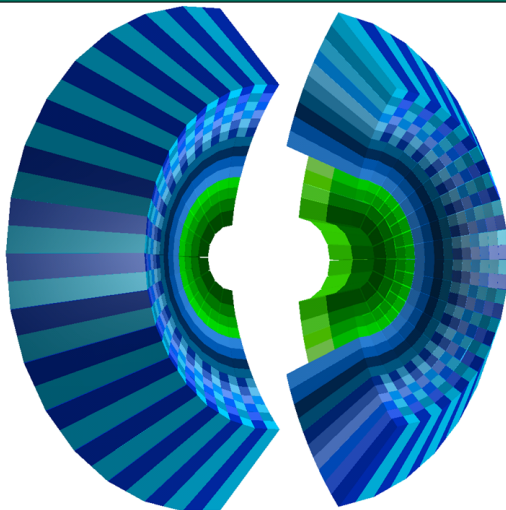


# The CALIFA Endcap

Anna-Lena Hartig for the R<sup>3</sup>B Collaboration



TECHNISCHE  
UNIVERSITÄT  
DARMSTADT





CALIFA

Detectors for the Endcap

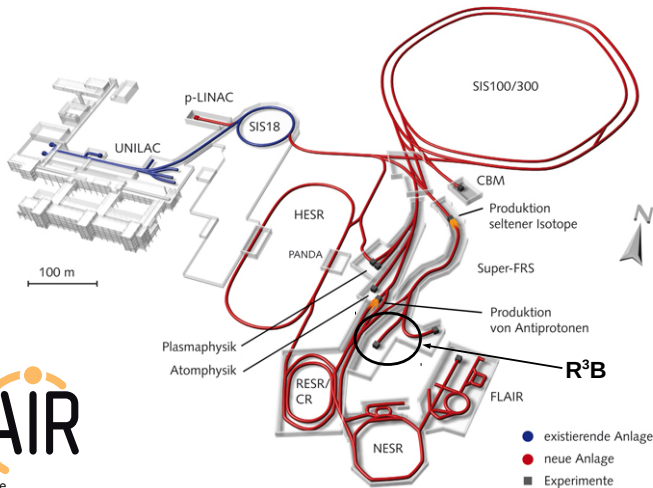
CEPA

IPHOS

Expected Performance

Summary

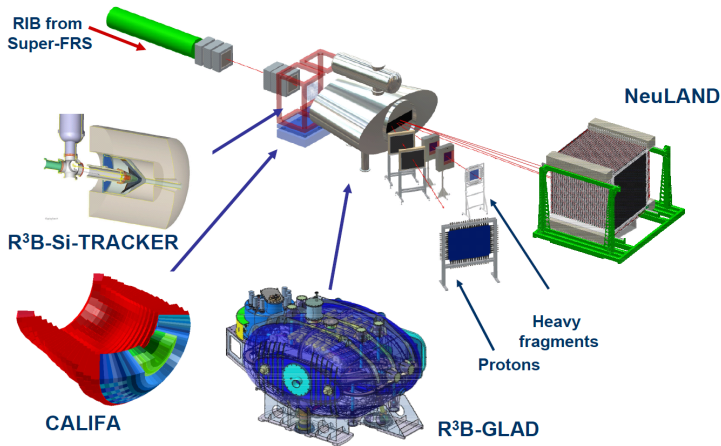
# Facility for Antiproton & Ion Research



FAIR

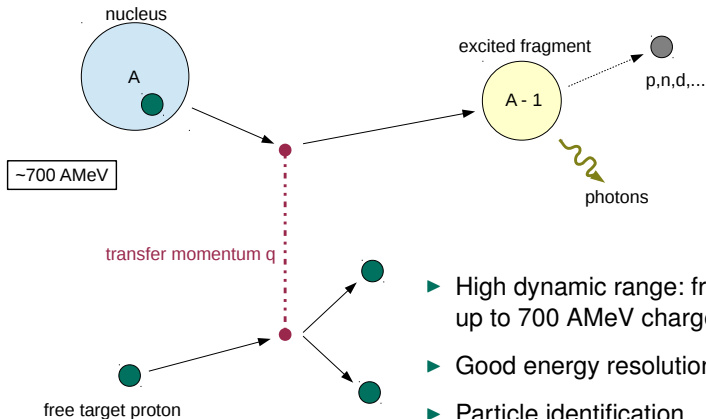
www.gsi.de

# R<sup>3</sup>B - Reactions with Relativistic Radioactive Beams



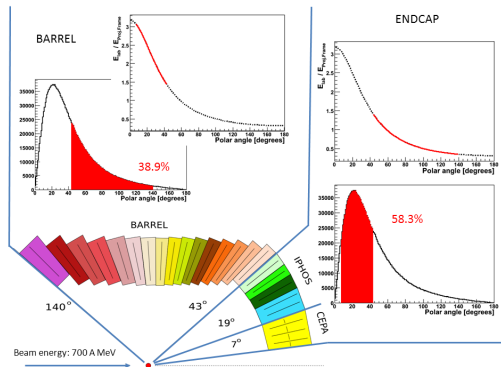
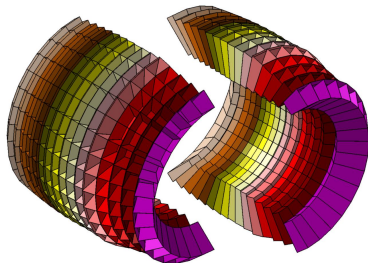


# Quasi-free Scattering of Exotic Nuclei in inverse Kinematics

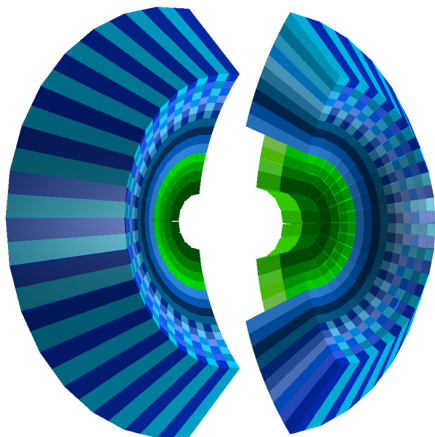


- ▶ High dynamic range: from 100 keV  $\gamma$ -rays up to 700 A MeV charged particles
- ▶ Good energy resolution
- ▶ Particle identification
- ▶ High granularity

# CALorimeter for the In Flight detection of $\gamma$ -rays and light charged pArticles



# Detectors for the Endcap



$\theta$ (°)	$E_p$ (MeV)	Proton range(mm) in CsI(Tl)
7	686	718
15	637	645
20	592	597
30	480	421
40	356	264

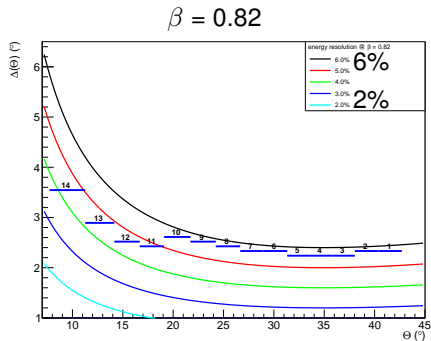
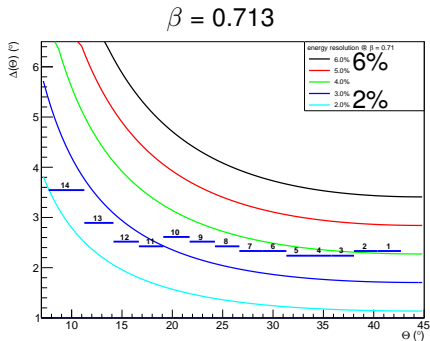
Protons from QFS(p,2p) induced by  
 $E_p=700$  AMeV

**CEPA** Califa Endcap Phoswich Array

**IPHOS** Intrinsic Phoswich Detectors



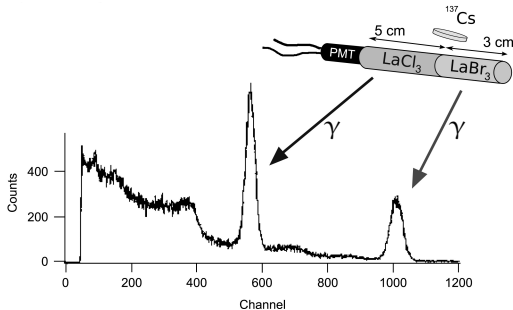
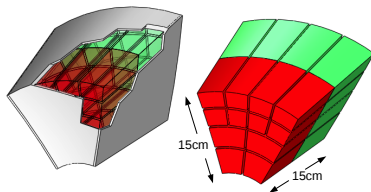
# Segmentation and Doppler Broadening



$\gamma$ s from  $^{18}\text{O}(p,2p)^{17}\text{N}$

# CEPA - The Phoswich Concept

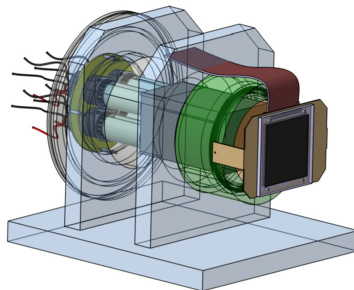
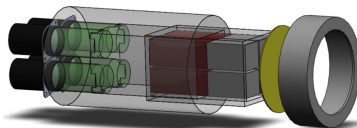
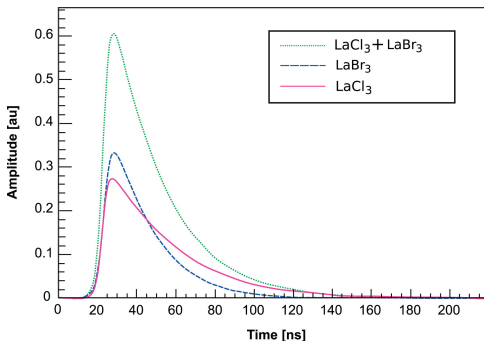
Material	Energy resolution for $\gamma$ (662 keV) in %	Light yield in $\frac{\text{photons}}{\text{keV}\gamma}$	Decay time in ns	$\lambda_{\text{emission}}$ in nm
LaBr <sub>3</sub> (Ce)	3.0 <sup>(1)</sup>	63 <sup>(2)</sup>	16 <sup>(2)</sup>	380 <sup>(2)</sup>
LaCl <sub>3</sub> (Ce)	3.1 <sup>(1)</sup>	49 <sup>(2)</sup>	28 <sup>(2)</sup>	350 <sup>(2)</sup>



<sup>(1)</sup> C.W.E. van Eijk, Radiation Measurements 33 (2001) 521–525

<sup>(2)</sup> Saint Gobain

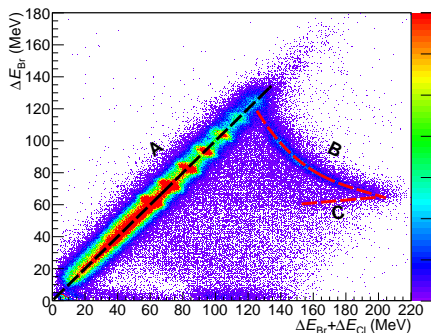
# CEPA - Performance of the Prototype CEPA4



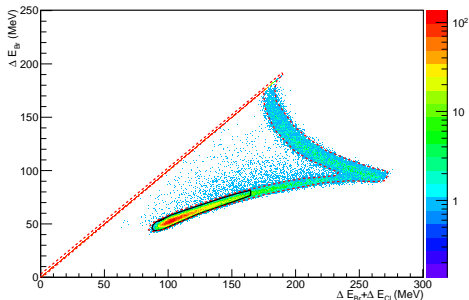
O. Tengblad et al., Nuclear Instruments and Methods in Physics Research Section A 704(0):19-26,2013

E. Nächer et al., Nuclear Instruments and Methods in Physics Research Section A 769(1):105-11,2014

# CEPA - Performance of the Prototype CEPA4

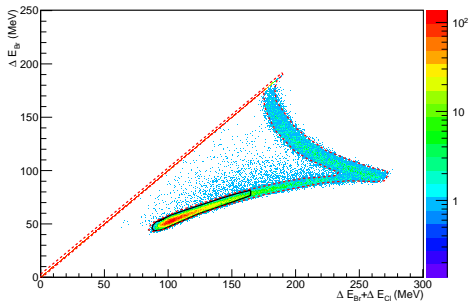
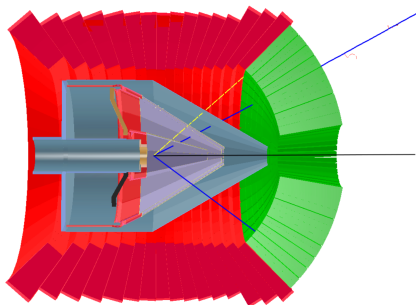


In-beam test with protons of  
70 MeV - 230 MeV



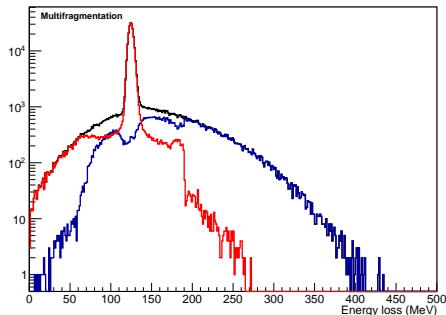
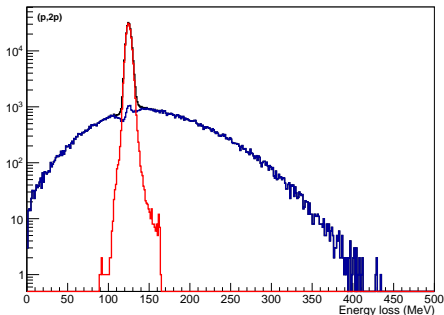
Simulation of protons of  
0 MeV - 1000 MeV

# CEPA - Suppression of Nuclear Reactions



Multifragmentation  
(p,2p)

# CEPA - Suppression of Nuclear Reactions



**Protons of 500 MeV**

(p, 2p)

multifragmentation

**Purity**

99.7 %

88.0 %

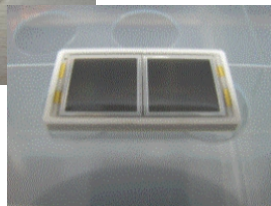
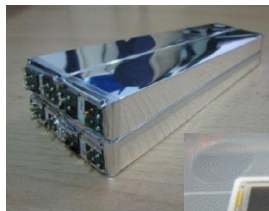
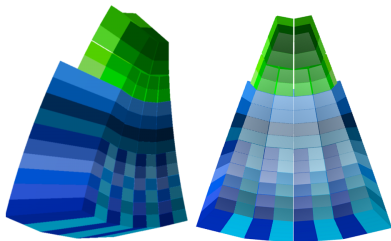
**Efficiency**

65.0 %

77.7 %

# IPHOS - Intrinsic Phoswich Array

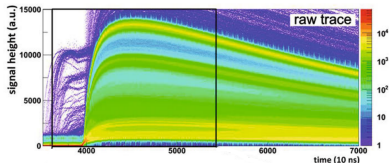
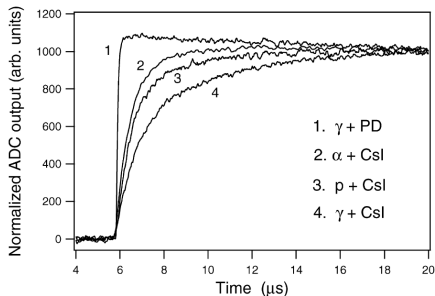
Material	Energy resolution for $\gamma$ (662 keV) in %	Light yield in $\frac{\text{photons}}{\text{keV}\gamma}$	Decay time in ns	$\lambda_{\text{emission}}$ in nm
CsI(Tl)	6 <sup>(2)</sup>	54 <sup>(1)</sup>	600/3500 <sup>(2)</sup>	550 <sup>(1)</sup>



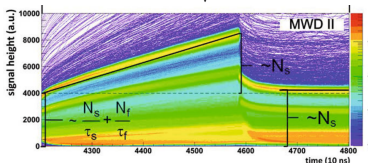
<sup>(1)</sup> Saint Gobain

<sup>(2)</sup> M. Bendel et al., Journal of Physics: Conf. Ser. **587** (2015) 012049

# IPHOS - Intrinsic Phoswich Array

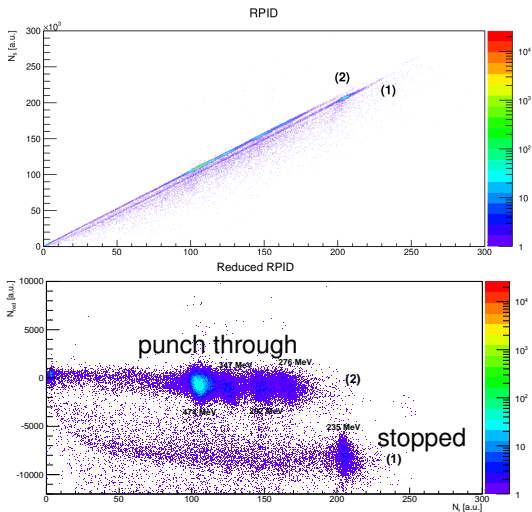
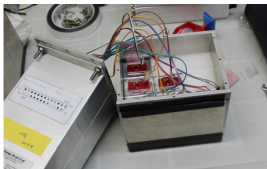
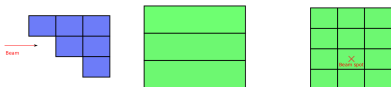


Reconstructive particle identification  
(RPID)

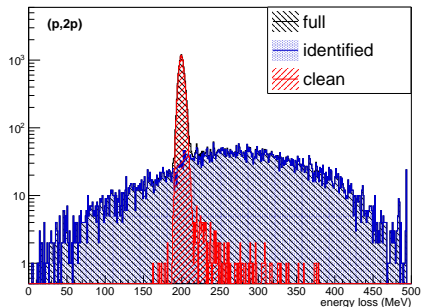
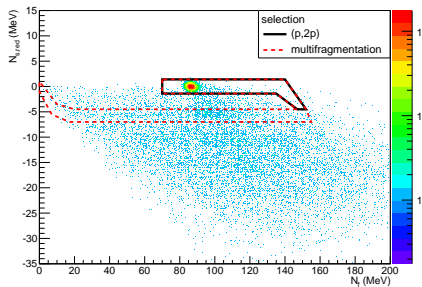




# IPHOS - Prototype Test at TRIUMPF



# IPHOS - Suppression of Nuclear Reactions



**Protons of 500 MeV**

(p, 2p)

multifragmentation

**Purity**

98.7 %

90.5 %

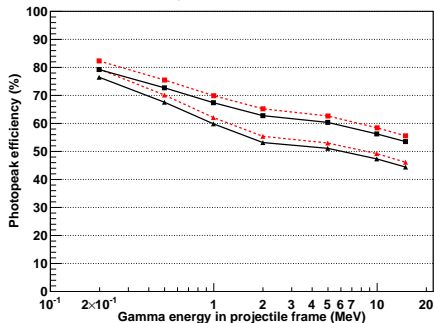
**Efficiency**

52.1 %

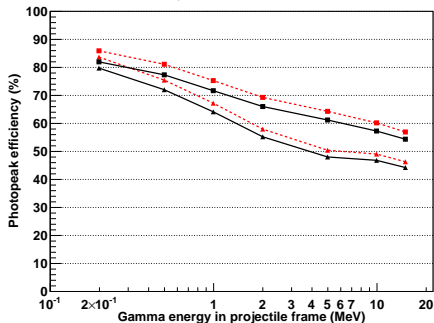
58.1 %

# Photopeak Efficiency of CALIFA

$\beta = 0.82$



$\beta = 0.713$



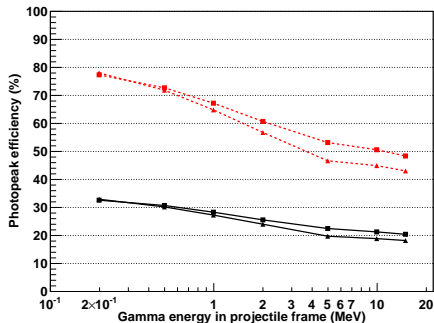
□ Calorimetric mode

△ Single  $\gamma$  mode

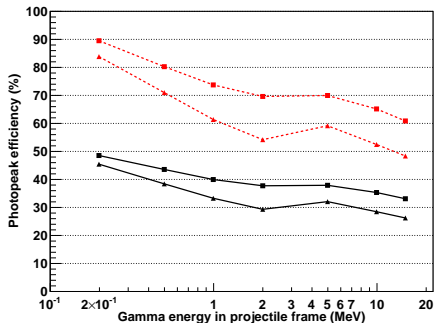
# Photopeak Efficiency of Barrel and Endcap for

$$\beta = 0.82$$

## Barrel



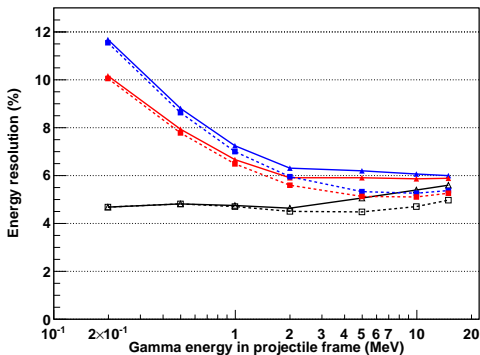
## Endcap



□ Calorimetric mode

△ Single  $\gamma$  mode

# Energy Resolution of CALIFA at $\beta = 0.82$



Perfect detector

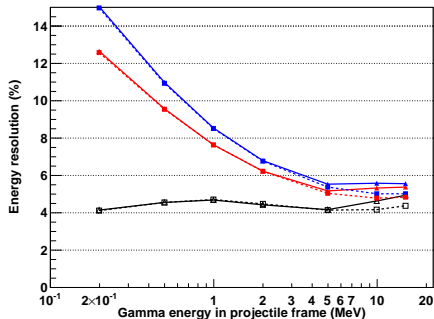
5% for CsI(Tl) @ 1 MeV

6% for CsI(Tl) @ 1 MeV

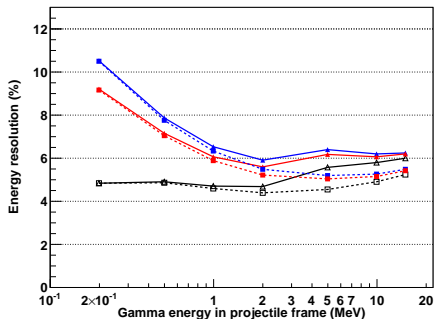
# Energy Resolution of Barrel and Endcap for

$$\beta = 0.82$$

## Barrel



## Endcap

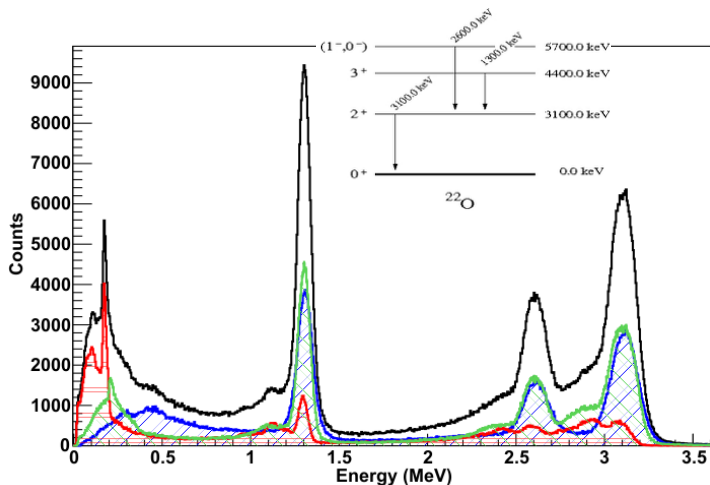


Perfect detector

5% for CsI(Tl) @ 1 MeV

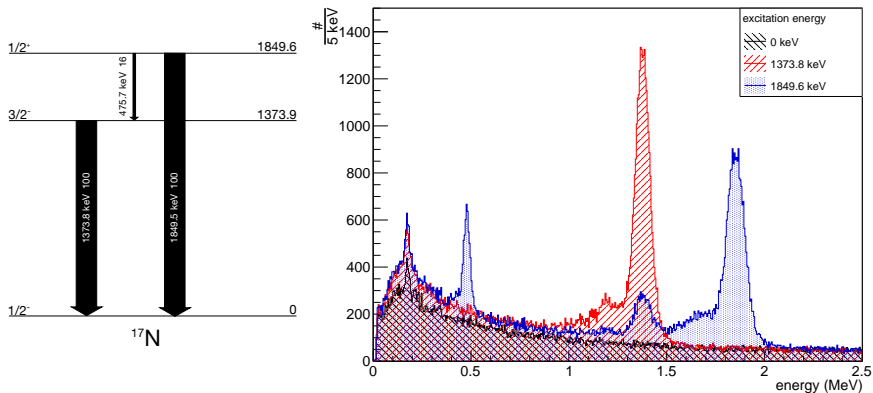
6% for CsI(Tl) @ 1 MeV

# $\gamma$ -Spectrum from one-neutron Knockout in $^{23}\text{O}$



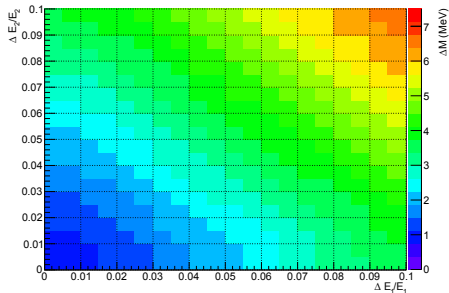
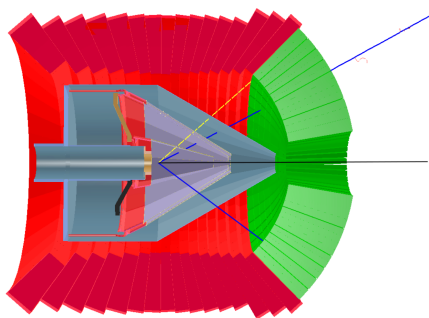
IPHOS  
CEPA  
Barrel

# Quasi-free Scattering $^{18}\text{O}(p,2p)^{17}\text{N}$





# Quasi-free Scattering $^{18}\text{O}(p,2p)^{17}\text{N}$





- ▶ CALIFA Endcap TDR handed in (November 2014)
  - ▶ Very good efficiency up to 15 MeV  $\gamma$ s
  - ▶ Energy resolution of 6 % above 1 MeV
  
- ▶ Combination of IPHOS and CEPA
  - ▶ Successful in-beam tests of CEPA demonstrator
  - ▶ IPHOS method for high energy particles proven
  
- ▶ Start of construction in 2015



# Thank you for your attention!

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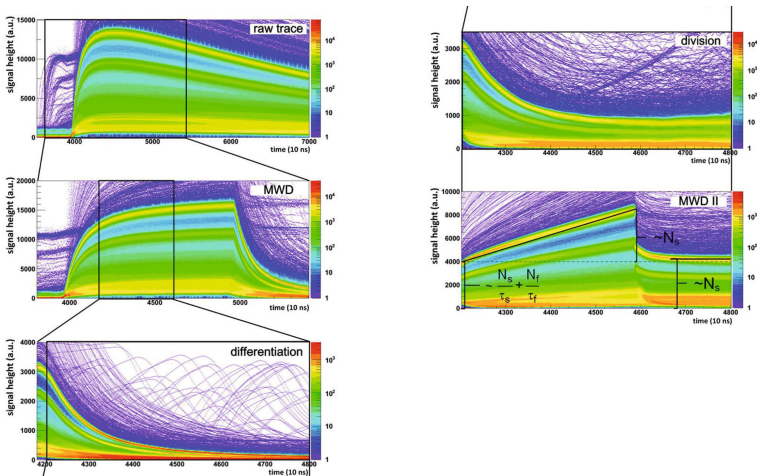
Helmholtz International Center

**R<sup>3</sup>B**

and the R<sup>3</sup>B Collaboration



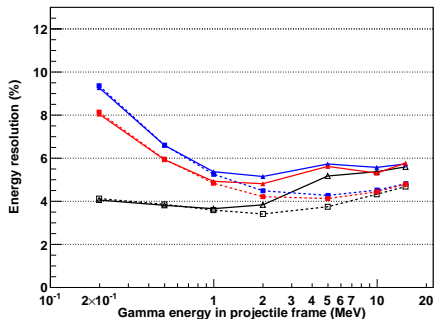
# IPHOS - Reconstructive Particle Identification (RPID)



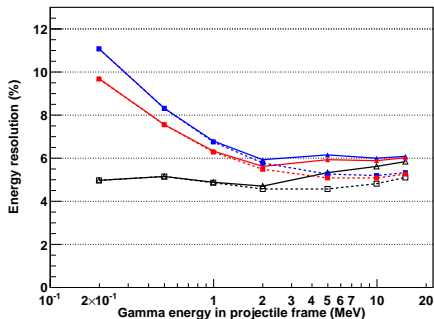
# Energy Resolution of CEPA and IPHOS for

$$\beta = 0.82$$

## CEPA



## IPHOS



Perfect detector

5% for CsI(Tl) @ 1 MeV

6% for CsI(Tl) @ 1 MeV