IMP's activities in COSY programs and the extension to HPLUS

Xiaohua Yuan

Institute of Modern Physics (IMP) - CAS, Lanzhou 73000 &
Institut für Kernphysik, Forschungszentrum Jülich

Outline

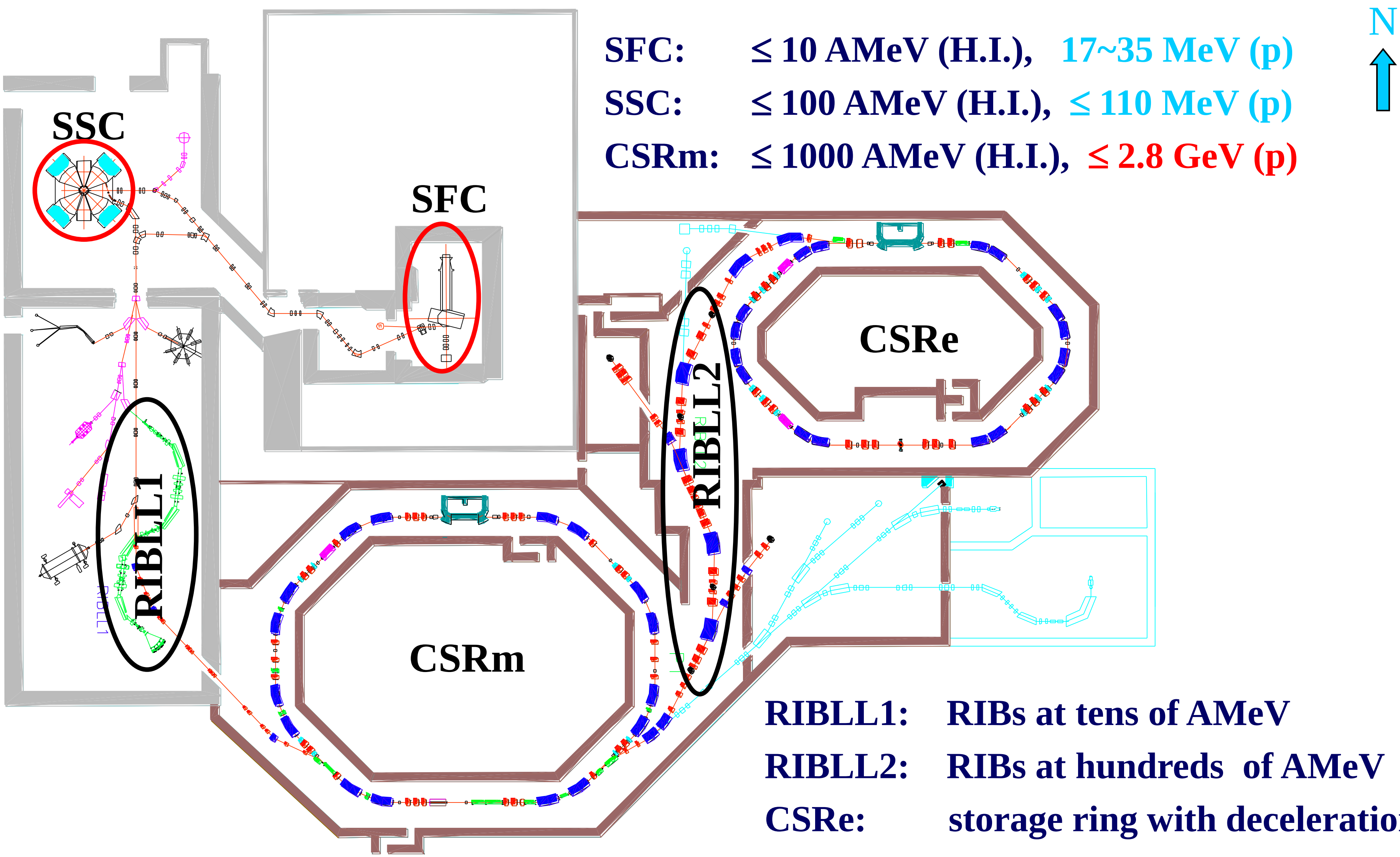
- Introduction to HIRFL
  - Beam facilities
  - Experimental sites
- Introduction to COSY
  - Beam facility
  - Experimental sites
- Physics on COSY and the extension to CSR
  - ANKE, WASA, PISA
  - PISA, HPLUS
- Recent plans on CSR
- Summary & Future Development

Introduction to HIRFL: Beam facilities

SFC: ≤ 10 AMeV (H.I.), 17~35 MeV (p)

SSC: ≤ 100 AMeV (H.I.), ≤ 110 MeV (p)

CSRm: ≤ 1000 AMeV (H.I.), ≤ 2.8 GeV (p)

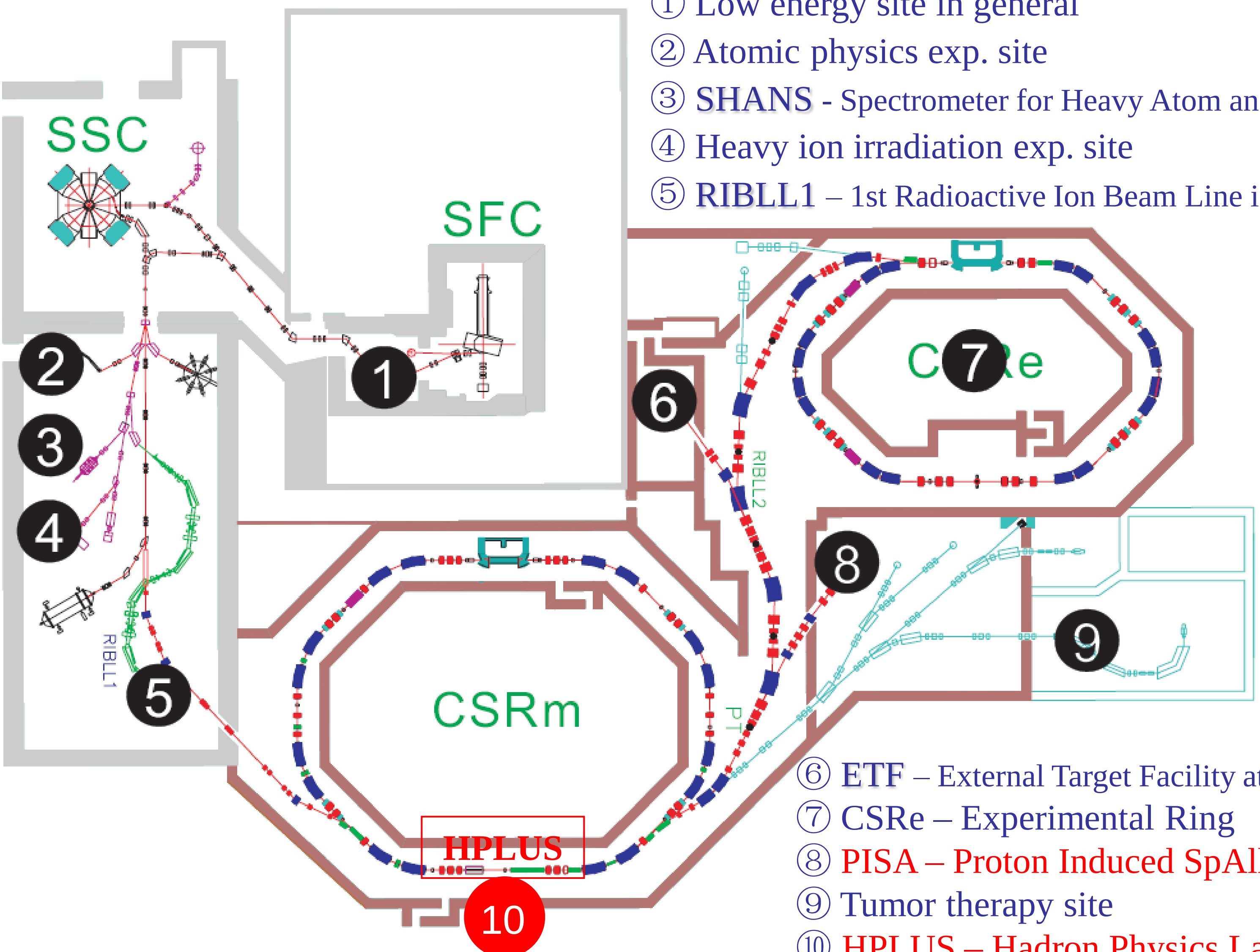


RIBLL1: RIBs at tens of AMeV

RIBLL2: RIBs at hundreds of AMeV

CSRe: storage ring with deceleration

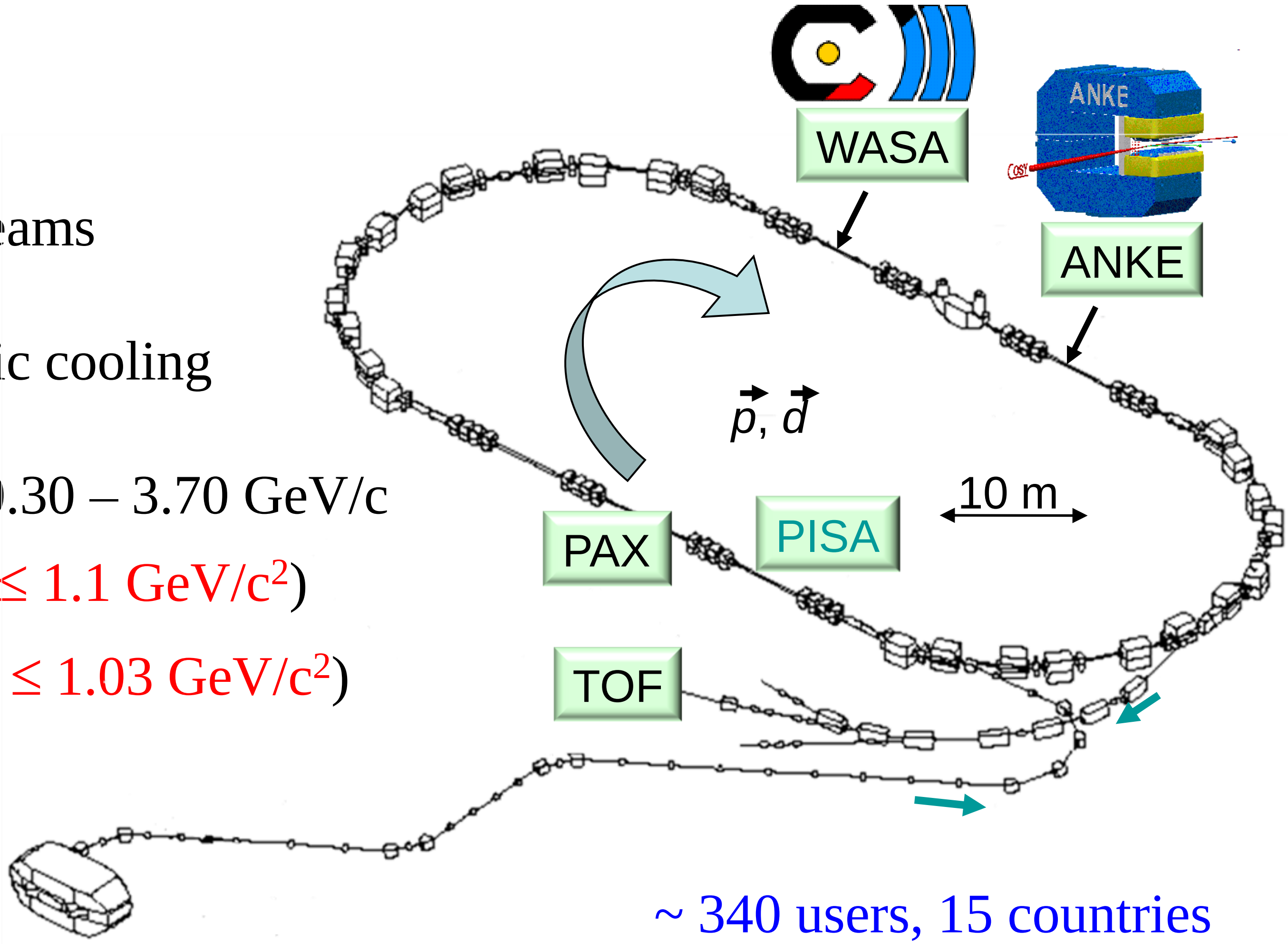
Introduction to HIRFL: Exp. Sites



① Low energy site in general
② Atomic physics exp. site
③ SHANS - Spectrometer for Heavy Atom and Nuclear Structure
④ Heavy ion irradiation exp. site
⑤ RIBLL1 – 1st Radioactive Ion Beam Line in Lanzhou
⑥ ETF – External Target Facility at CSR
⑦ CSRe – Experimental Ring
⑧ PISA – Proton Induced SpAllation
⑨ Tumor therapy site
⑩ HPLUS – Hadron Physics LanzhoU Spectrometer

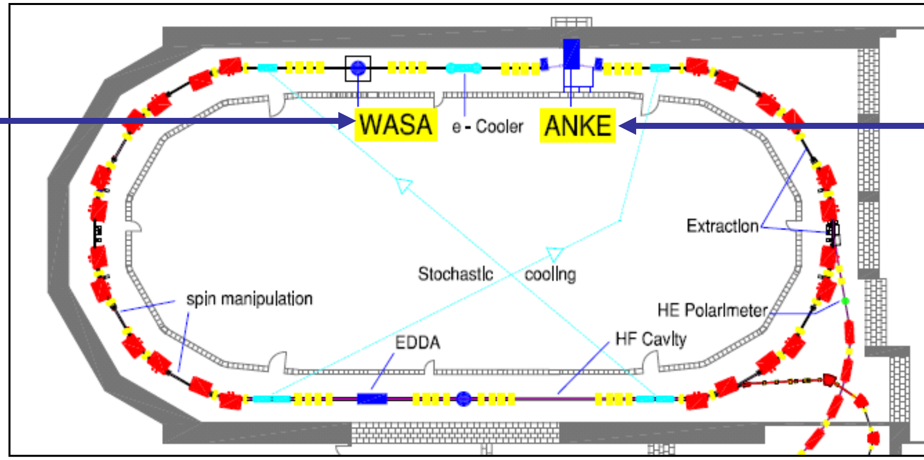
Introduction to COoler SYnchrotron

- (Polarized) *p* & *d* beams
- Electron & stochastic cooling
- Beam momentum: 0.30 – 3.70 GeV/c
  - $pp \rightarrow pp\, X$ ($m_X \leq 1.1$ GeV/c^2)
  - $dd \rightarrow {}^4\text{He}\, X$ ($m_X \leq 1.03$ GeV/c^2)

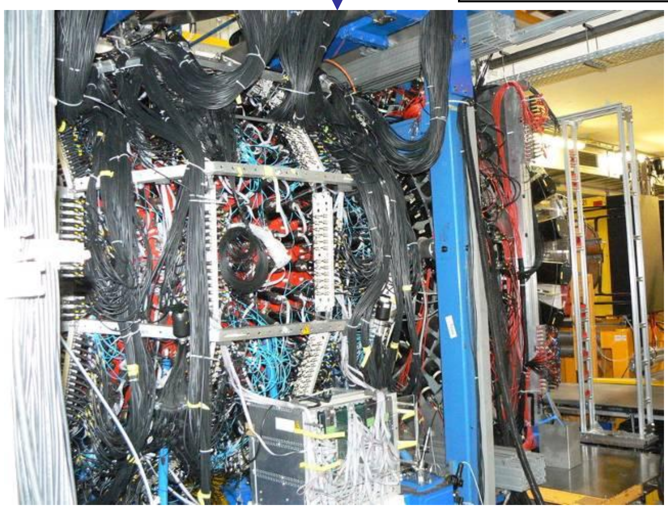


~ 340 users, 15 countries

WASA and ANKE

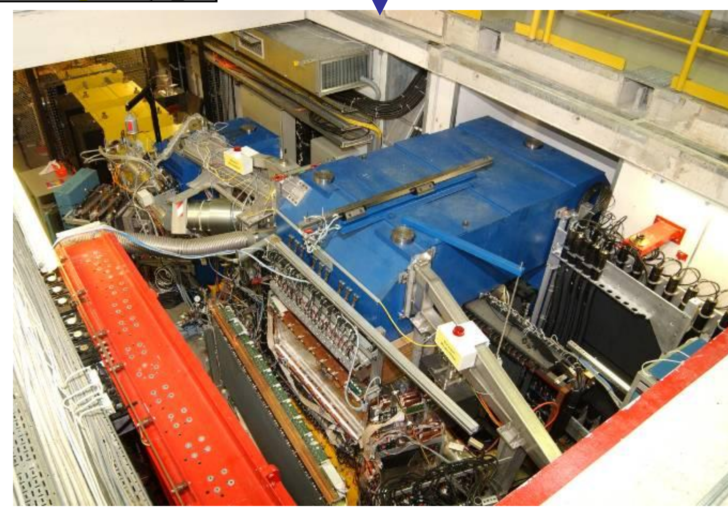


WASA



- Almost 4π coverage
- Charged and neutral particle detection
- Frozen-pellet target ($\mathcal{L} \sim 10^{32}$ cm^{-2}s^{-1})

ANKE



- Forward spectrometer
- Excellent K^{+}/K^{-} i.d.
- Cluster-jet target ($\mathcal{L} \sim$ few$\cdot 10^{31}$ cm^{-2}s^{-1}) Polarized target

p/*d*-induced $K\bar{K}$ production: World data set

$pp \to ppK^+K^-$

$pp \to dK^+\underline{K}^0$

$pn \to dK^+K^-$

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

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

test for

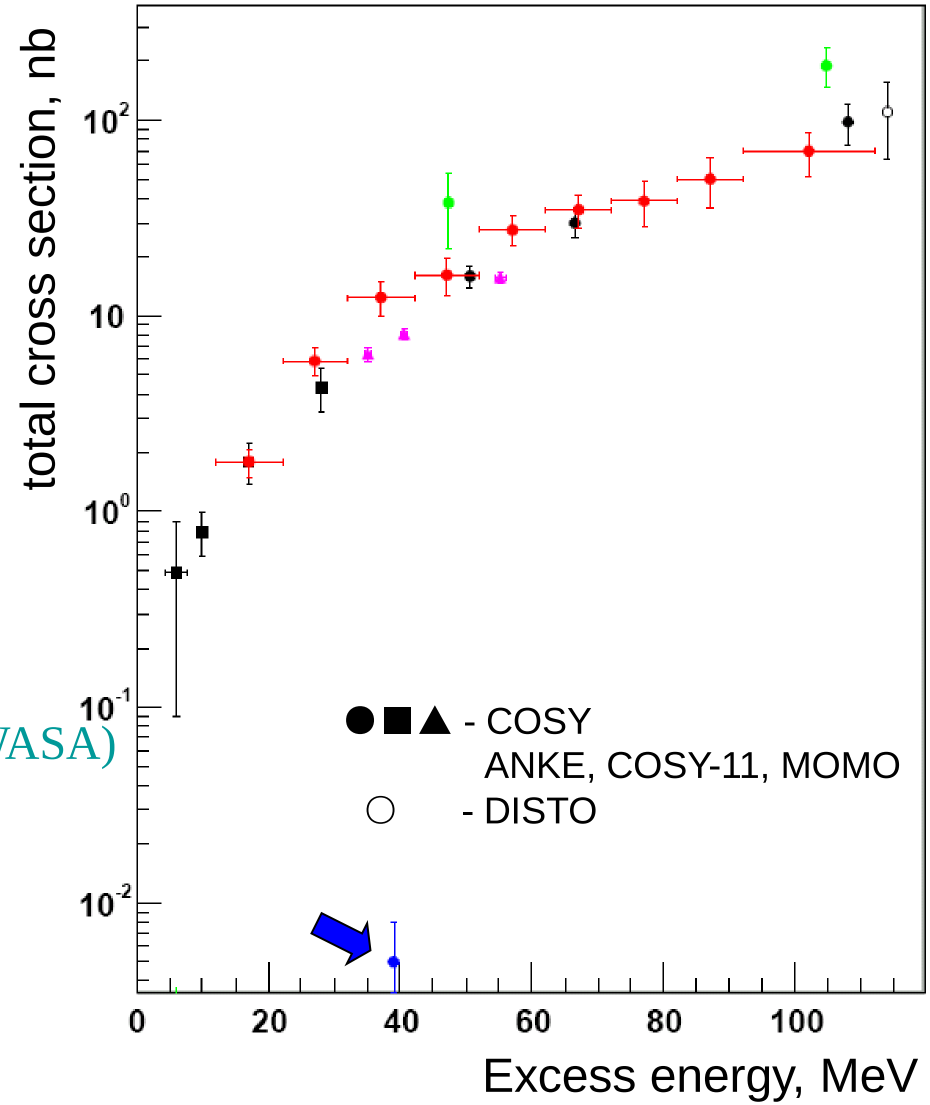
$dd \to \alpha f_0(980) \to \alpha a_0(980) \to \alpha\pi^0\eta$ (on WASA)

$I = 0$ $I = 1$ $I = 1$

↳ αK^+K^- ("isospin filter")

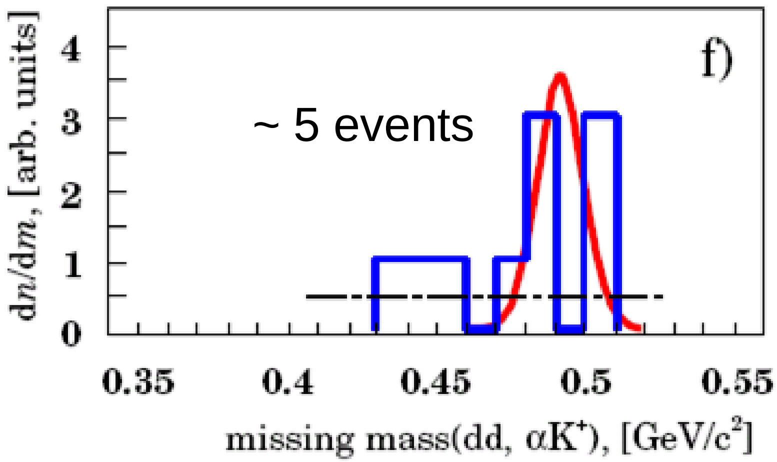
$I = 0$

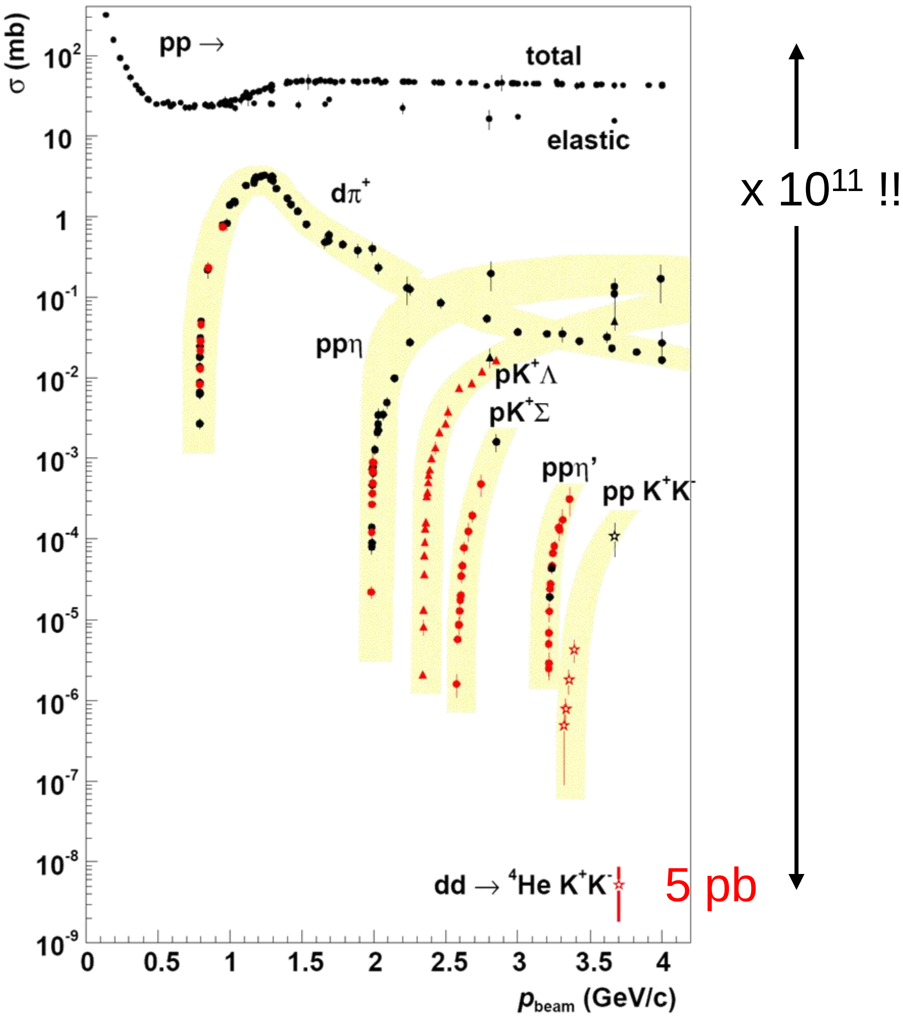
"isospin violation" ! !



d d → ^{4}He K^+K^-

X.Yuan et al., EPJ A in print
DOI 10.1140/epja/i2009-10849-7
arXiv:0905.0979 [nucl-ex]



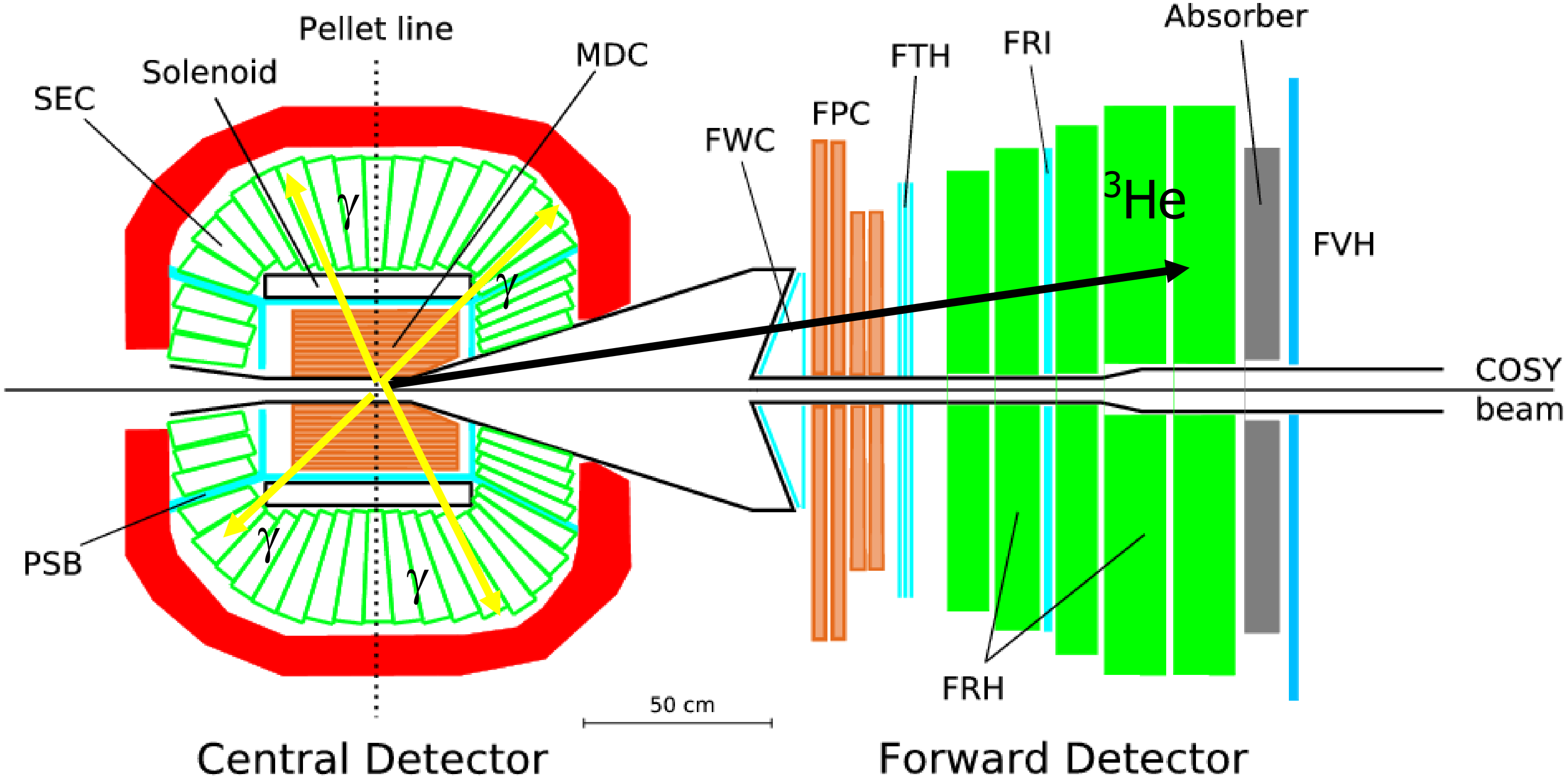


cross section for the "isospin filter" $dd \to {}^4\text{He}X$ is extremely small

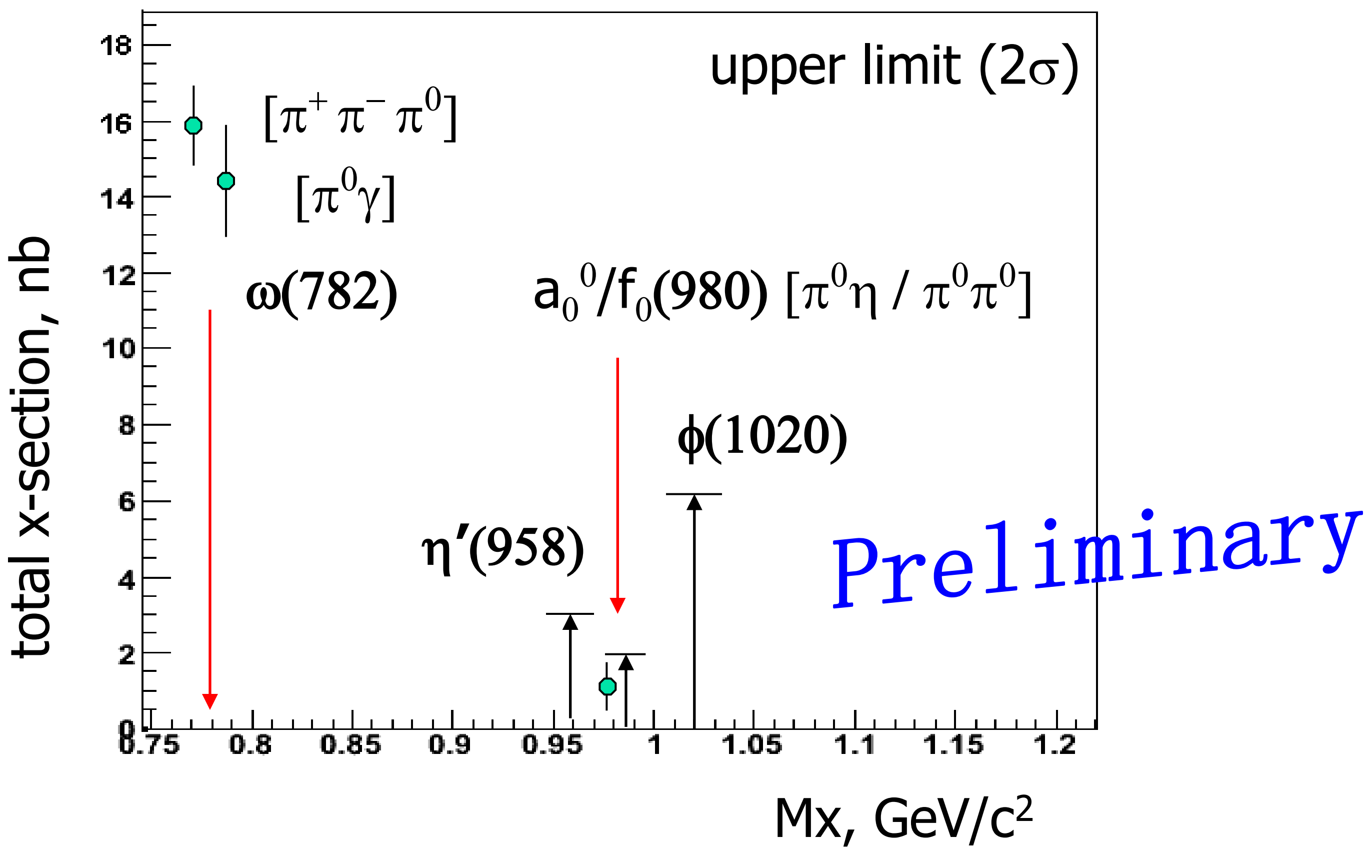
$\to$ better @BES ($J/\psi \to \phi f_0 \to \phi a_0 \to \phi(\pi^0\eta)$)

pd → ^{3}He X @ 2.935 GeV/c

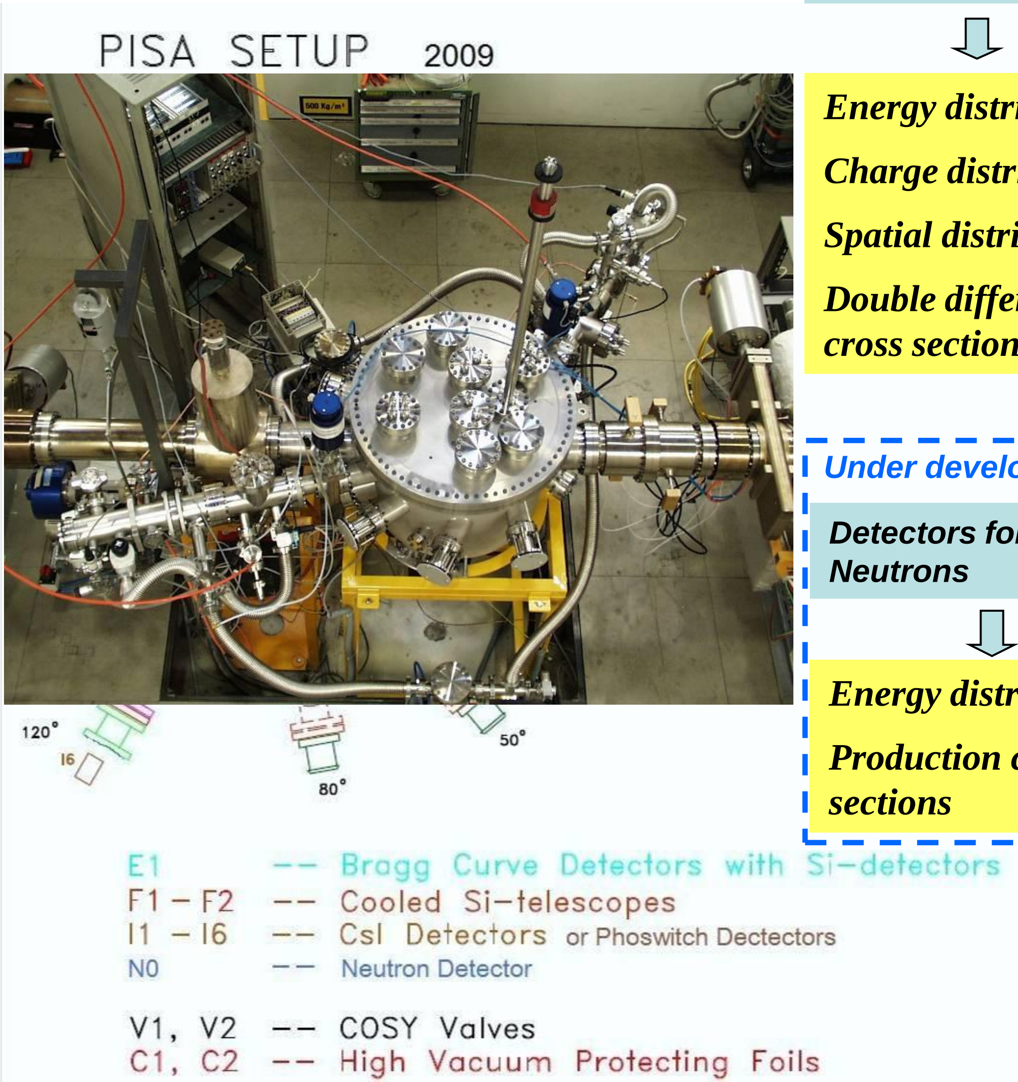
- pd → ^{3}He a_0^0 → ^{3}He $\pi^0\eta$ → ^{3}He 4γ
- pd → ^{3}He f_0 → ^{3}He $\pi^0\pi^0$ → ^{3}He 4γ



Summary of total x-sections for pd → ^{3}He X @ 2.935 GeV/c



PISA



Identification for Charged Particles, E<15 MeV

Energy distribution

Charge distribution

Spatial distribution

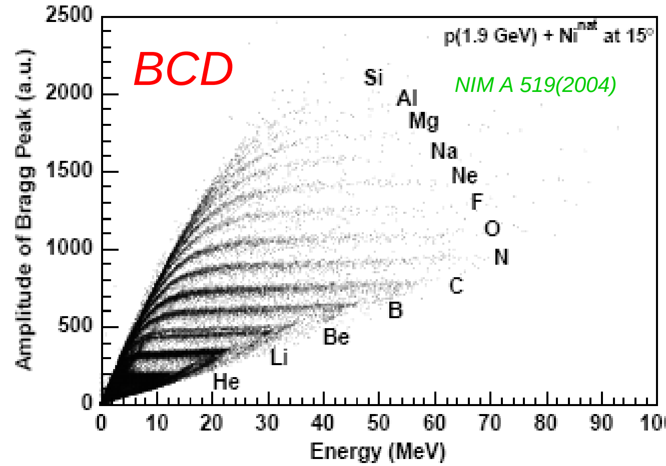
Double differential cross sections

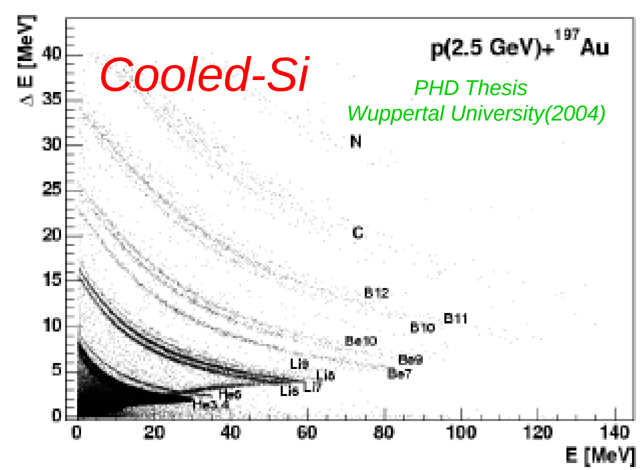
Under development

Detectors for E<15 MeV Neutrons

Energy distribution

Production cross sections



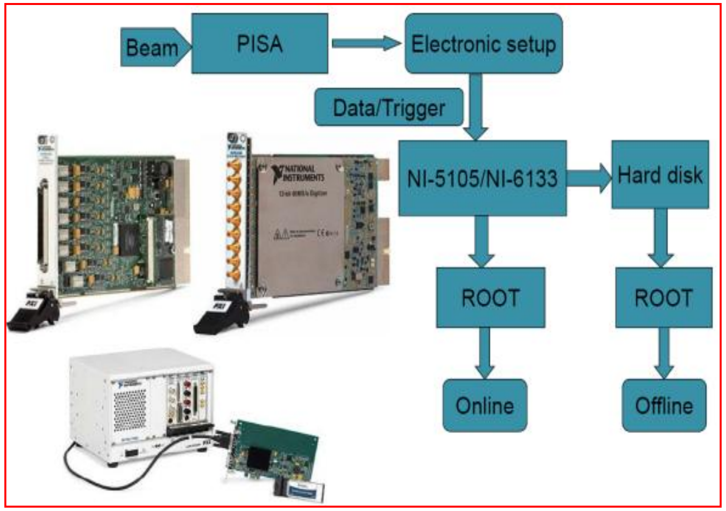


PISA – ADS

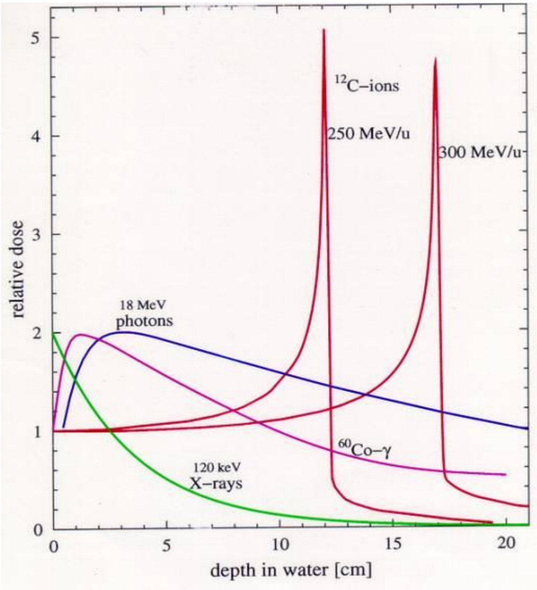
Running as an external target exp. at the end of 2010.

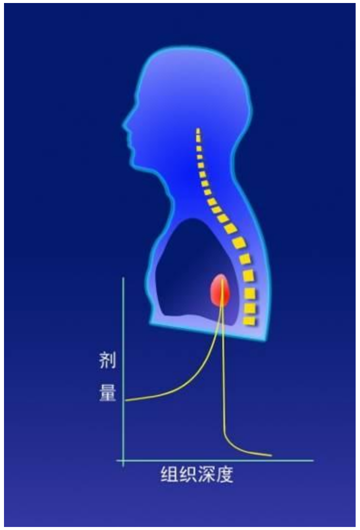
Mainly focusing on the requirements from the applications (p+Pb, p+Bi).

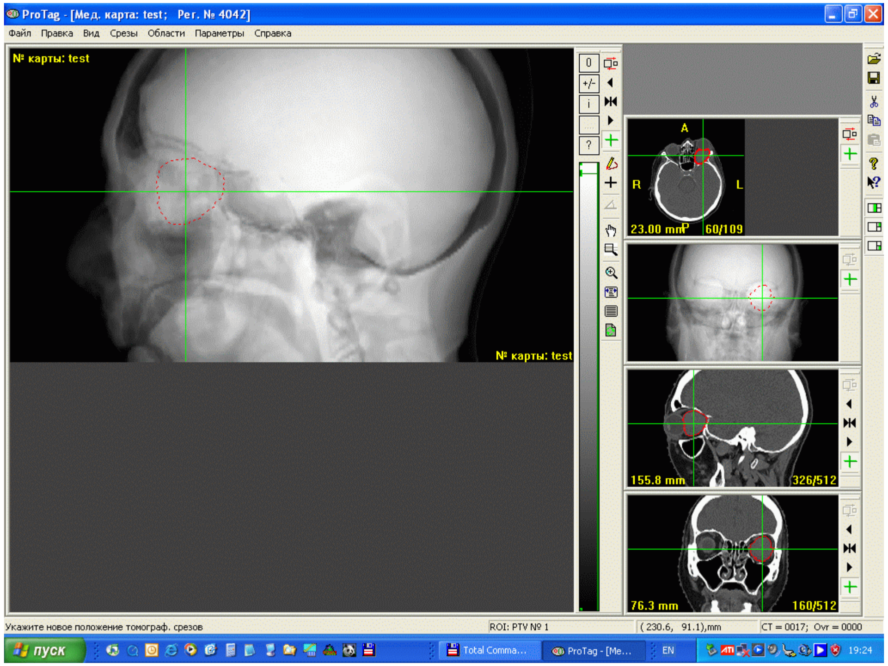
- *Measuring total and differential cross sections of spallation process*
- *Measuring the spectra of LCP, extracting the excitation energy, and comparing with model calculations*
- *Measuring neutron multiplicity and energy distributions*

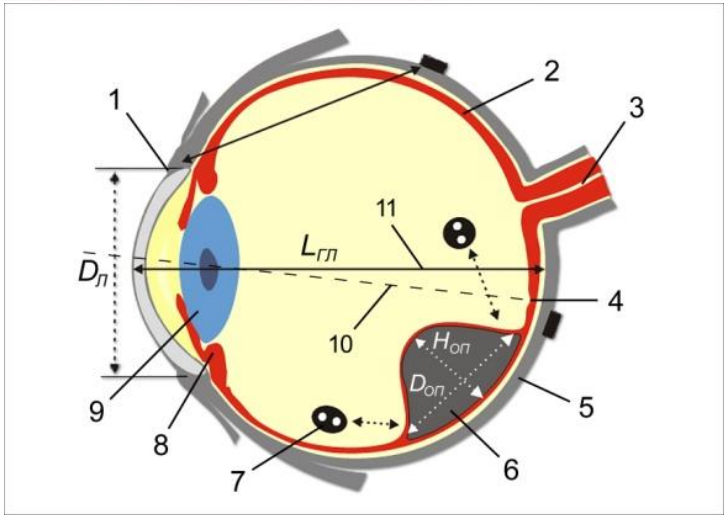


PISA – tumor therapy









Precise information

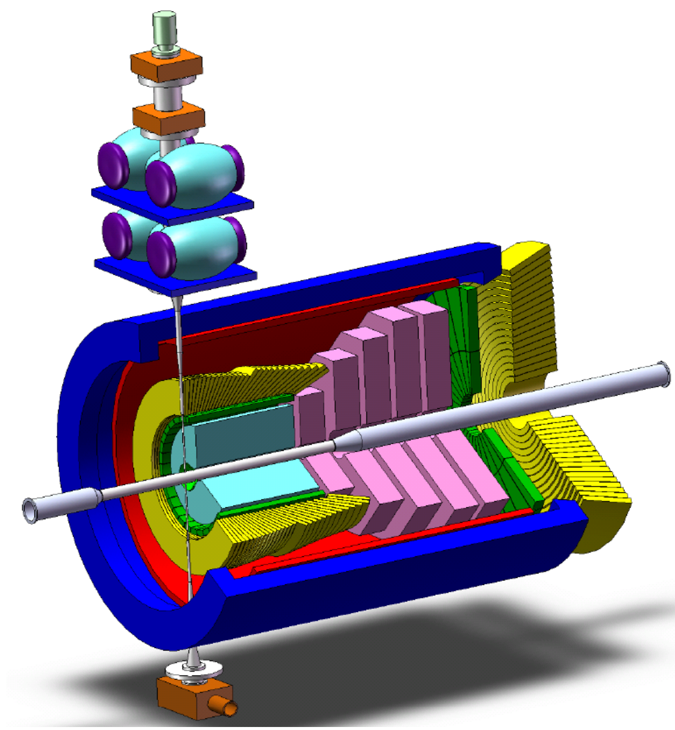
- The movement of C ions;
- The production cross sections, energy distribution, spatial distribution of other ejectiles i.e. light charged particles or fragments, neutrons, γ.

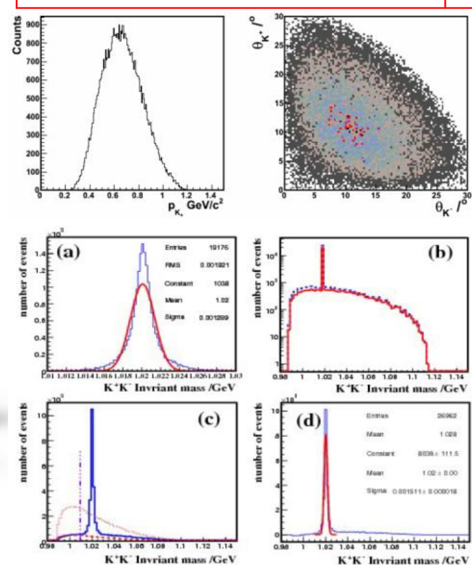
Hadron Physics at GeV energies

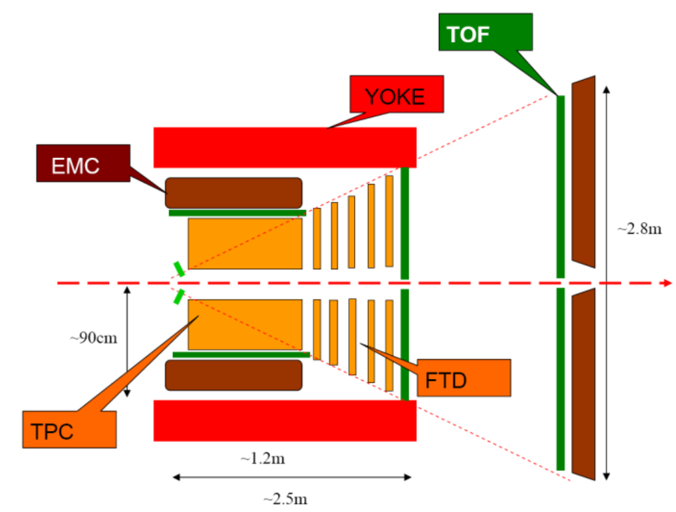
HPLUS

Hadron Physics
LanzhoU
Spectrometer

Channels	Threshold (GeV)	Physical interest
pp→ppϕ→ppK⁺K⁻	2.593	*Internal strange quark distribution and violation of symmetry*
pp→pK⁺Σ (Λ→n+γ)	1.793(1.582)	*Multi-quark states and strange constituent*
pp→da$_0$(980) (f$_0$(980))	2.483	*Mesons a_0/f_0 & internal quark-gluon structure*
pp→ppK⁺K⁻, pd→ ³He K⁺K⁻	2.494, 1.731	*direct K production*
pp→ppη (η′), pp→ppω	1.26(2.4), 1.89	*Isospin symmetry violation*
pp→N*, Δ⁺⁺(→KΛ…)	1.383	*Baryon resonance*
pα→N*α	0.795	*Baryon excited states with Big σN coupling*
pA→ρ(ω, η), pA→ϕ→ K⁺K⁻	Sub-threhold	*Medium effect*



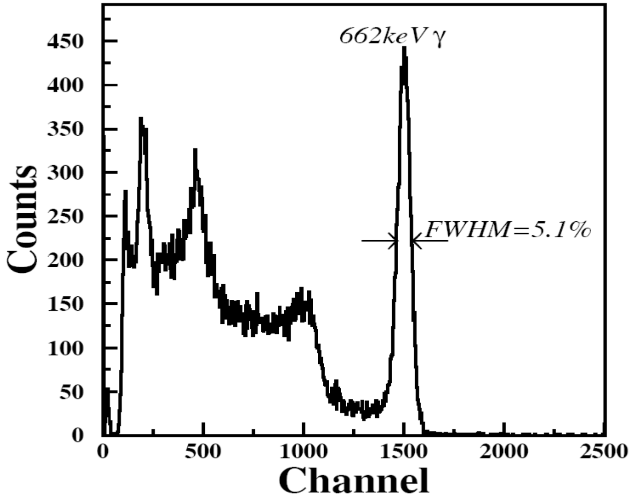




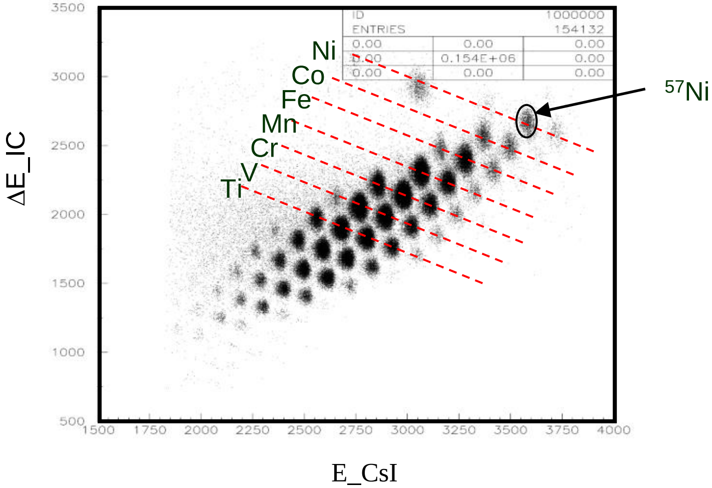
CsI crystals

IMP has developed the techniques to produce CsI scintillator.

10×10×10 cm^3 samples，APD readout

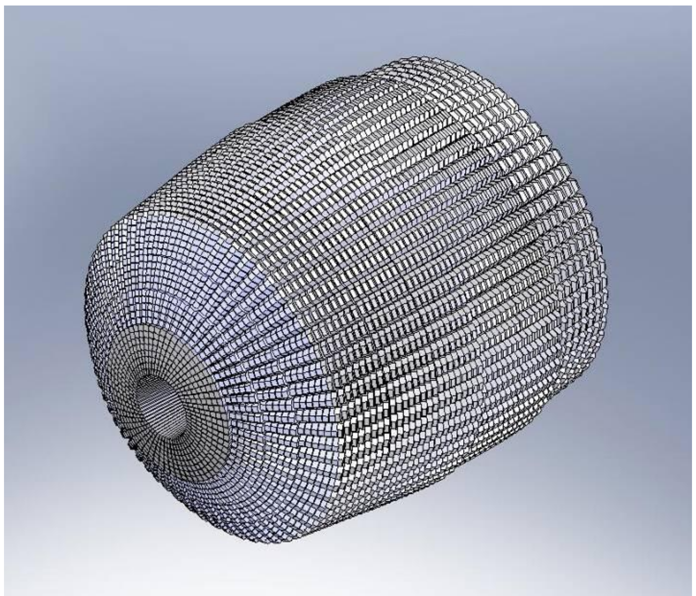


20×20×20 cm^3 samples，PD readout



EMC prototype

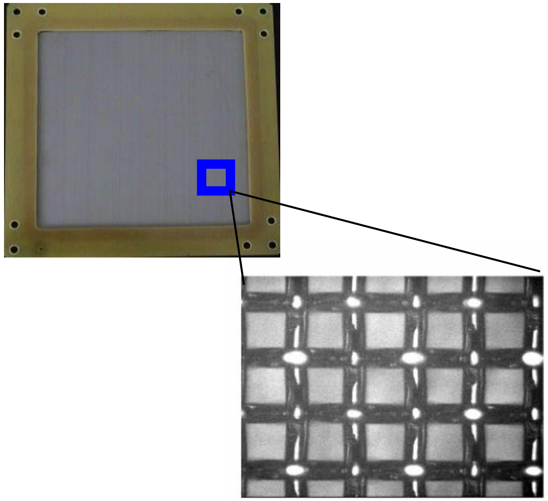
The MC simulation is assisting in optimizing the performance of both the full calorimeter and the individual modules.



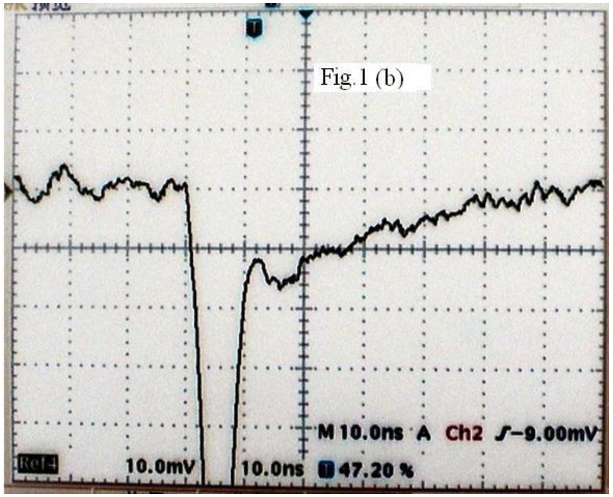
The shape, wrapping and the readout of the individual module have been fixed.

Configuration of Micromegas detector

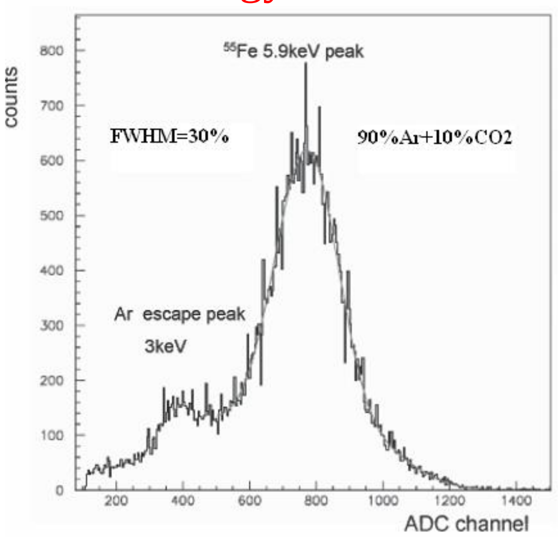
mesh structure



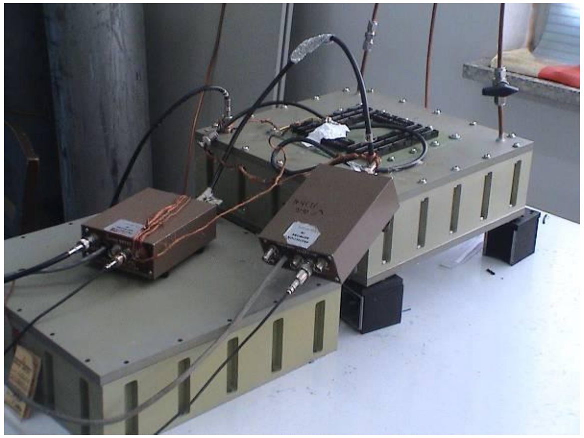
oscilloscope



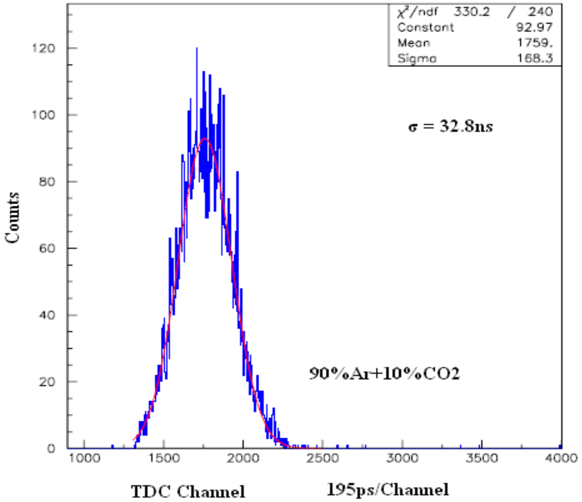
5.9 keV X-ray
energy resolution



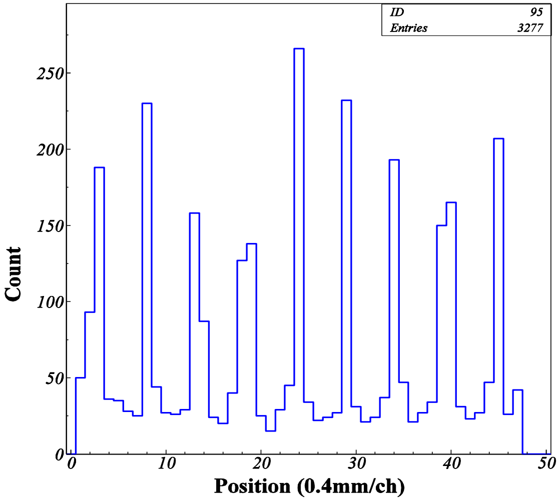
test platform



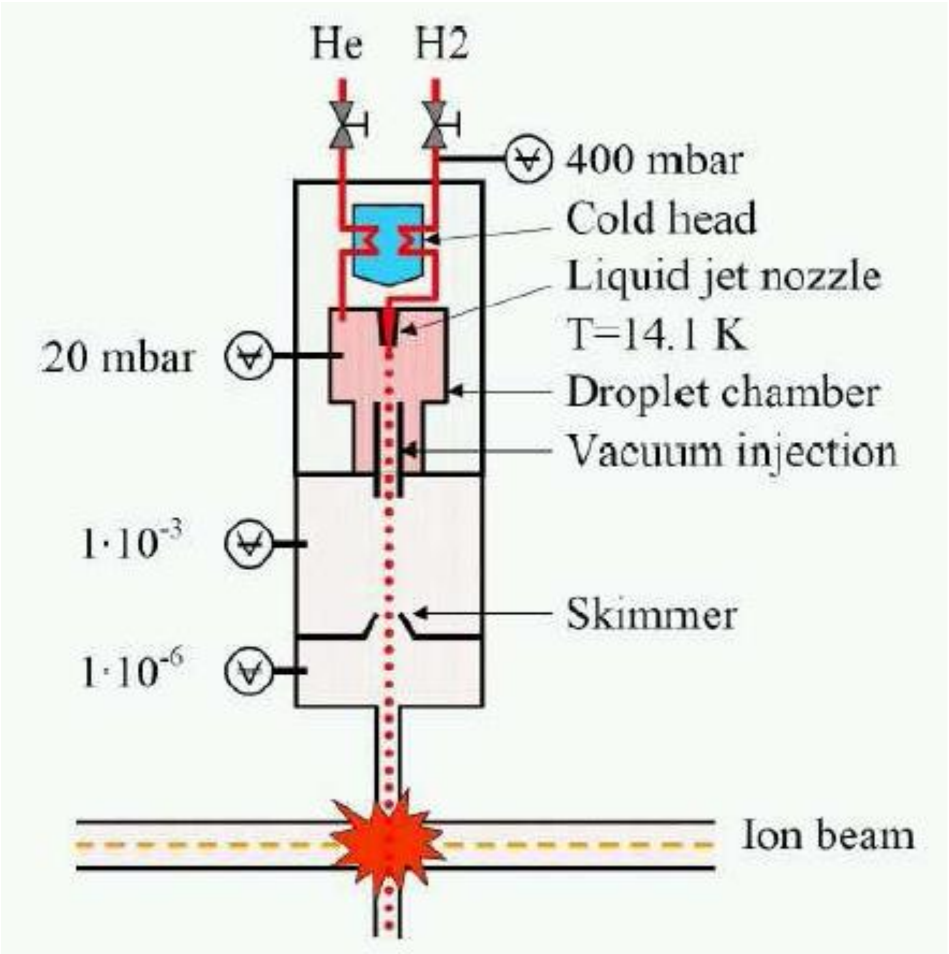
time resolution



position resolution



Pellet target for HPLUS



speed： 60 ~ 90 m/s，

diameter： 35 μm

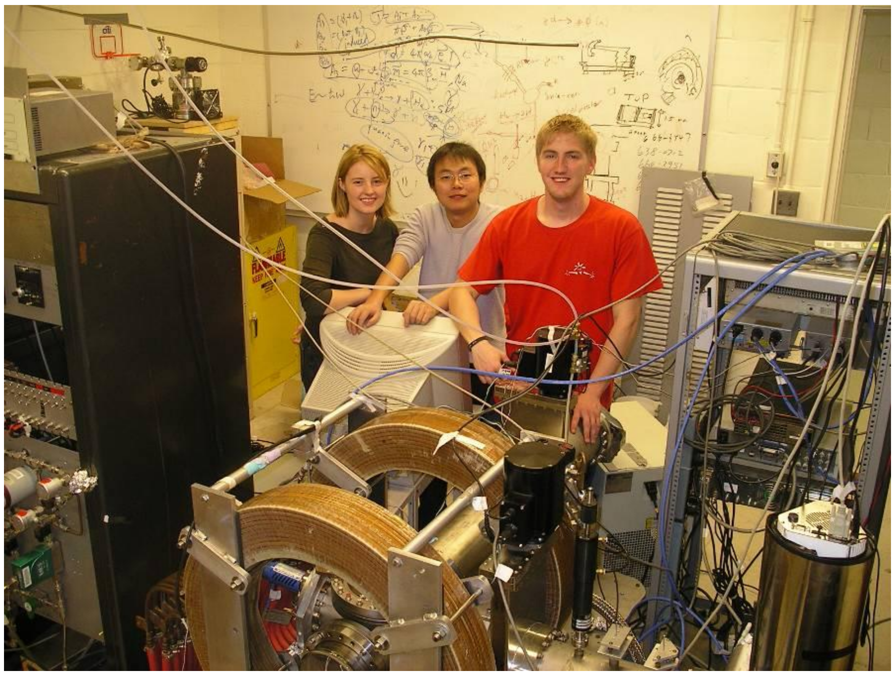
Luminosity: $10^{32}cm^{-2}s^{-1}$

Cold head, coordination system;

Monitoring system, thermal exchange system, vacuum system.

Laser-driven polarized hydrogen target

A laser-driven polarized hydrogen target will be transplanted from DUKE to IMP.



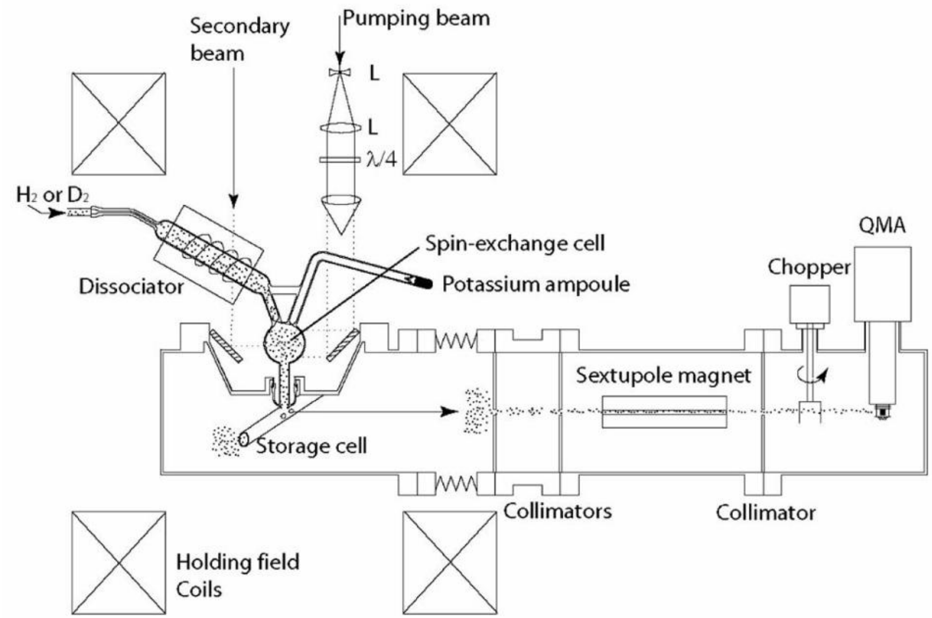
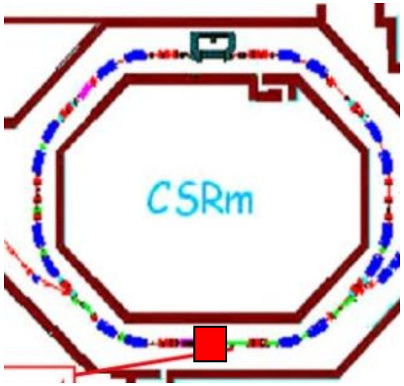


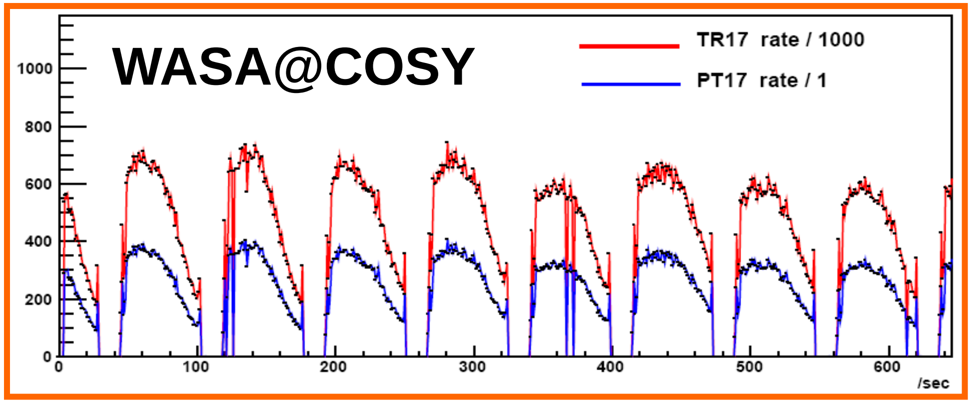
FIG. 1. Laser-driven target setup. Note that, for clarity, the polarimeter arm, storage cell, dissociator, and potassium ampoule are shown rotated by 90° from their actual positions (in the actual setup, the polarimeter arm and ampoule would come out of the page). An optional secondary beam can be used to measure the alkali-metal density and polarization via a Faraday polarimeter.

B. Clasie, H. Gao et al. Phy. Rev. A **73**, 020703R 2006

It provides a possibility to carry out the spin physics study at CSR.

Luminosity Determination





Trigger conditions for selecting elastic events,

red curve: trigger rate

blue curve: DAQ rate

Proton beam tuning

↓

First time beam tuning in CSRm in 2010, 1 GeV.

↓

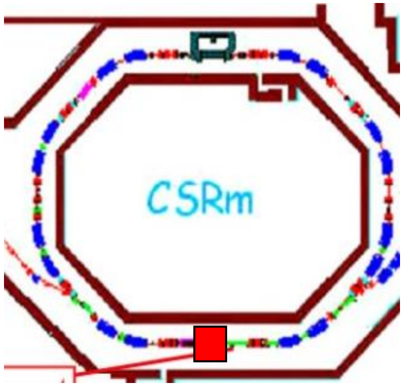
2.8 GeV in the future

A monitor for the effective luminosity is needed because the beam conditions are not constant.

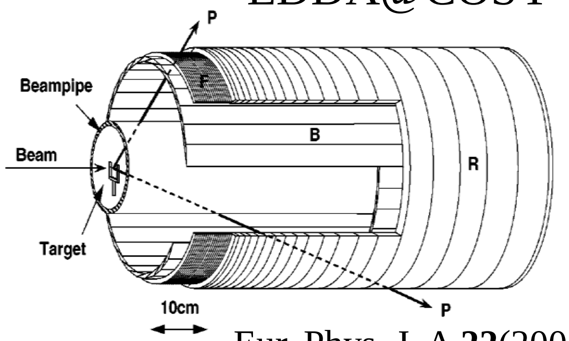
1. beam envelop position & distribution;

2. beam intensity attenuation.

Luminosity Determination



EDDA@COSY



Eur. Phys. J. A **22**(2004)125

Dr. Zheng
16:30 today

Proton beam tuning → Proton - proton elastic → HPLUS, Hadronic physics study

First time beam tuning in CSRm in 2010, 1 GeV.

↓

2.8 GeV in the future

A monitor for the effective luminosity is needed because the beam conditions are not constant.

1. beam envelop position & distribution;
2. beam intensity attenuation.

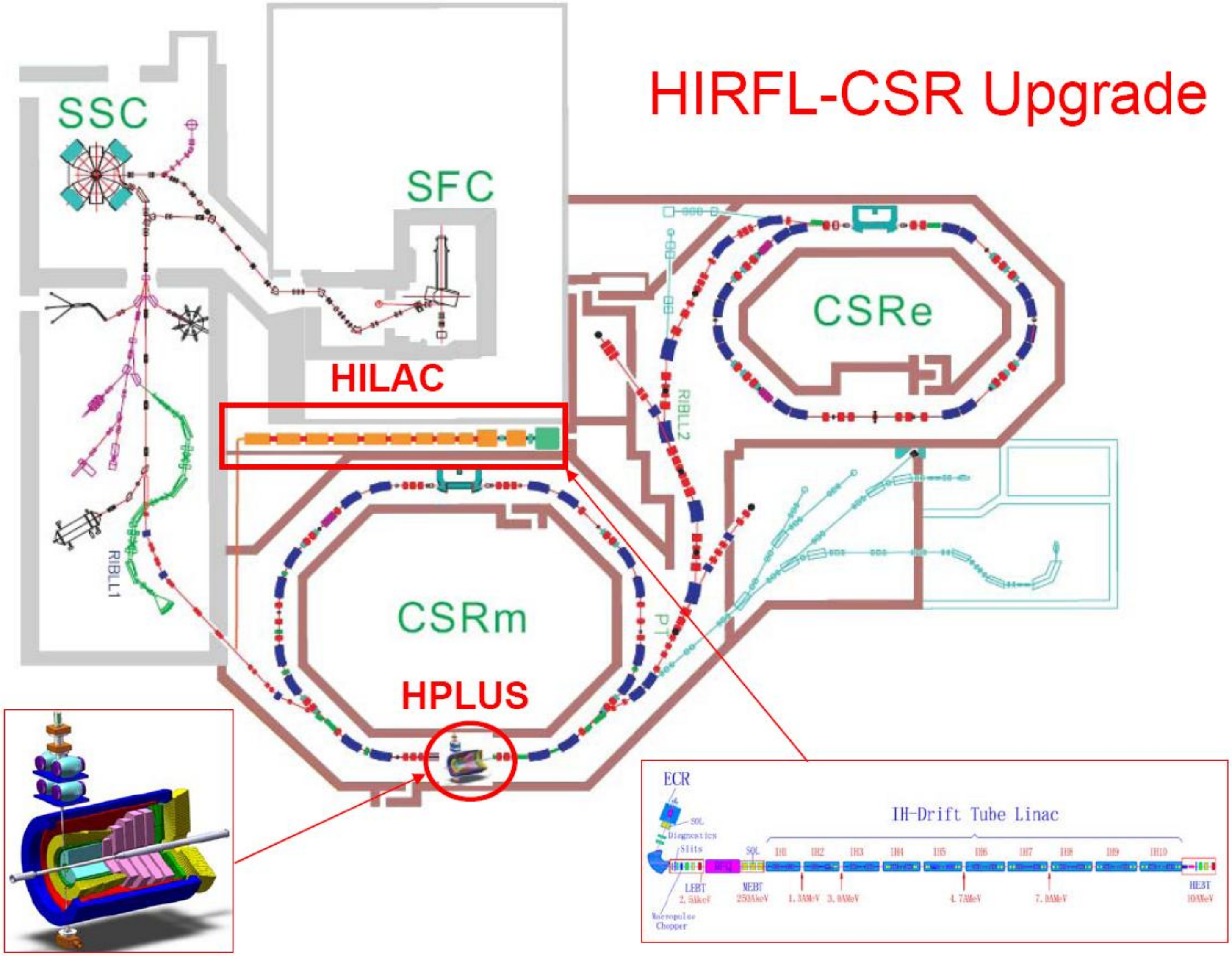
☺

Recent Plan

- **Budget**
- **Stratagem before the budget available**
  - **HPLUS simulation, key tech. R&Ds, physics preparation**
  - **Proton beam from CSR, CSR upgrade accordingly**
  - **Pellet target platform construction / LDPT**
  - **Simple experiment**
  - **Adding the detectors step by step**

Budget close to 200 million Chinese Yuan needed !

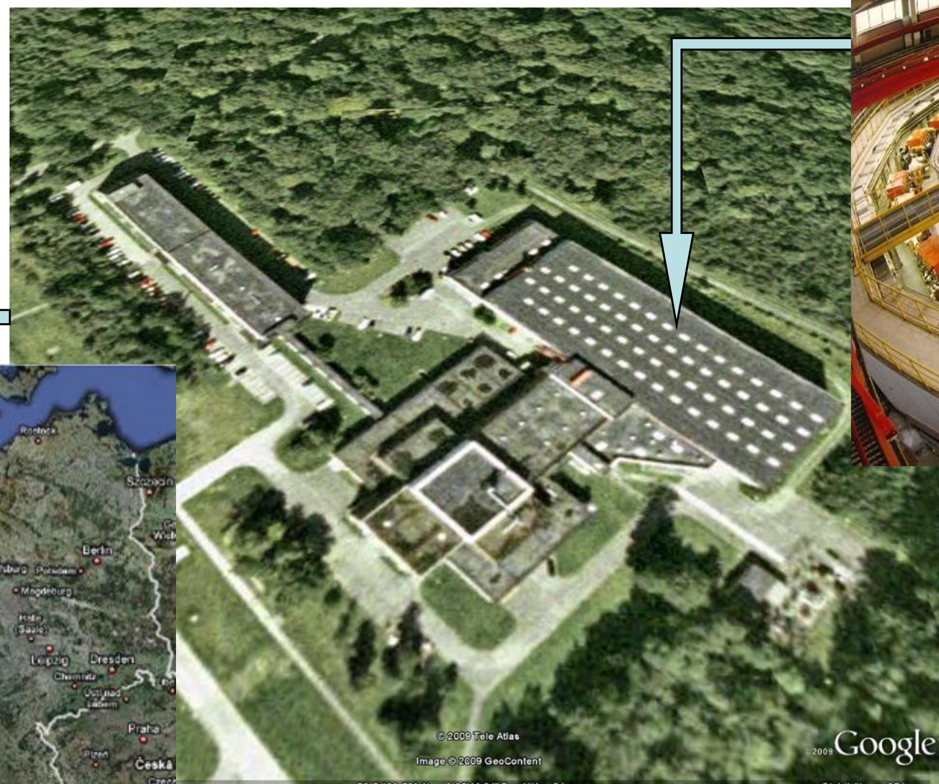
Future Plan

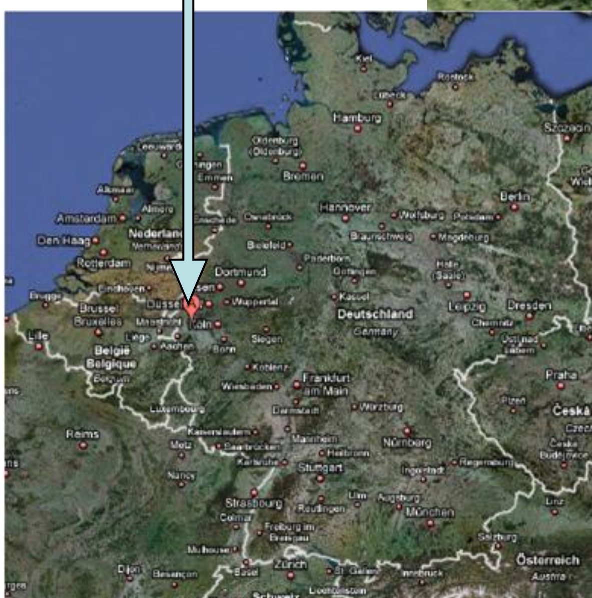

HIRFL-CSR Upgrade
SSC
SFC
HILAC
CSRe
CSRm
HPLUS
RIBLL1
RIBLL2
PT
ECR
IH-Drift Tube Linac
LEBT
MEBT
HEBT

Thank you for your attention!

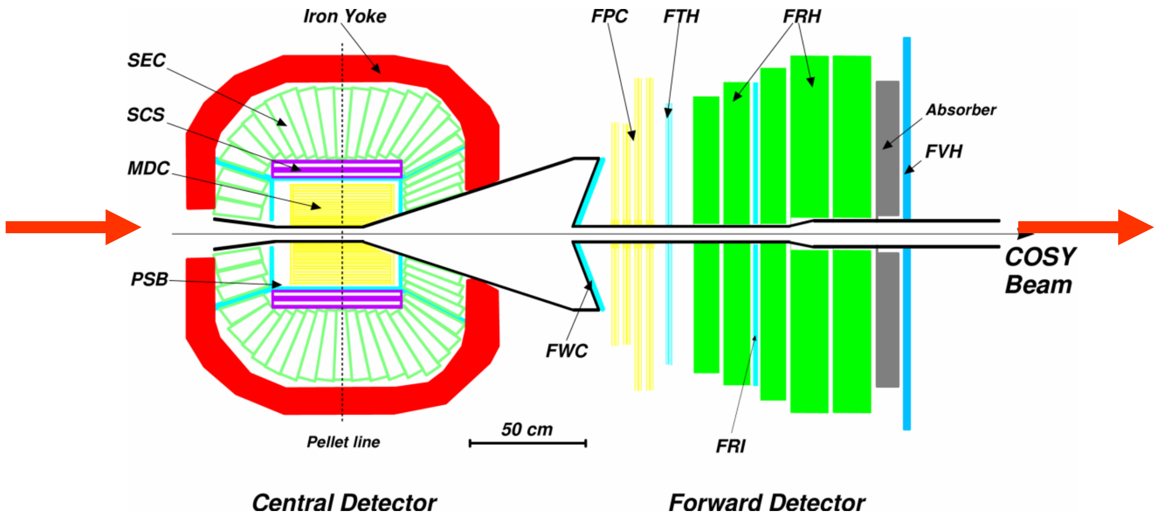
Spare foils

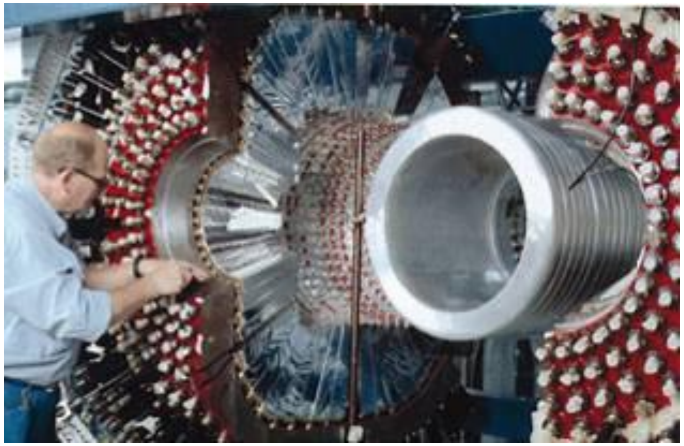
Tools: COoler SYnchrotron COSY-Jülich

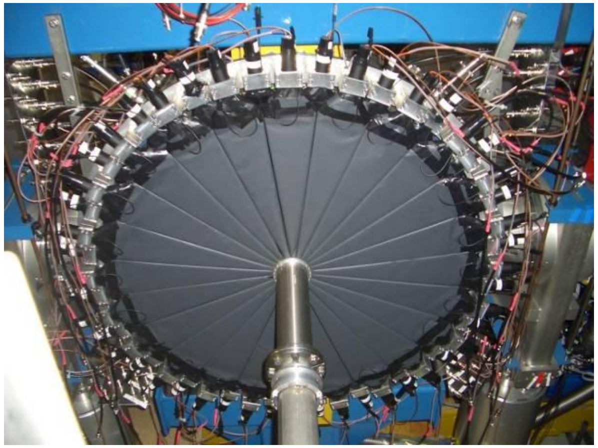




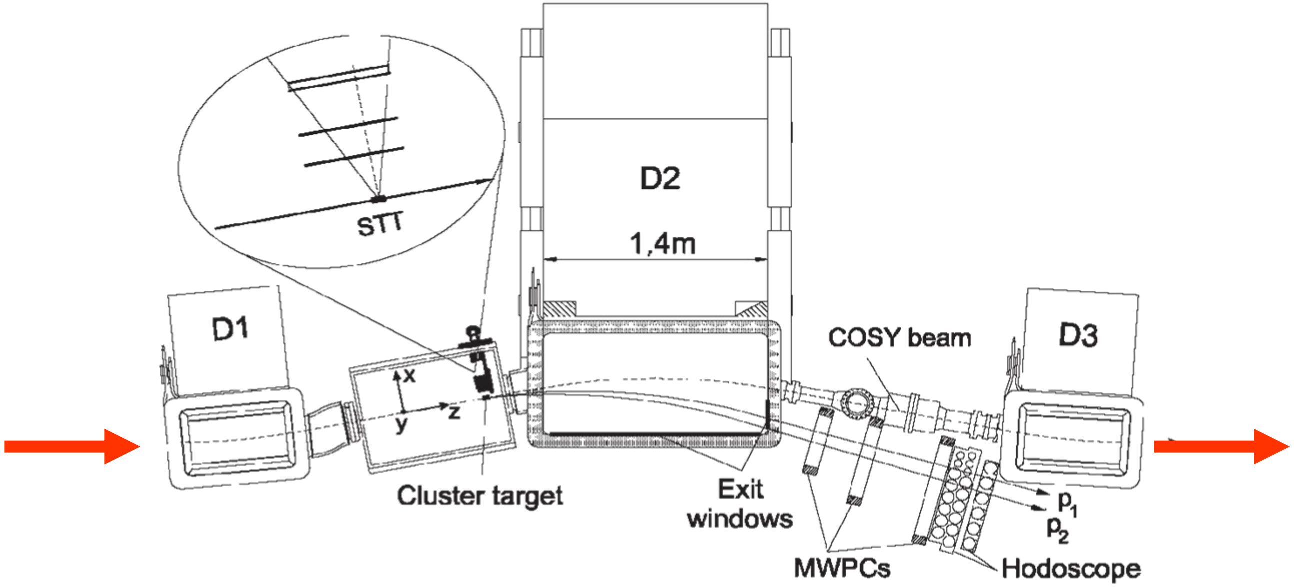
WASA - Wide Angle Shower Apparatus

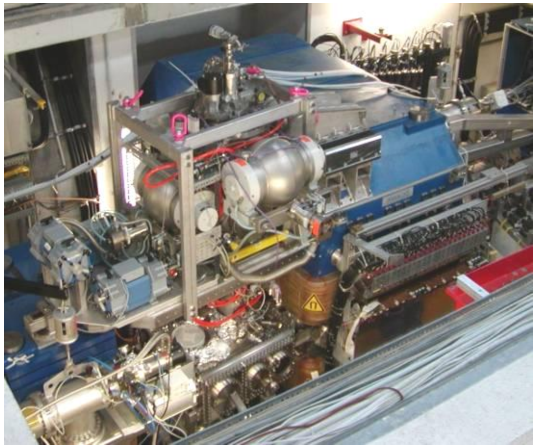


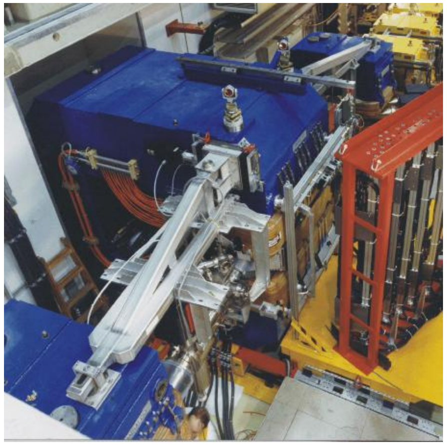


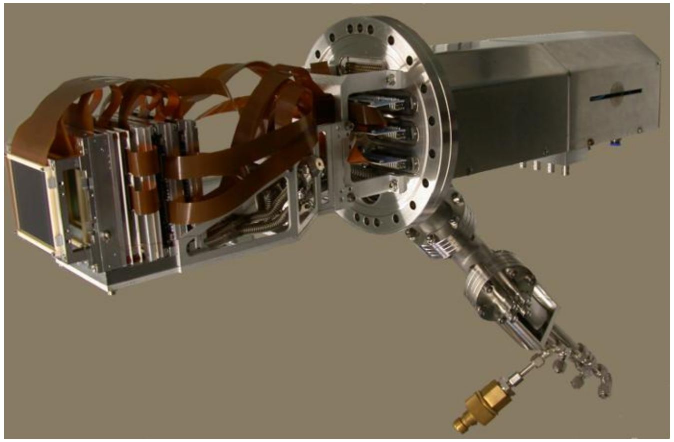


ANKE – Apparatus for detection of Nucleon and Kaon Ejectiles









PISA

- ***nn*** **scattering cross section at CSR energies**
- **L-G phase transition of nuclear matter**
- **Spallation process:**

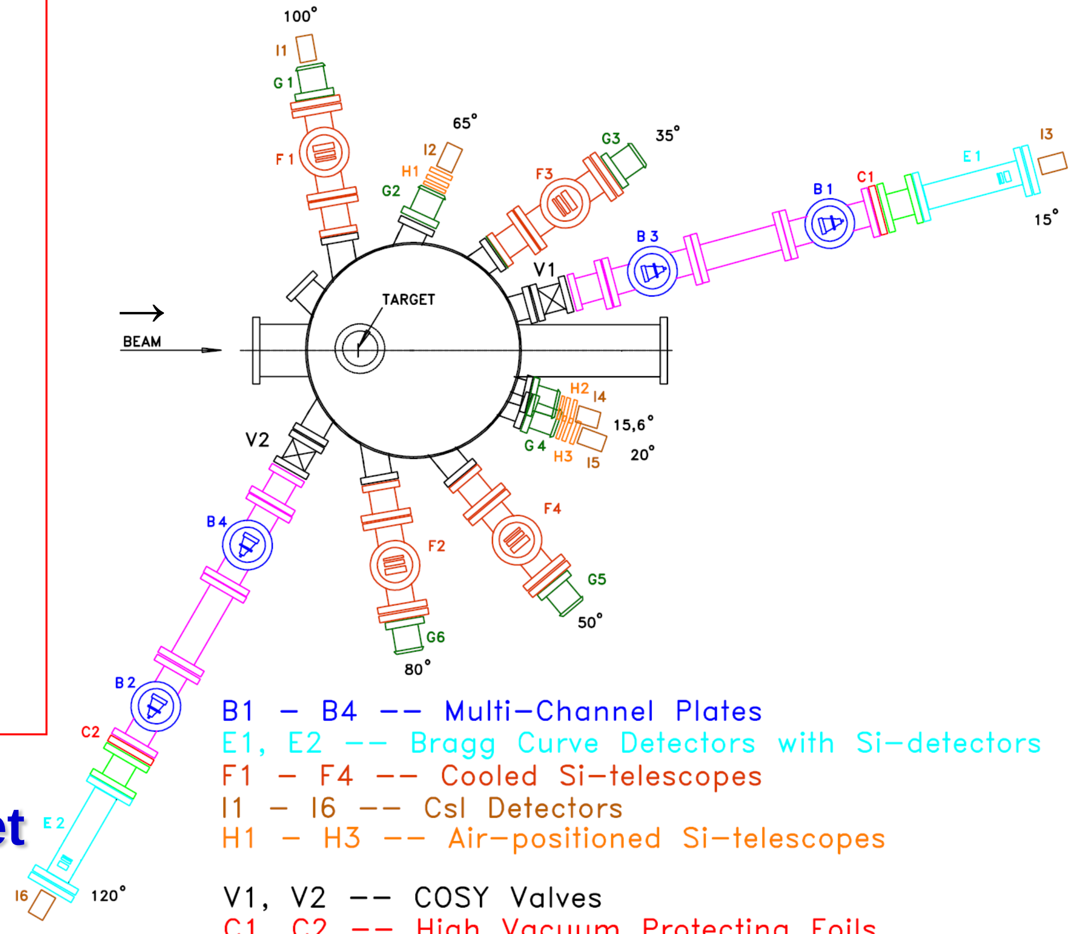
  measuring the spectra of LCP, extracting the excitation energy, and comparing with model calculations → mainly focusing on the requirements from the applications

- **Comparison of R_{AA} & R_{pA} at CSR energies**

  as a part of the energy scanning from RHIC energy down to CSR energy

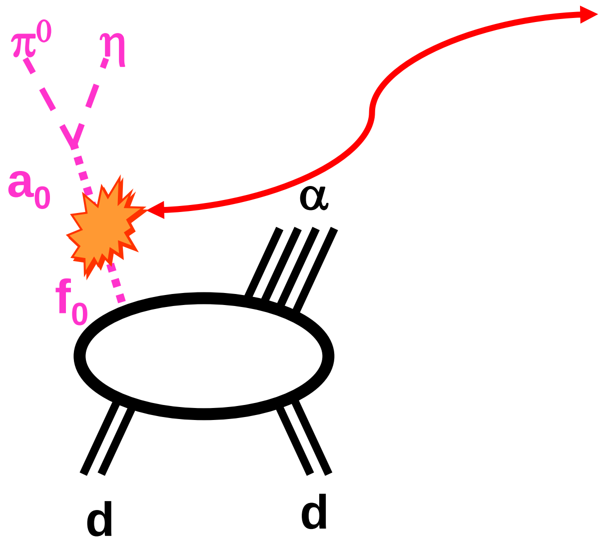
Nucl. Instr. & Methods A 519 (2004)610-622

Shipped from FZJ to IMP in 2008



Running as an external target exp. in the end of 2010.

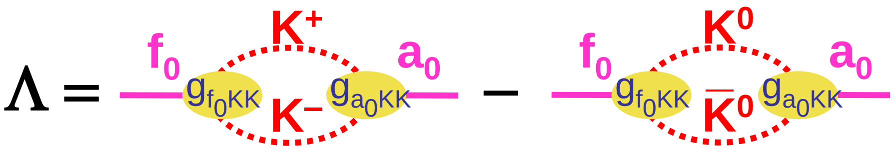
$a_0^0(980)$ – $f_0(980)$ mixing: Kaon loops



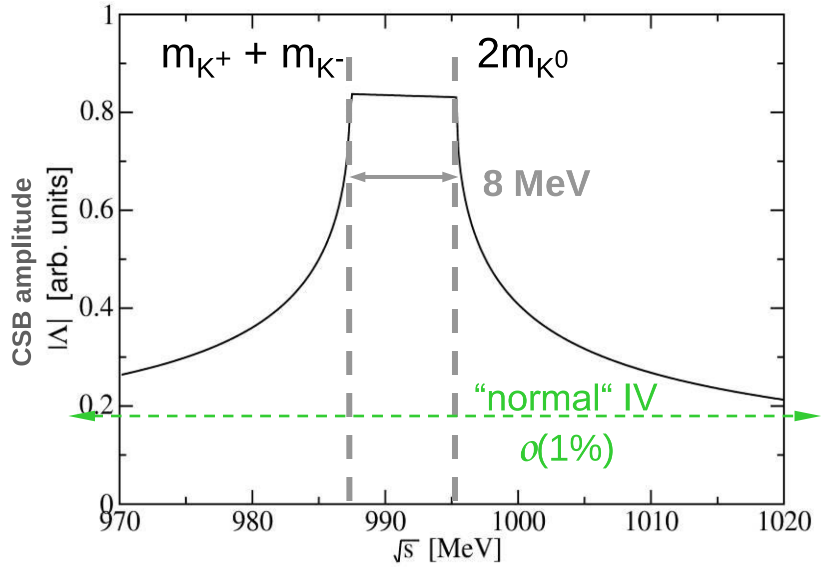
$$\frac{d\sigma}{dm}\left[dd \to \alpha(\pi^0\eta)\right] \propto$$

(Product of mixing amplitude Λ and f_0 production operator)^2

Enhanced mixing by “Kaon loops“



$$\Lambda = \langle f_0|T|a_0\rangle = i g_{f_0KK}\, g_{a_0KK} \sqrt{s}\left(p_{K^0} - p_{K^+}\right) + o\left(p_K^2\right)$$



N.N.Achasov *et al.*, PL B **88**, 367 (1979)

$a_0^0(980) - f_0(980)$ mixing: Kaon loops

Plan for WASA/COSY: $dd \to \alpha\ f_0(980) \to \alpha\ a_0(980) \to \alpha\ \pi\ \eta$

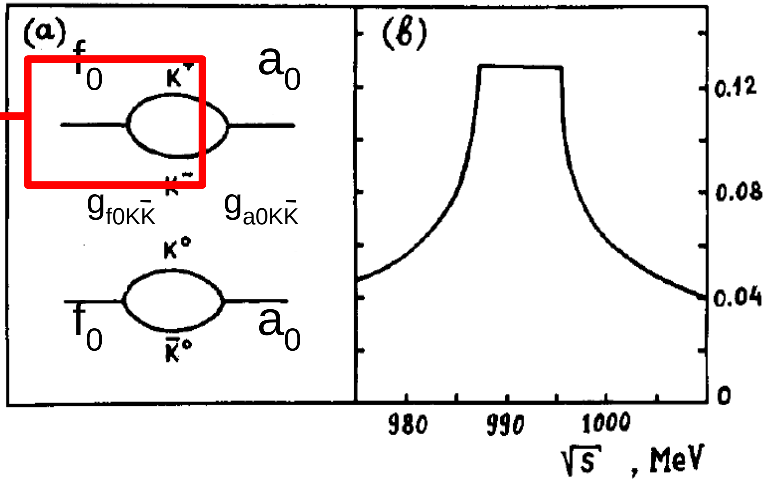
Isospin violation

Isospin: 0 0 1 1

Possible experiment @ BES: $J/\Psi \to \Phi\ f_0(980) \to \Phi\ a_0(980) \to \Phi\ \pi\ \eta$

[N.N. Achasov et al., Phys. Lett. B 88 (1979) 367]

$$\frac{d\sigma}{dm}\left[dd \to \alpha(\pi^0\eta)\right] \approx |\Lambda|^2 \times \sigma_{tot}(dd \to \alpha\ f_0)$$

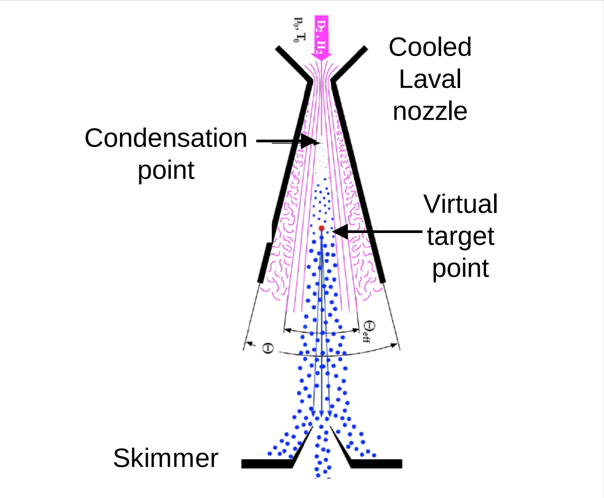


$\sigma\ (dd \to \alpha\ f_0(980))$ is not known!

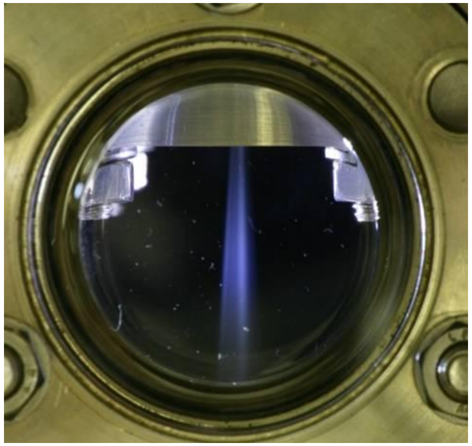
$dd \to \alpha\ f_0(980) \to \alpha\ K^+K^-$ can be measured at ANKE/COSY !

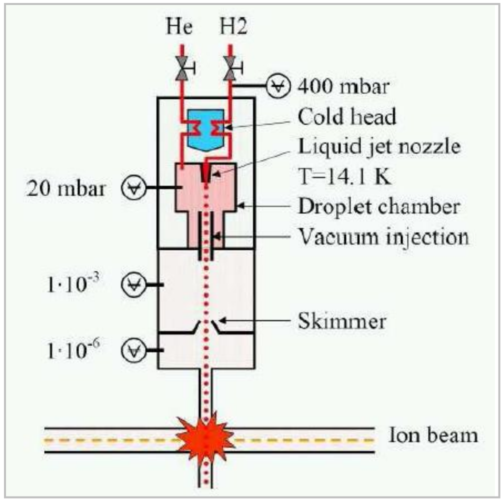
$\sigma\ (dd \to \alpha\ K^+K^-) \approx 0.4$ nb (estimate, 2003)

Internal targets at COSY

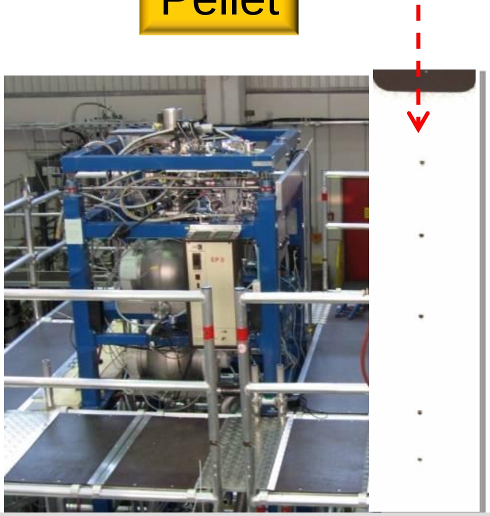


Cluster jet



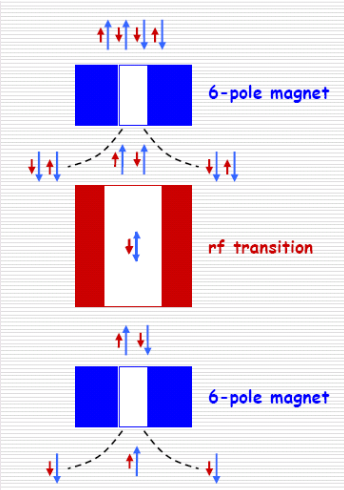


Pellet



Operation principle:

Focussing and defocussing of hydrogen or deuterium hyperfine states



Polarized (ABS)