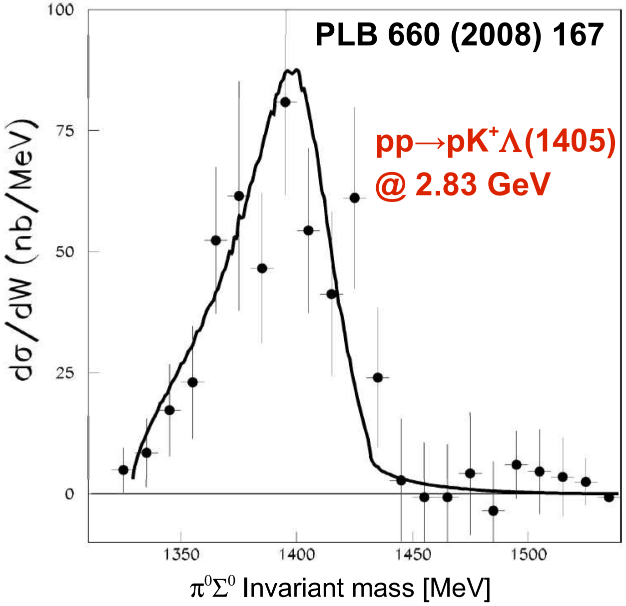
$\alpha(\pi^-) = 0.495 \pm 0.005$ (1%)

$\alpha(\pi^+) = 0.380 \pm 0.018$ (5%)

$d^2\sigma/dpd\Omega \sim A^\alpha$



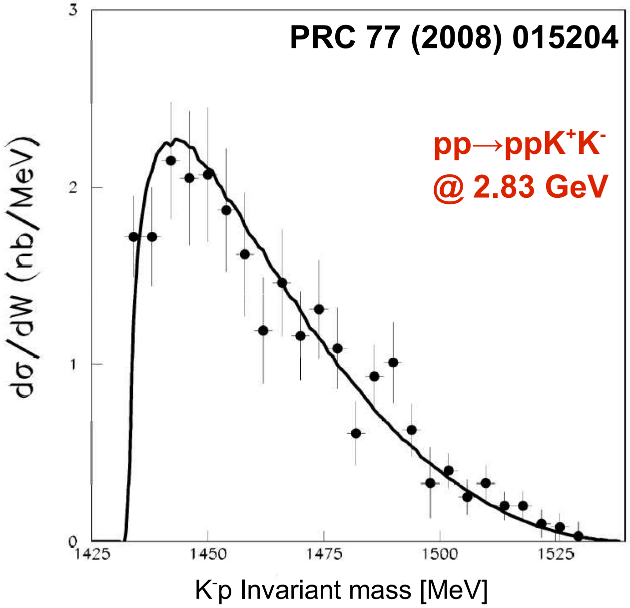
$pp \to pK^+Y^0$(1405, width 50MeV)$\to K^-p$



$\pi^0\Sigma^0/K^-p$

C. Wilkin, pers. communication

arXiv:0812.0098



Simplest description of the I = 0 coupled-channel system is provided by a separable-potential model **[e.g. PRC 76 (2007) 055204]**.

Suggests that Λ(1405) is the main doorway state also for ppK^+K^- .
(similar conclusion: Xie & Wilkin PRC 82 (2010) 025210; N*(1535) ⇔ Λ(1405)K).

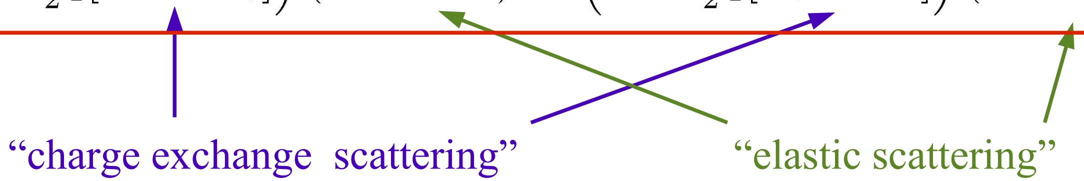
Should analyse $\pi^0\Sigma^0$ and K^-p production at the same time !

Model: elastic K^+K^- rescattering plus contribution of a $K^0\bar{K}^0$ pair production followed by charge exchange rescattering

PLB 668 (2008) 315

K-matrix formalism, three basic simplifications:
(I) constant elements of K-matrix
(ii) isospin invariance broken only by $K^0 - K^\pm$ mass difference
(iii) distortions are taken only in first order (s-wave scattering, formula have transparent interpretations)

$$\mathcal{F} = \left| \frac{B_1/(B_1+B_0)}{\left(1 - i\frac{1}{2}q[A_1 - A_0]\right)(1 - ikA_1)} + \frac{B_0/(B_1+B_0)}{\left(1 - i\frac{1}{2}q[A_0 - A_1]\right)(1 - ikA_0)} \right|^2$$


"charge exchange scattering"

"elastic scattering"

$K\bar{K}$ production amplitudes (I=0,1): $|B_1/B_0|^2 = 0.38^{+0.24}_{-0.14}$