Mitglied der Helmholtz-Gemeinschaft

Operation of WASA-at-COSY

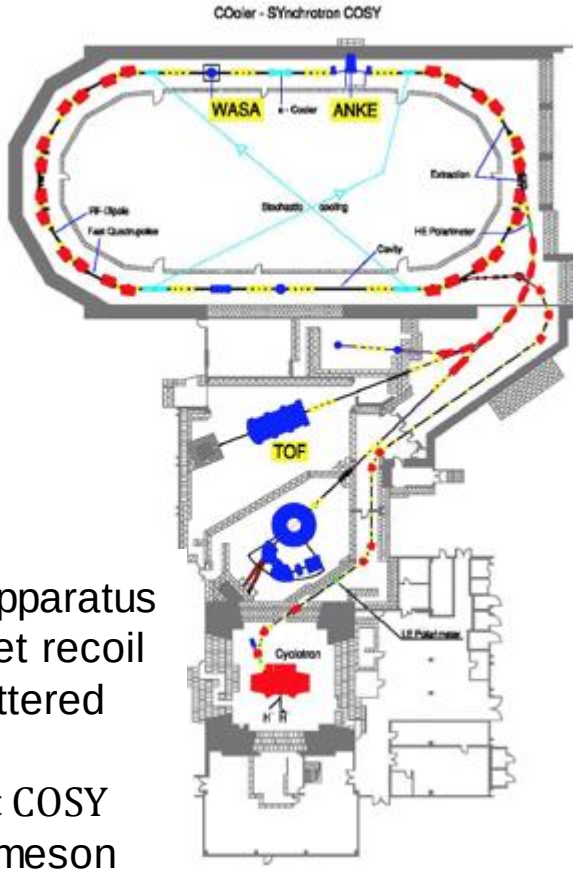
for planning WASA at FRS/GSI

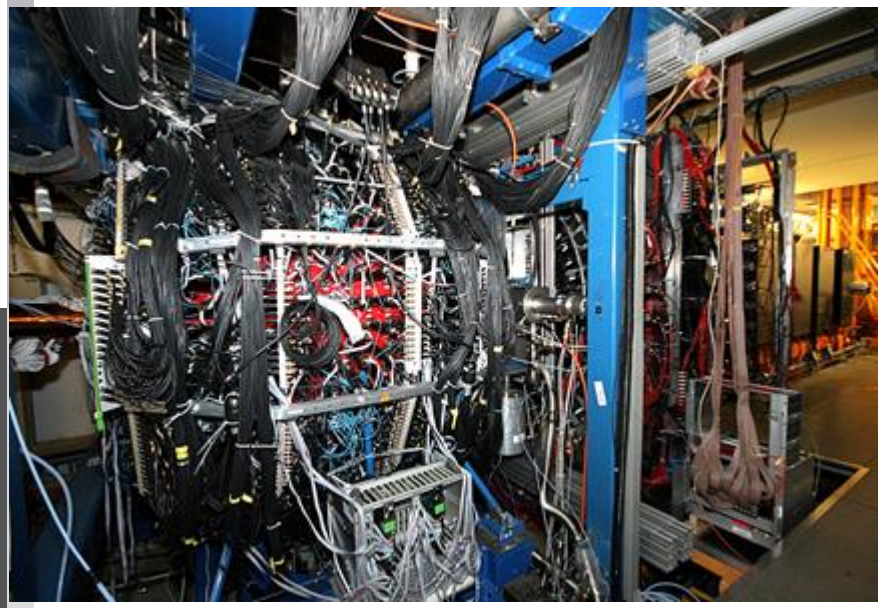
27-28 November 2017, GSI

Frank Goldenbaum

WASA operation at COSY

- p,d beams up to p=3.65 GeV/c
  $E_p = 2.82$ GeV, $E_d = 2.2$ GeV
- operated as internal, fixed target experiment (until 2015)
- polarized beams
- beam cooling (stochastic, electron)

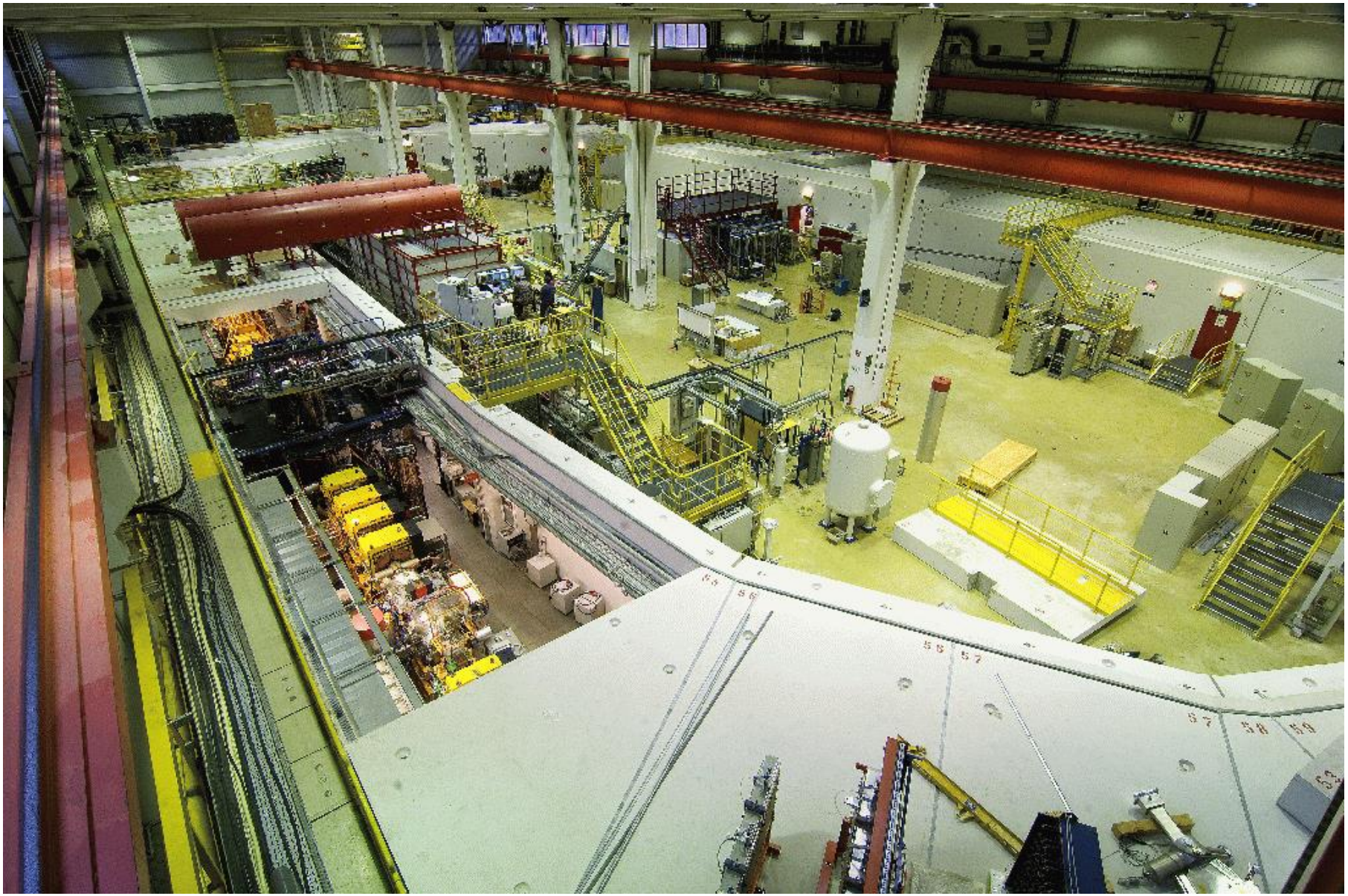




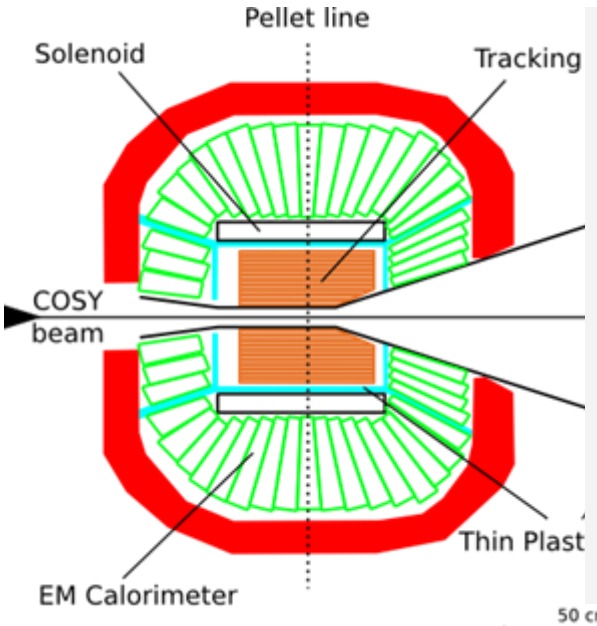
Wide **A**ngle **S**hower **A**pparatus

- FD: charged target recoil particles and scattered projectiles
  → continued use at COSY
- CD: detection of meson decay products; charged particle($e^{\pm}$,$\pi^{\pm}$) and γ
  → to be moved to FRS at GSI

WASA operation at COSY

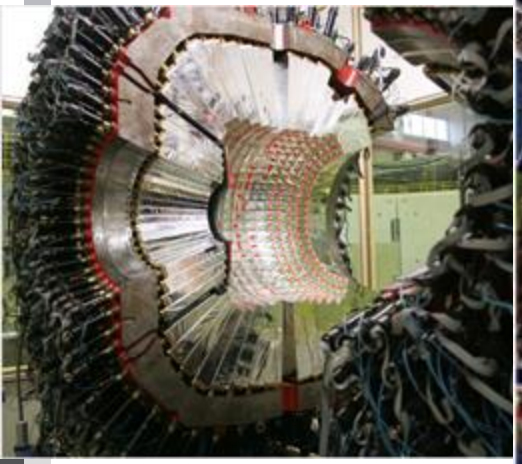


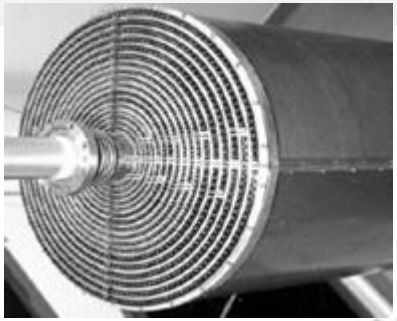
WASA central detector components



central detector consists of:

- electromagnetic calorimeter 1012 CsI(Na)crystals
- supercond. solenoid - axial field 1.3T
- mag.flux return by 5T Fe yoke outside calorimeter, yoke is support for crystals
- barrel of thin plastic scintillators
- cylindrical chamber of drift tubes
- beryllium beam pipe with target cross

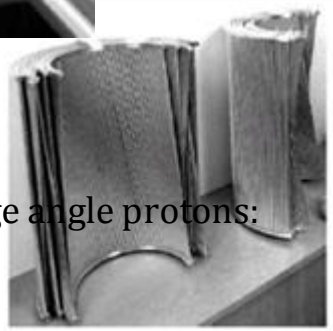




17 cyl. layers
1738 straws
24°..159°
vertex res. for large angle protons:
$\sigma_{\perp}$ =0.2mm
$\sigma_{\parallel}$=3mm

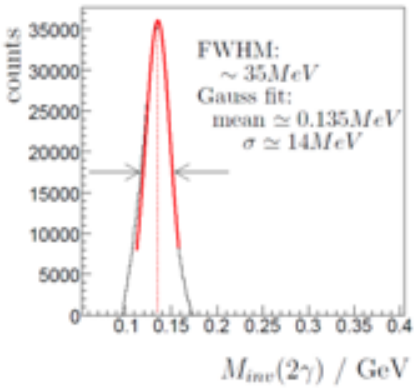
→ few dead tubes!

beam pipe:
1.2mm Be
wall thickness
Ø=60mm

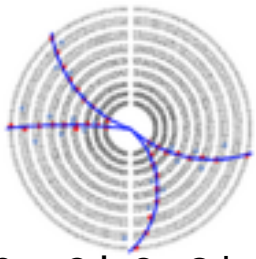


WASA particle identification

calorimeter

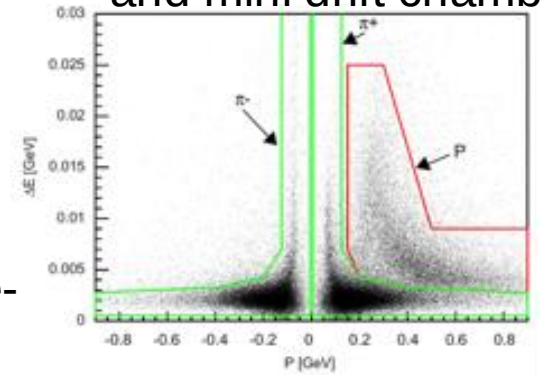


mini drift chamber

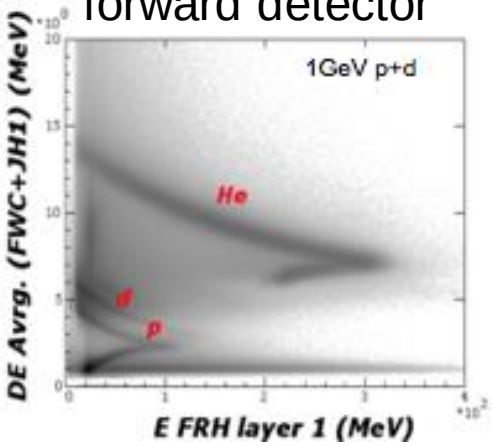


η→e+ e- e+ e-

thin plastic scintillators and mini drift chamber

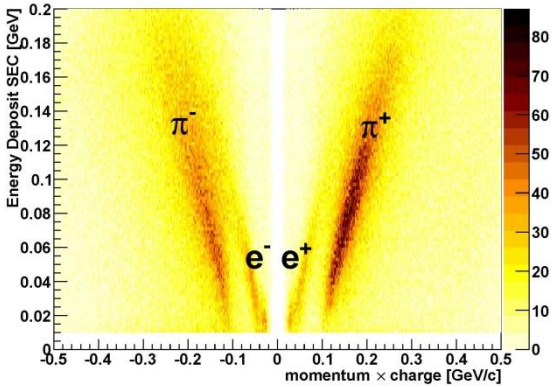


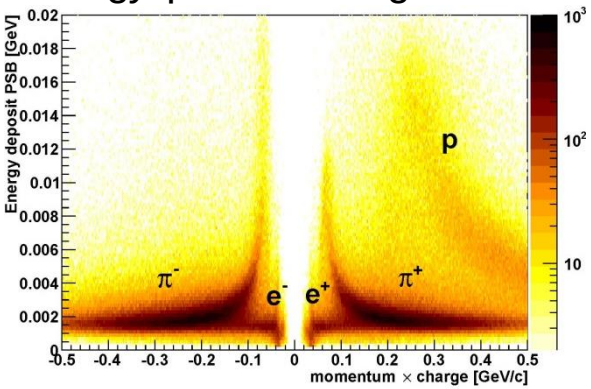
forward detector



example PID:
analysis of p + d → ^{3}He + η
(after ^{3}He selected in WASA forward detector, low-energy proton background visible)

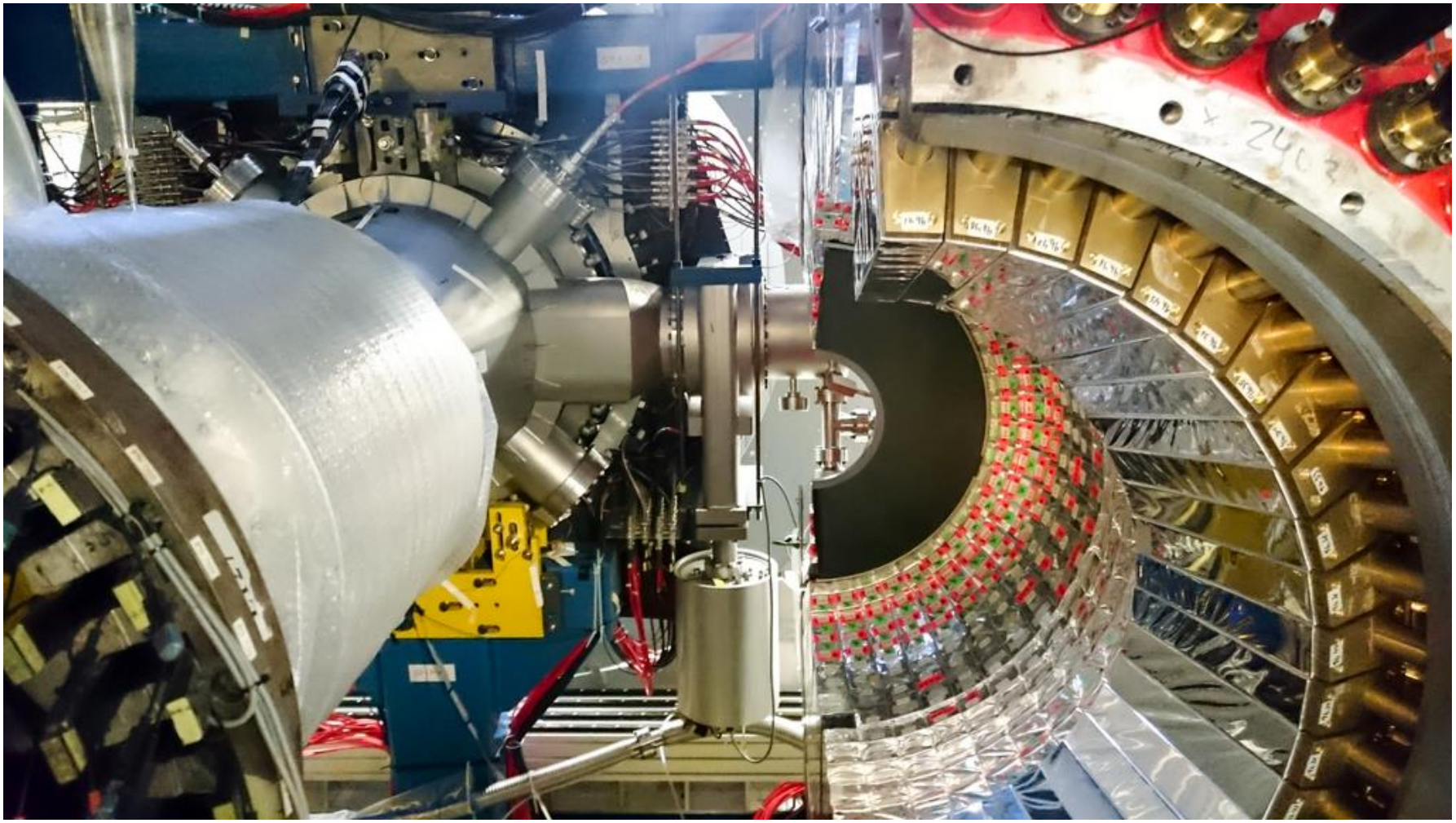
calorimeter vs signed momentum



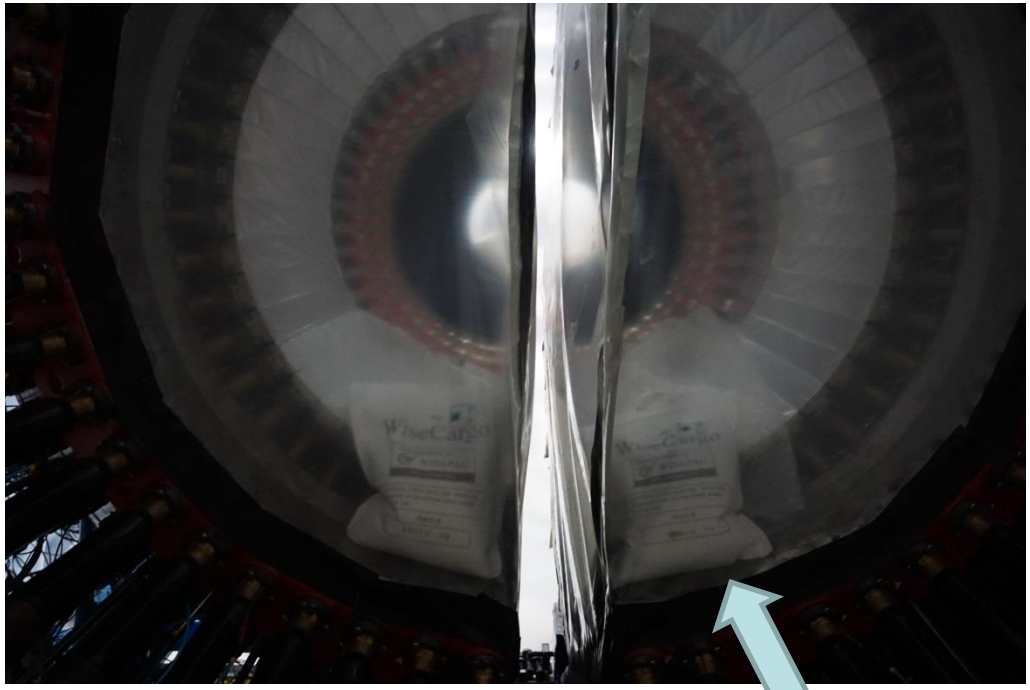


plastic scintillator vs signed momentum

View into CD opened



Current status of CsI calorimeter:



CsI(Na) cystals hydrophilic
→ dry powder during storage

Drying plant (hydrophilic Crystals)

→ to be moved to FRS at GSI

Solenoid parameters

Superconducting coil	
Inner/outer radius [mm]	267.8 / 288.8
Superconductor (stabilizer)	NbTi/Cu (pure Al)
Total winding length	465 mm
Maximum central magnetic flux density, $\mathbf{B}_c$	1.3 T
Field uniformity in the mini drift chamber	1.22 T ±20%
Cooling	Liquid He, 4.5°K
Cryostat	
Material	Aluminium
Inner / outer radius [mm]	245 / 325
Overall length [mm]	555
superconducting solenoid wall thickness (coil+cryostat) [radl]	**0.18**

B_{max} tested up to 1.3 T, generally operated@COSY: 1T
Current in solenoid at 1T: 693A

Cold box, dewar, He Tank

http://wasasrv.ikp.kfa-juelich.de/WasaWiki/index.php/Superconducting_Solenoid:Documentation

incl. cooling down, steady state operation, excitation, discharge, maintenance…

→ to be moved to FRS at GSI

Liq.-He Compressor

→ to be moved to FRS at GSI

CsI Calorimeter parameters

Scintillator Electromagnetic Calorimeter	
Amount of sensitive material	135 g/cm^2
[radiation lengths]	≈ 16
[nuclear interaction length]	≈ 0.8
Geometric acceptance:	96%
polar angle	$\approx 20° - 169°$
azimuth angle	$\approx 0° - 360°$
Max kinetic energy for stopping	
$\pi^{\pm}$/proton/deuteron	190/400/500
Scattering angle resolution	$\approx 5°$(FWHM)
Time resolution	
charged particles	5 ns(FWHM)
photons	$\approx$40 ns(FWHM)
Energy resolution	
charged particles	$\approx 3\%$(FWHM)
photons	$\approx 8\%$(FWHM)

1012 CsI(Na) crystals

Designed for handling luminosities 10^{32} cm^{-2}s^{-1}

photon threshold ~2MeV

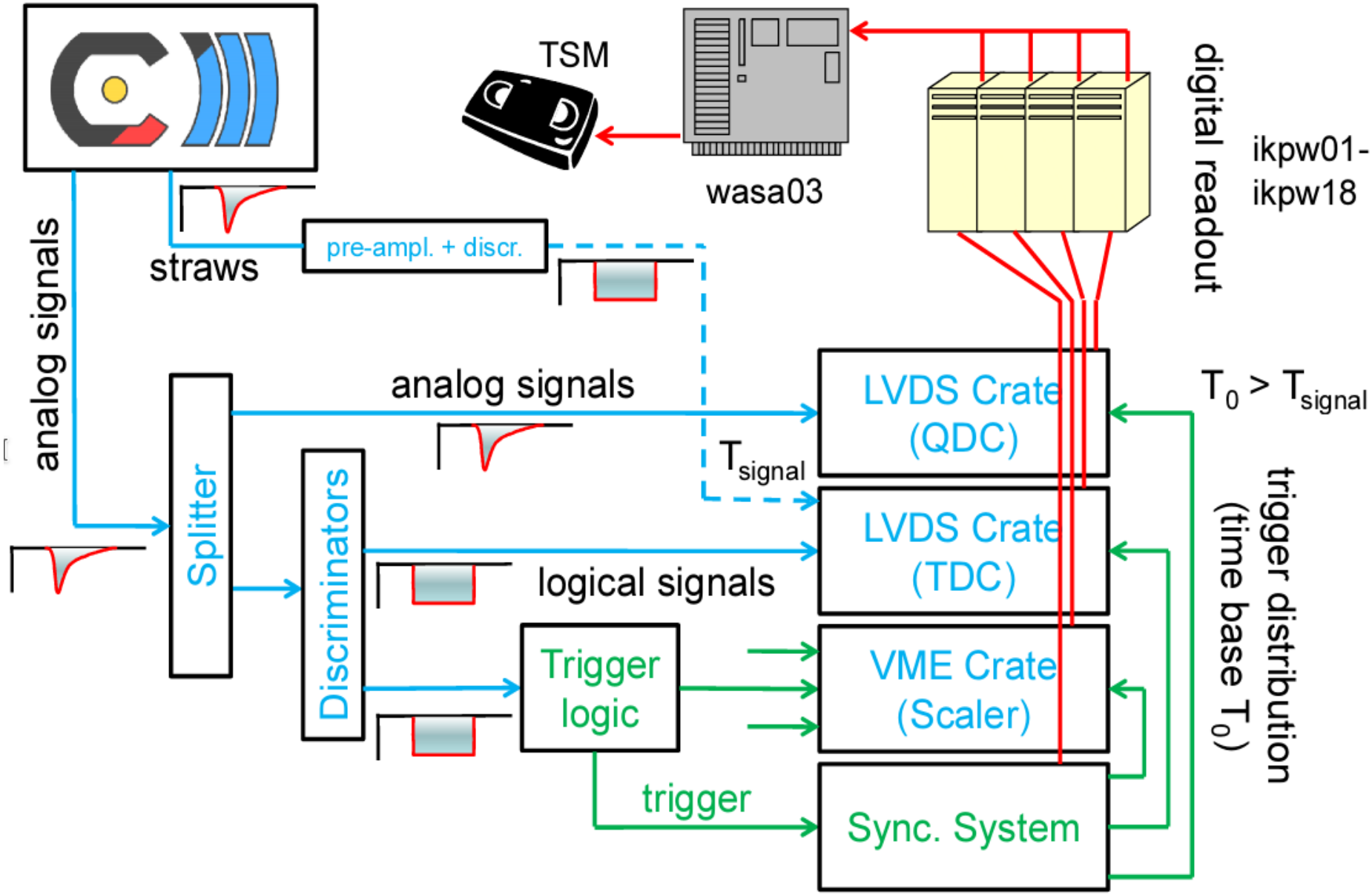
Momentum resolution:

$e^{\pm}$ (20-600MeV/c): $\sigma_p/p<2\%$

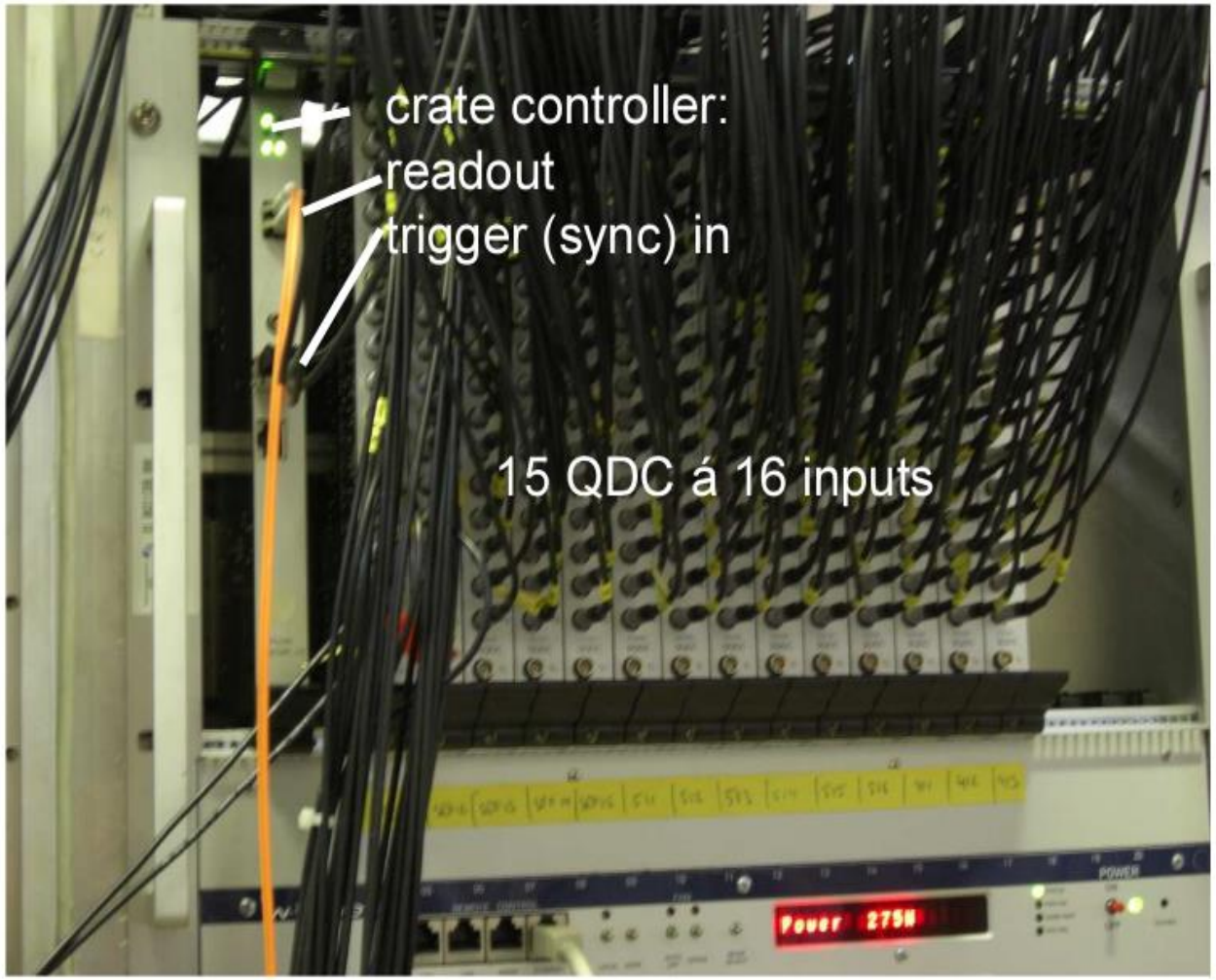
π, μ(100-600MeV/c): $\sigma_p/p<4\%$

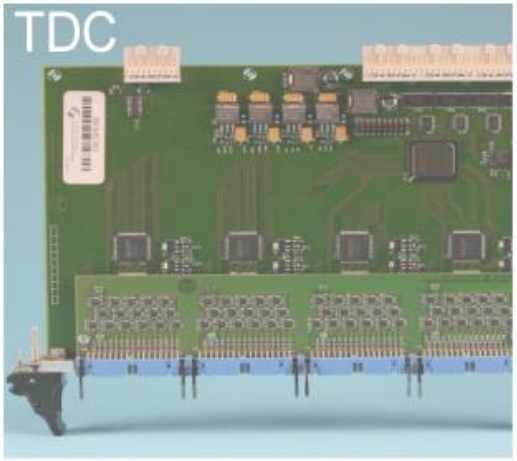
p(200-600MeV/c): $\sigma_p/p<6\%$

Readout scheme



LVDS crate and modules





Overview on the timing

Transfer from Uppsala to Jülich:	almost finalized in June 2005
Installation of all detector components:	Calendar weeks 22-29 2006
Test phase with beam-target interaction: (commissioning)	second half 2006
Regular beam operation/experiments:	started in Jan 2007

De-installation in Uppsala: ca. 8 weeks
Installation at COSY: ca. 12 weeks

however with considerable person-power!

Overview on the costs

transfer, upgrade of detectors for operation at COSY and commissioning

(taken from 2005 report)

Investitionen			
Gewerk	Investition in k€		
Reisekosten	40		
Baumaßnahmen	45		
Transportauftrag	40		
Elektronik: Prototypen	100		
Erweiterung Lüftung COSY	25		
Elektronik MDC, FPC	15		
Änderungen Support	50		
Messkabine DAQ	25		
Änderungen Vakuumsystem 1	50		
Änderungen Pellettarget	20		
Elektronik: DAQ 1. Teil	300		
Triggerelektronik	100		
Summe 2005	810		
Änderungen Vakuumsystem 2	100		
Elektronik: DAQ 2. Teil	650		
Änderungen am Detektor	500		
Summe 2006	1250		
Summe Investitionskosten	**2060**		

finally….

Costs

DAQ:	700k€
Support structures:	60k€
Travel:	55k€
Vacuum:	200k€
Upgrade FD	350k€
Transport	68k€
Misc	600k€

Formal aspects of the transfer were fixed by MoU between Univ. Uppsala and the Forschungszentrum Jülich

Report by the committee for the evalutation of the project „WASA-at-COSY“ (9-11-Feb.2004)

JÜLICH FORSCHUNGSZENTRUM

Based on the proposal “WASA at COSY”, the oral presentations and discussions during the meeting the committee unanimously makes the following observations and recommendations:

- The installation of the WASA detector at COSY provides an opportunity for making unique contributions towards the settling of several of the most compelling outstanding issues in strong-interaction physics.
- The Committee fully endorses the presented physics programme for WASA at COSY and is therefore united in its enthusiastic endorsement of the proposal to operate WASA at COSY. We are very impressed by the proposal and suggest only some minor modifications; see Section 4.
- The Committee has considered the feasibility and global technical aspects and is quite satisfied.
- The Committee recommends the drafting of a Memorandum-of-Understanding (MoU) between the various institutions of the new WASA collaboration at COSY.

Main recommendation/concern:

1. …available floor space
2. …crucial to the success will be the proposed electronic upgrade…new DAQ with goal 10kHz event rate
3. …luminosity $10^{31-32}cm^{-2}s^{-1}$ adequate for much of the proposed program …using pellet rate 10^4 pellets/s of 70m/s
4. …intensity limitations known:
   - Space charge effects in multi-wire drift chambers
   - Pile up in trigger
   - After glow/pile up in CsI crystals

All fine

Summary of beam time periods 2006-14

2014 pd → 3He η and pd → (3He η)bound
2014 dd → 4He π0
2013 pp → pp π0
2013 dp breakup
2012 pp → pp π0
2012 ABC in d(pol)p
2012 η decays in pp
2011 ω and η' decays in pp
2011 ω decays in pd
2010 dd → (4Heη)b.s.
2010 pp → ppη polarized
2010 charged η decays in pp (pt 2)
2010 pp → pp π0
2010 charged η decays in pp (pt 1)

2009 η decays in pd
2008 η decays in pd and pp
2008 dd → α π0
2008 dd → α η
2008 charged η, η' and ω decays
2008 ABC effect in pd
2007 pd/dd experiments
2007 dd commissioning
2007 η → π0π0π0 production run
2007 Tests/run preparation
2006 Commissioning II
2006 Commissioning I

Total 826.0 TB of data

Example: η production with WASA-at-COSY

	$pd \to {}^3\mathrm{He}\eta$	$pp \to pp\eta$
T_{beam}	$1\,\mathrm{GeV}$	$1.4\,\mathrm{GeV}$
$\sigma(\eta)^{a),b)}$	$(0.412 \pm 0.016)\,\mu\mathrm{b}$	$(9.8 \pm 1)\,\mu\mathrm{b}$
Suited for	study of not-so-rare η decays	study of (not-so-) rare η decays
Background	low multi-pion background	high multi-pion background

~10^9 η produced (pp)

Reaction	$T_{beam}[\mathrm{GeV}]$	$\sigma[\mu\mathrm{b}]^{b),c)}$
$pd \to {}^3\mathrm{He}\pi^0\pi^0$	0.893	2.8 ± 0.3
$pd \to {}^3\mathrm{He}\pi^+\pi^-$	0.893	5.1 ± 0.5
$pp \to pp\pi^+\pi^-\pi^0$	1.36	4.6 ± 1.5
$pp \to pp\pi^0\pi^0$	1.36	200 ± 30
$pp \to pp\pi^+\pi^-$	1.36	660 ± 100

a) R. Bilger et al., *Phys. Rev.*, C65(044608), 2002

b) CELSIUS/WASA coll.., *Phys. Lett.*, B649:122-127, 2007

c) M. Bashkanov et al.., *Phys. Lett.*, B637:223-228, 2006

WASA-at-COSY papers, technical papers, Proceedings,…

http://collaborations.fz-juelich.de/ikp/wasa/publications.shtml

WASA-at-COSY PhD theses

1. Investigation of the Charge Symmetry Breaking Reaction dd->4Hepi0 with the WASA-at-COSY Facility, Maria Żurek, University of Cologne, Germany, 2016
2. Hadronic Decays of the ω Meson, Lena Heijkenskjöld, Uppsala University, Sweden, 201626.
3. Determination of the analysing power for the vec{p}p -> ppeta reaction using WASA-at-COSY detector system, Iryna Schätti-Ozerianska, Jagiellonian University, Cracow, Poland, 2015
4. Search for eta-mesic helium via dd->3He n pi0 reaction by means of the WASA-at-COSY facility, Magdalena Skurzok, Jagiellonian University, Cracow, Poland, 2015
5. Investigation of Dipion Final State Interactions in pp→ppη[η→π+π-γ] with the WASA-at-COSY Facility, Daniel Lersch, Bergische Universität Wuppertal, Germany, 2014
6. Development and Applications of Tracking of Pellet Streams, Andrzej Pyszniak, Uppsala University, Sweden, Jagiellonian University in Krakow, Poland, 2014
7. ABC Effect and d* Resonance in Double-Pionic Fusion to 3He, Elena Perez del Rio, Universität Tübingen, Germany, 2014
8. Study of η meson leptonic decays with WASA detector, Marcin Berlowski, Nat. Centre for Nuclear Research, Warsaw, Poland, 2013
9. Analysis of dd →3He p π− reaction at the beam energy 350 MeV, Wojtek Weglorz, University of Silesia, Katowice, Poland, 2012
10. Studies of the Decay η→π+π- π0 with WASA-at-COSY, Patrik Adlarson, PhD Thesis, Uppsala University, Sweden, 2012
11. Test of charge conjugation invariance in eta->pi0 e+e- and eta->pi+pi-pi0 decays, Marcin Zielinski, Jagiellonian Univ., Cracow, Poland, 2012
12. Measurement of the η→e+e-e+e- double Dalitz decay and the search for new physics beyond the Standard Model in η→e+e- with WASA-at-COSY, Patrick Wurm, Universität zu Köln, Germany, 2012
13. The Branching Ratio and CP-Violating Asymmetry of η→π+π-e+e-, Daniel Coderre, Ruhr Universität Bochum, Germany, 2012
14. Study of the eta -> e+e-g decay using WASA-at-COSY detector system, Malgorzata Hodana, Jagiellonian University, Cracow, Poland, 2012
15. Search for eta-mesic 4He with the WASA-at-COSY detector, Wojciech Krzemien, Jagiellonian University, Cracow, Poland, 2011
16. Leading modes of the 3π0 production in proton-proton collisions at incident proton momentum 3.35 GeV/c, Benedykt R. Jany, Jagiellonian Univ, Cracow, Poland, 2011
17. Investigations of the reaction dd→3He n π0 at 350 MeV beam energy with WASA-at-COSY, Pawel Podkopal, Jagiellonian University, Cracow, Poland, 2011
18. Study of a rare decay η→e+e-γ using WASA-at-COSY, Himani Bhatt, IIT Bombay, India, 2011
19. Double Pionic Fusion to 4He - Kinematically Complete Measurements over the Energy Region of the ABC Effect, Annette Pricking, Universität Tübingen, Germany, 2011
20. Study of the decay η→e+e-e+e- with WASA-at-COSY, Leonid Yurev, Universität zu Köln, Germany, 2011
21. Analyse des verbotenen eta-Meson Zerfalls eta-> pi0 e+e− am Experimentaufbau WASA-at-COSY, Alexander Winnmöller, Universität Münster, Germany, 2011
22. Measurement of the branching ratio of a rare decay eta->pi^{0} gamma gamma with WASA-at-COSY, Kavita Lalwani, IIT Bombay, India, 2010
23. Experimental study of ppeta dynamics with WASA-at-COSY, Neha Shah,, IIT Bombay, India, 2010
24. Study of the eta meson decay into pi+pi-e+e- using WASA-at-COSY detector system, Michal Janusz, Jagiellonian University, Cracow, Poland, September 2010
25. Experimental Investigation of Double-Pion Production in Proton-Proton Interactions, Tamer Tolba, Ruhr-Universität Bochum, Germany, July 2010
26. In search of the Box-Anomaly with the WASA facility at COSY, Christoph Redmer, Bergische Universität Wuppertal, Germany, March 2010
27. Measurement of pd-> 3A X reactions with WASA-at-COSY aiming at studies of the light scalar mesons a0/f0(980), Chuan Zheng, Lanzhou, China, 2009
28. Analysis of the eta->3pi0 decay in the pp interaction, Peter Vlasov, Ruhr-Univ. Bochum, Germany, September 2008

WASA-at-COSY Diploma/Master theses

1. Energy Calibration for the Forward Detector at WASA-at-COSY with particular Consideration of the Reaction p + d → ³He + η,,Kay Demmich, Universität Münster, 2013, Germany
2. Design of the new detector setup for the dd→απ0 reaction measurement, Maria Żurek,Jagiellonian University, Cracow, Poland, 2013
3. Untersuchungen zur Optimierung der Dropleterzeugung innerhalb des Pellettargets des Experimentaufbaus WASA-at-COSY, Christina Husmann, Universität Münster, Germany, 2012
4. Feasibility study of measuring CP symmetry violation via η → 4π decay using WASA-at-COSY detector, Tomasz Bednarski, Jagiellonian University, Cracow, Poland, 2011
5. Bestimmung von totalen und differentiellen Wirkungsquerschnitten der Reaktion p + d → 3He + η bei 49 und 60 MeV Überschussenergie am Experimentaufbau WASA-at-COSY, Annika Passfeld, Universität Münster, Germany, 2010
6. Feasibility study of eta-mesic nuclei production by means of the WASA-at-COSY and COSY-TOF facilities, Magdalena Skurzok,, Jagiellonian University, Cracow, Poland, 2010
7. Towards measurement of the ratio BR(eta -> 3pi0) / BR(eta -> pi+pi-pi0), Lena Heijkenskjöld, Uppsala University, Sweden, 2010
8. Measurements of the Response Characteristics of CsI(Na) Crystals, Jona Hampe, RWTH Aachen, Germany 2010
9. Upgrade of the Forward Veto Hodoscopes at WASA, Elena Pérez del Río,, Tübingen Univ., Germany, 2009
10. Studien zum seltenen Zerfall des eta-Mesons eta -> pi0 e+ e- am Experimentaufbau WASA-at-COSY, Florian Sebastian Bergmann,, Münster University, Germany, 2009
11. Simulations of some eta and eta' decay modes, Carl-Oscar Gullstrom, Uppsala University, Sweden, 2008
12. Simulations for the pi0 -> e+e- decay experiment in the pp -> pp pi0 reaction at WASA-at-COSY, Glenn Wouda,, Uppsala University, Sweden, 2008
13. Feasibility study of the eta-prime -> pi+ pi- pi0 decay using WASA-at-COSY apparatus, Marcin Zielinski, Jagiellonian University, Cracow, Poland, 2008
14. Messung zur Ortsabhängigkeit der Energiedeposition geladener Teilchen in Szintillationszählern am Beispiel des WASA-Zentraldetektors, Mathias Mittag, Hochschule Merseburg (FH), Germany, 2007
15. Perfomance of the MDC - Central Part of WASA - before installation at COSY, Leonid Yurev,,Voronezh State University, Russia, 2006
16. Development of Software for the Slow Control of the High Voltage System of the WASA Central Detector Calorimeter, Mourice Akuku Odoyo, Fachhochschule Mannheim, Germany, 2006
17. Untersuchungen der Charakteristika eines Szintillatorhodoskopes des Wide Angle Shower Apparatus (WASA) am COoler SYnchrotron (COSY), Marcus AngelsteinFachhochschule Jena, Germany, 2006
18. Groß- und kleinflächige Szintillatorhodoskope in der Teilchen- und Atomphysik, Christoph F. Redmer, Ruhr-Universität Bochum, Germany, 2006
19. Assembly and measurements of the Electromagnetic Calorimeter components for WASA-at-COSY setup, Benedykt R. Jany, Jagiellonian University Cracow, Germany, 2006

+ Bachelor theses…

Member Institutions (32)

1. Department of Physics and Astronomy, Uppsala University, 75120 Uppsala, Sweden
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Deputy	Pawel Moskal
Physics Coordination	Andrzej Kupsc
Technical Coordination	Hans Calen Frank Goldenbaum
IT Coordination	Volker Hejny
Publication Committee	Markus Büscher Heinz Clement Volker Hejny (chair) Alfons Khoukaz Andrzej Kupsc Andrzej Magiera Pawel Moskal Andreas Wirzba
Speakers Committee	contact spokesperson, physics coordinator, or publication committee chair

Jülich Contact person for WASA-CD at FRS/GSI: Susan Schadmand

Numerous pictures of the WASA dismount (Uppsala) and the Installation (Jülich)

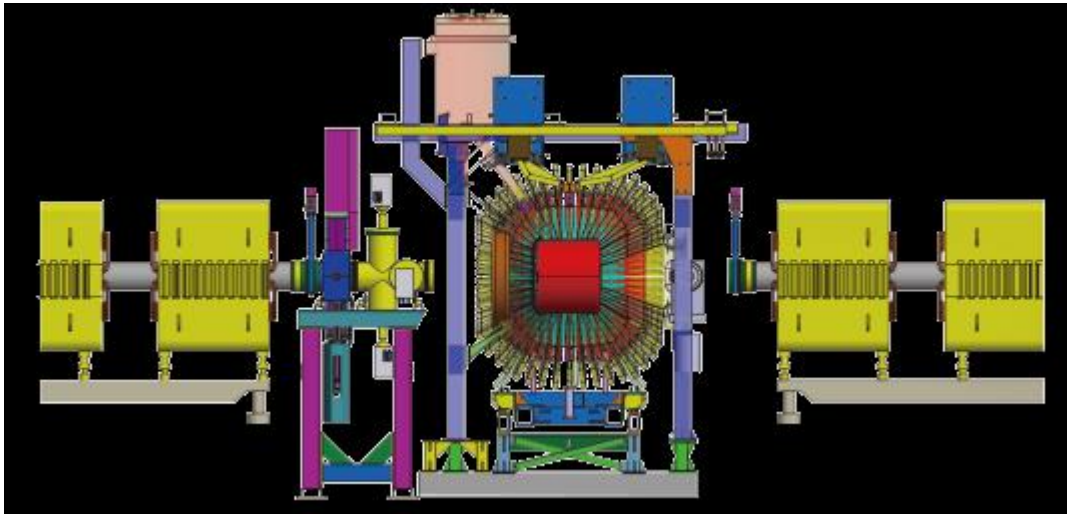
https://seafile.ikp.kfa-juelich.de/f/be5e9cecd1034a349320/?dl=1

8 GB tar file (compiled by Volker H.)…

unexpected: WASA-goes-camping...

photo by V.H.

we are looking forward
WASA at FRS/GSI



Status when WASA came to Jülich (2005)
Expected Count Rates for η‘ dacays

decay mode	branching ratio	world statistics	expected rate events / day
hadronic			
$\eta\pi^+\pi^-$	44.3 ± 1.5 %	≈ 8100	18000
$\eta\pi^0\pi^0$	20.9 ± 1.2 %	≈ 5400	14500
$\pi^+\pi^-\pi^0$	1.56 ± 0.26 $\cdot 10^{-3}$	≈ 70	145
$3\pi^0$	< 5 %		(2700)
$\rho^0\pi^0$	< 4 %		(2100)
$2\pi^+2\pi^-$	< 1 %		(260)
$4\pi^0$	< 5 $\cdot 10^{-4}$		(8)
radiative			
$\rho^0\gamma$	29.5 ± 1.0 %	≈ 8400	44000
$\omega\gamma$	3.03 ± 0.31 %	≈ 160	1200
$\gamma\gamma$	2.12 ± 0.14 %	≈ 2800	17000
$\pi^0\gamma\gamma$	< 8 $\cdot 10^{-4}$		(250)

from LoI #13: M. Wolke

More Rates on η' decays …

decay mode	branching ratio	world statistics	expected rate events / day
(semi-)leptonic			
$\mu^+\mu^-\gamma$	$1.04 \pm 0.26 \cdot 10^{-4}$	≈ 33	15
$e^+e^-\gamma$	$< 9 \cdot 10^{-4}$		(130)
$\mu^+\mu^-e^+e^-$	$< 6 \cdot 10^{-3}$		(150)
e^+e^-	$< 2.1 \cdot 10^{-7}$		(0.04)
CP violating			
$\pi^+\pi^-$	< 2 %		(4800)
$\pi^0\pi^0$	$< 9 \cdot 10^{-4}$		(280)
C violating			
$\pi^0e^+e^-$	$< 1.4 \cdot 10^{-3}$		(80)
ηe^+e^-	$< 2.4 \cdot 10^{-3}$		(100)
$\pi^0\mu^+\mu^-$	$< 6 \cdot 10^{-5}$		(4)
$\eta\mu^+\mu^-$	$< 1.5 \cdot 10^{-5}$		(0.5)
3γ	$< 1 \cdot 10^{-4}$		(50)

from LoI #13: M. Wolke