The Low Energy Photon Tagger NEPTUN:

Toward a Detailed Study of the Pygmy Dipole Resonance with Real Photons

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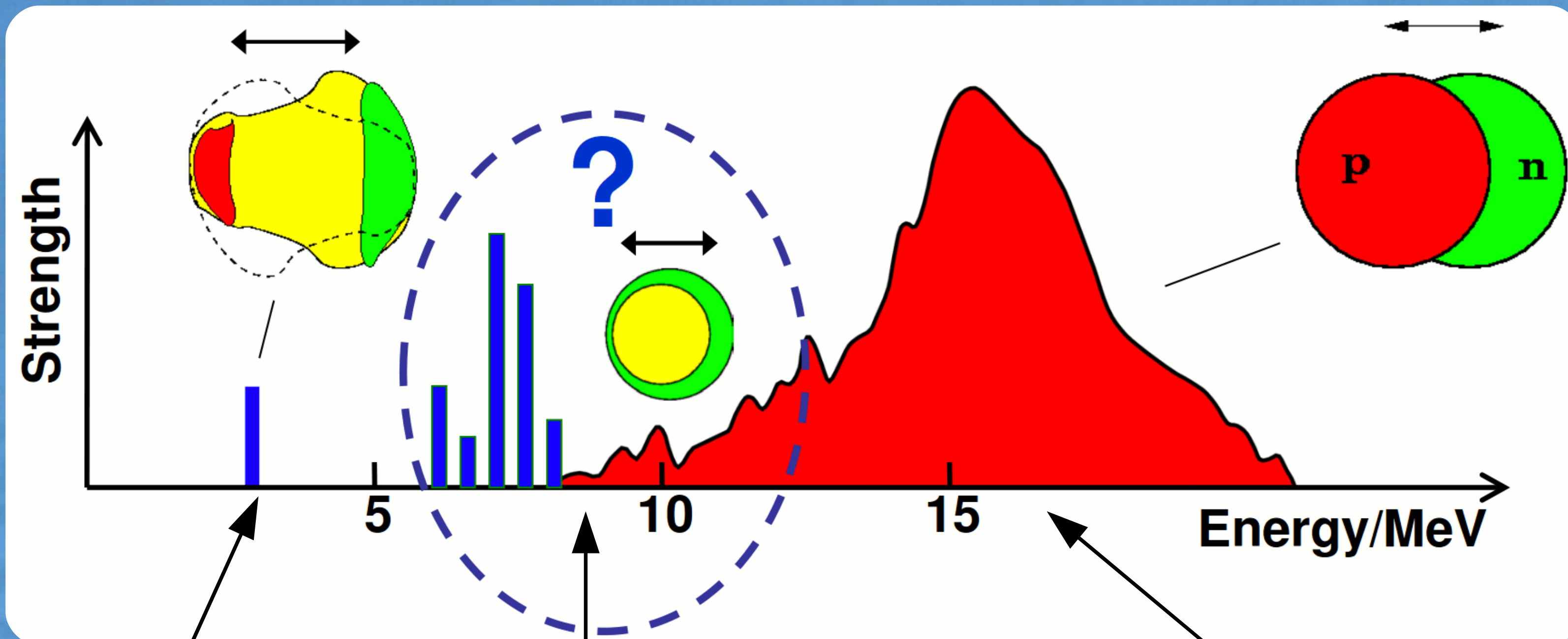
Outline

- The Pygmy Dipole Resonance (Motivation)
- Overview About The Full Project
  - γ^3 @ HIγs
  - CoulEx (R^3B @ GSI)
  - (α,α') @ RIKEN
- NEPTUN @ S-DALINAC
  - The Principle of Photon Tagging
  - NEPTUN Setup
  - Results from the Last Beam Time

The Pygmy Dipole Resonance



Two phonon excitation

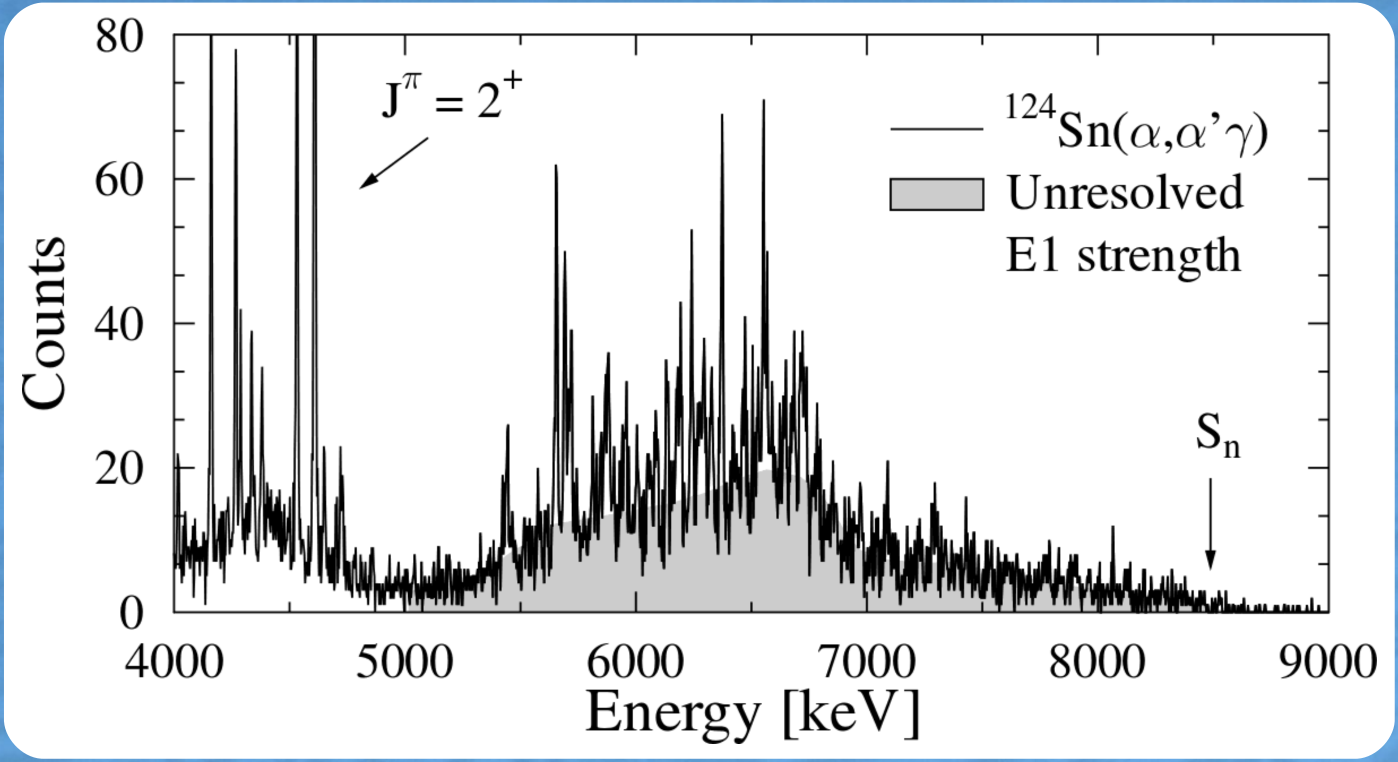
Giant dipole resonance

Pygmy Resonance?

Graphic from Andreas Zilges: E1 excitations in atomic nuclei

- Nature of the pygmy dipole resonance still unknown
- Addresses the understanding of the strong force
- Important also for astrophysical questions
  - e.g. supernova models, isotope abundances

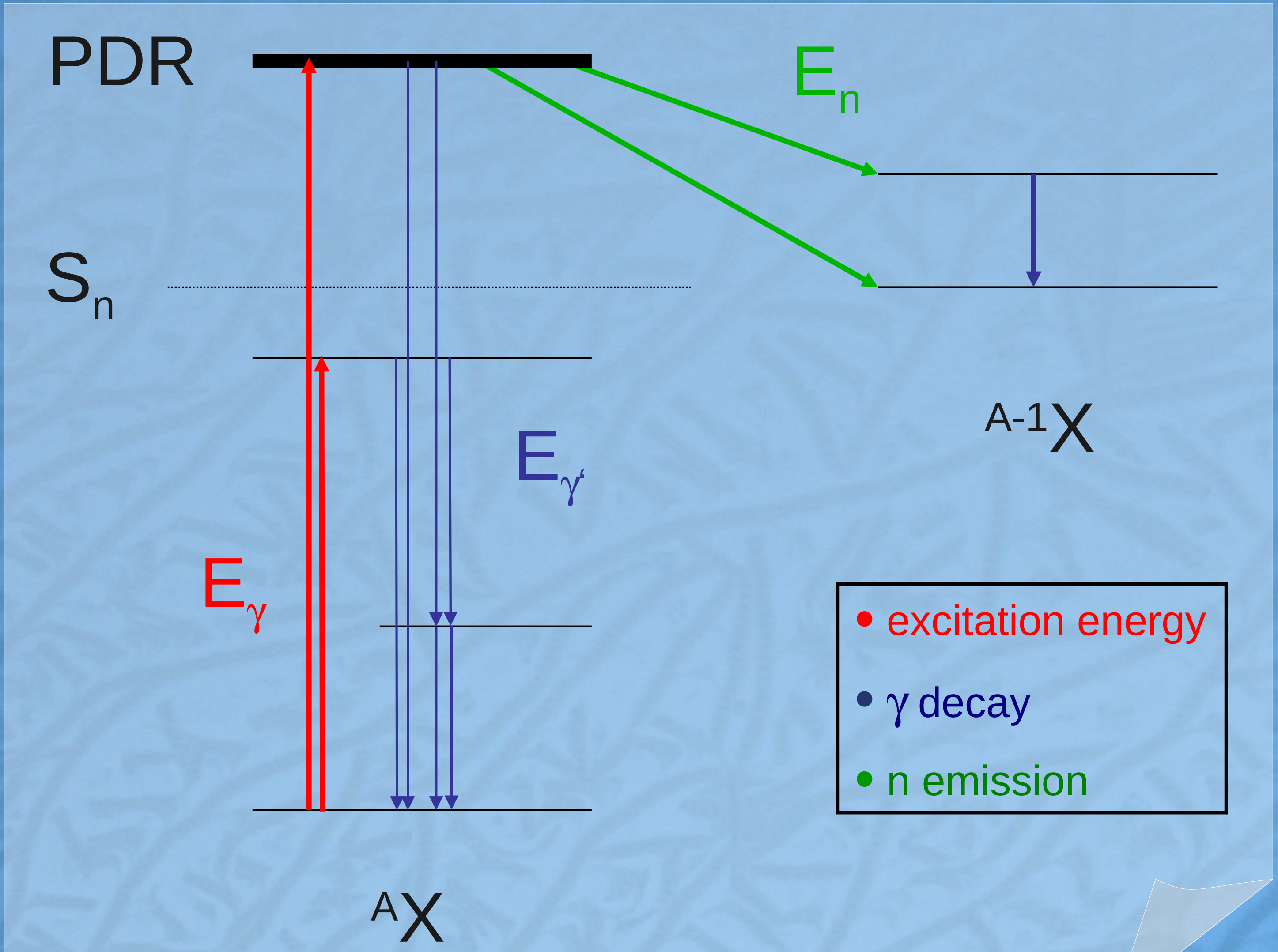
The Pygmy Dipole Resonance



Graphic from J. Endres et al.: PRL 105, 212503 (2010)
Isotope: 124Sn

- The pygmy dipole resonance is hard to measure
- Lot of weak states
  - ➔ Not to distinguish from background
- Measurements below and above neutron threshold required

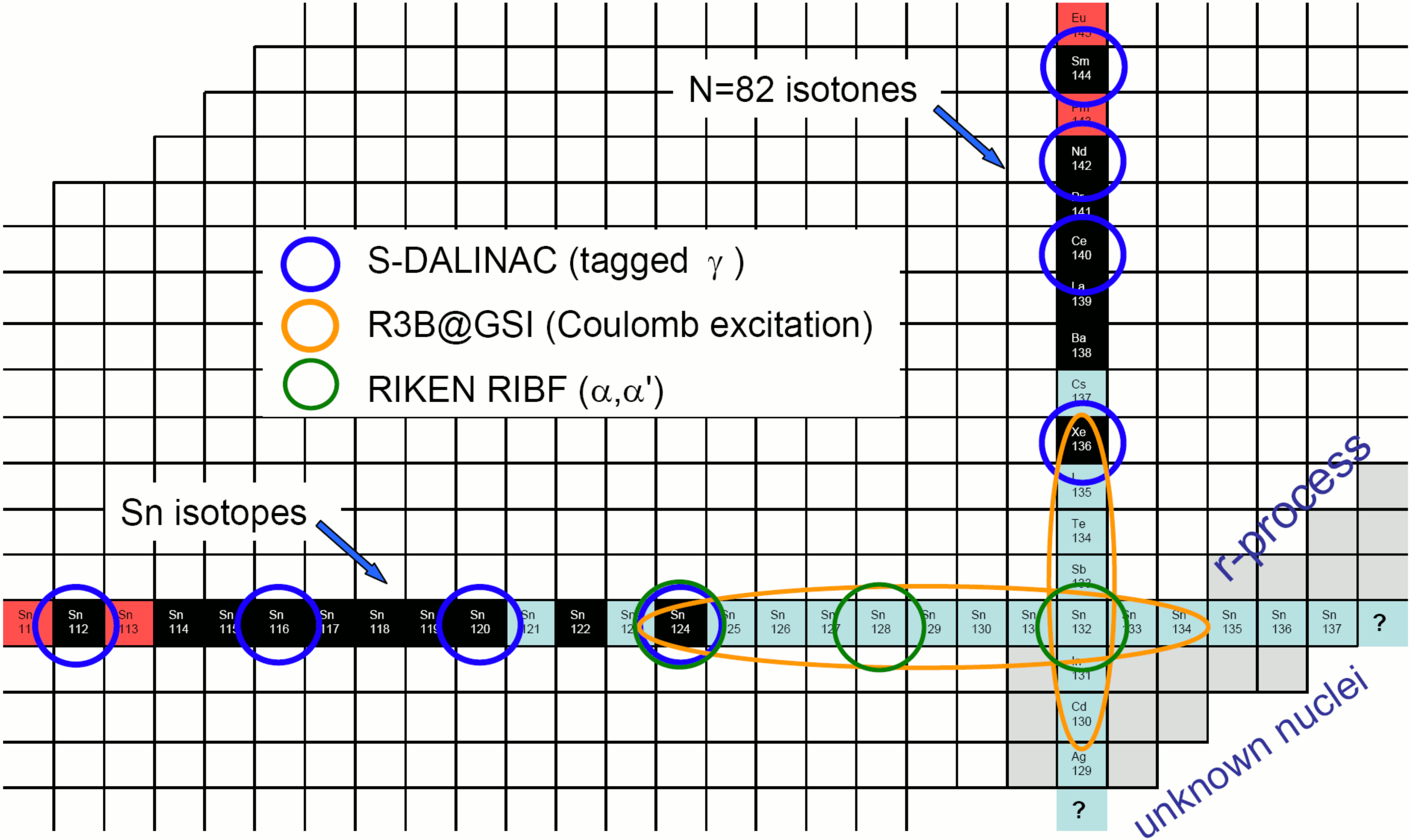
Experiments below and above S_n



Graphic from Linda Schnorrenberger

- NEPTUN is able to measure below and above neutron separation energy S_n
- Unique ability
- Measure the complete pygmy dipole resonance

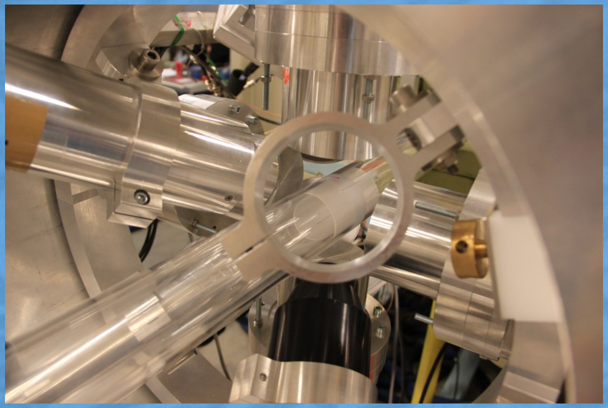
Overview About The Full Project

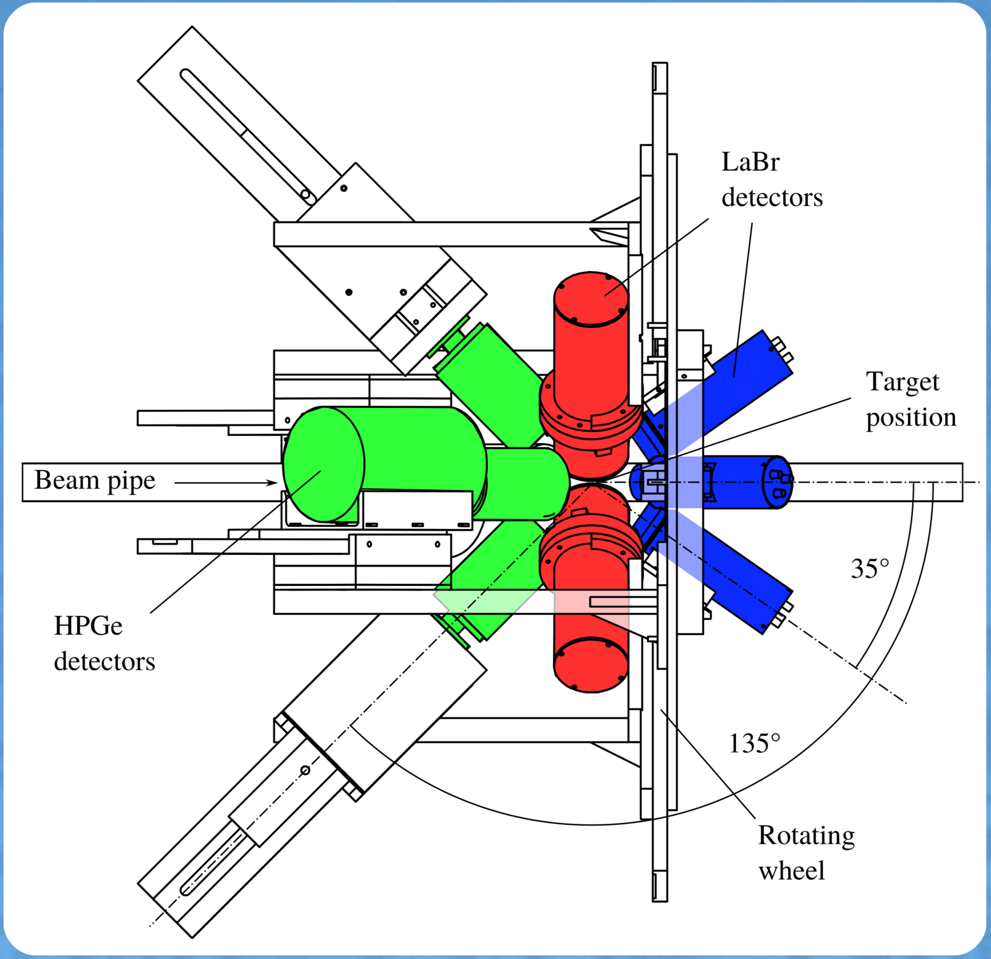


γ³ @ HIγS

	HPGe	135°	0°, 90°
	LaBr Large	90°	45°
	LaBr Small	35°	0°, 90°

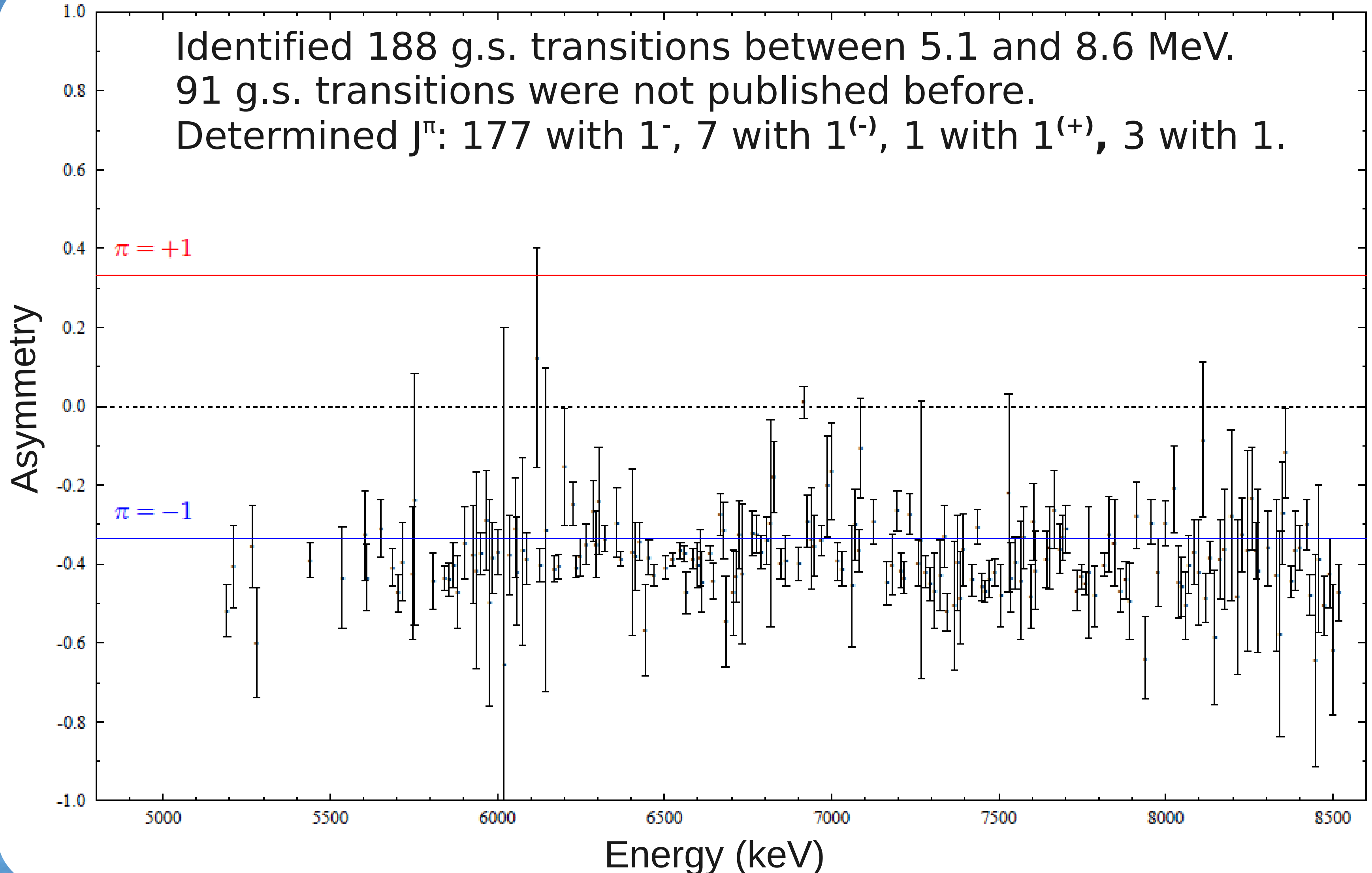
- Determination of
  - ➔ Parities with HPGe
  - ➔ Branching ratios with all detectors in coincidence
  - ➔ Reduced transition probabilities with HPGe
- Shieldings and filters (Pb, Cu)





Graphics from B. Löher at al.:
Nucl. Instr. Meth. Phys. Res. A 723 (2013) 136

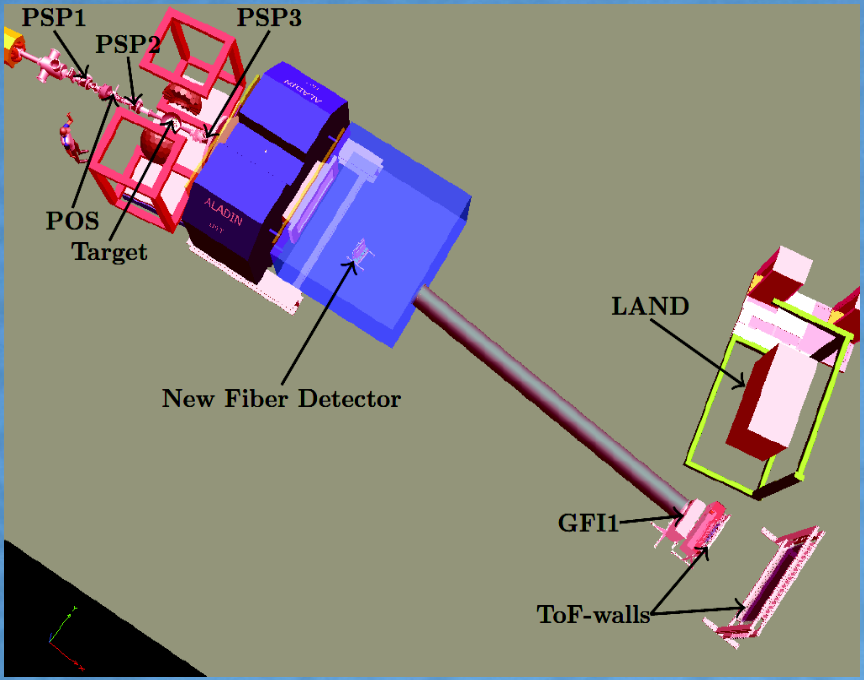
γ³ @ HIγs



Master thesis of Marc Duchêne

CoulEx (R³B @ GSI)

Isotopes: ^{124}Sn, ^{126}Sn, ^{128}Sn, ^{130}Sn, ^{132}Sn

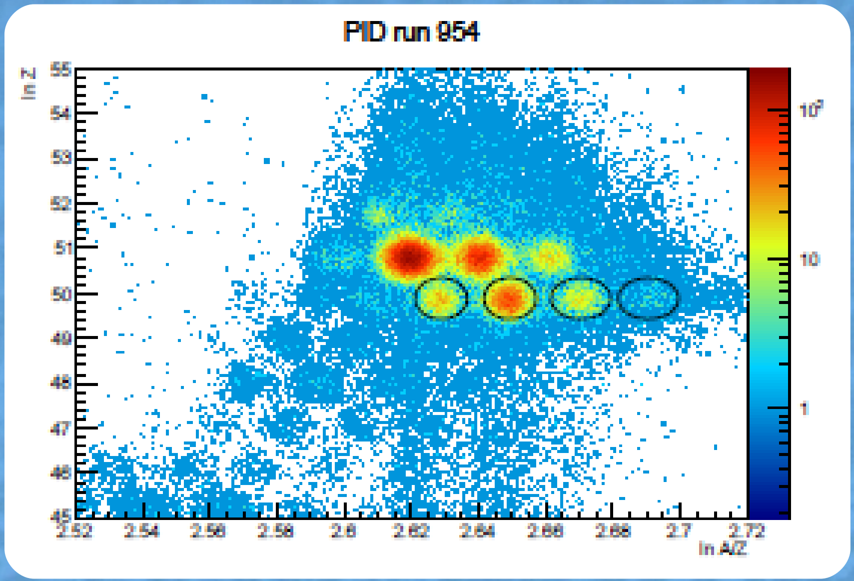


Detection:

n: LAND
(Fe converter + organic scintillator)

Charged fragments:
TFW (scintillation detector)

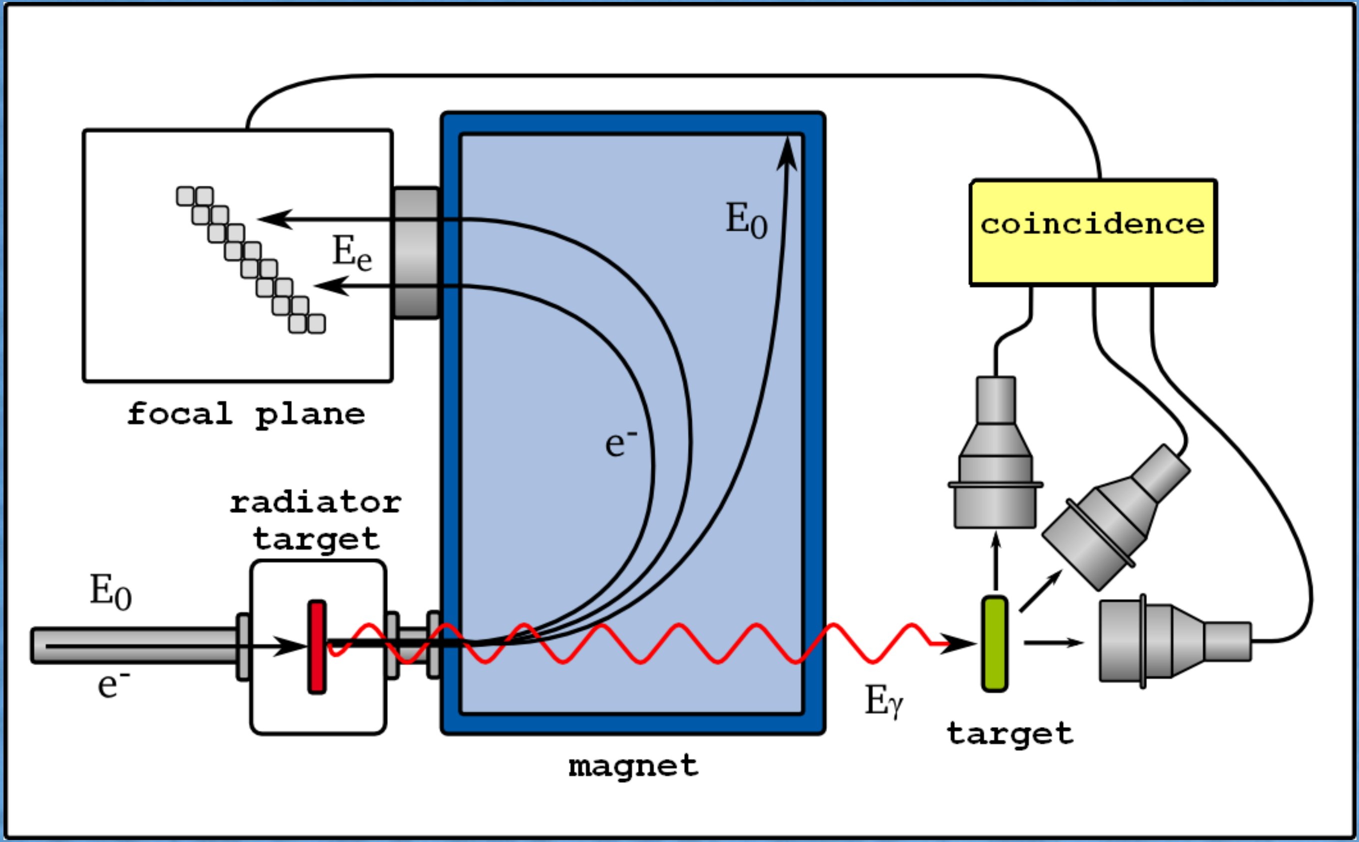
γ: Crystal Ball (CsI-detectors array)



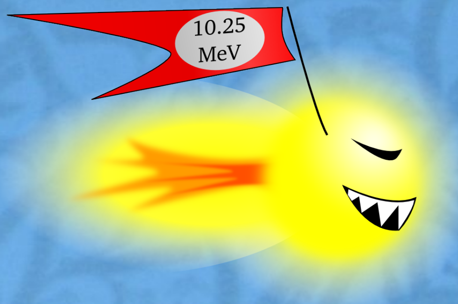
PhD thesis of Philipp Schrock (data under analysis)

Photon Tagging

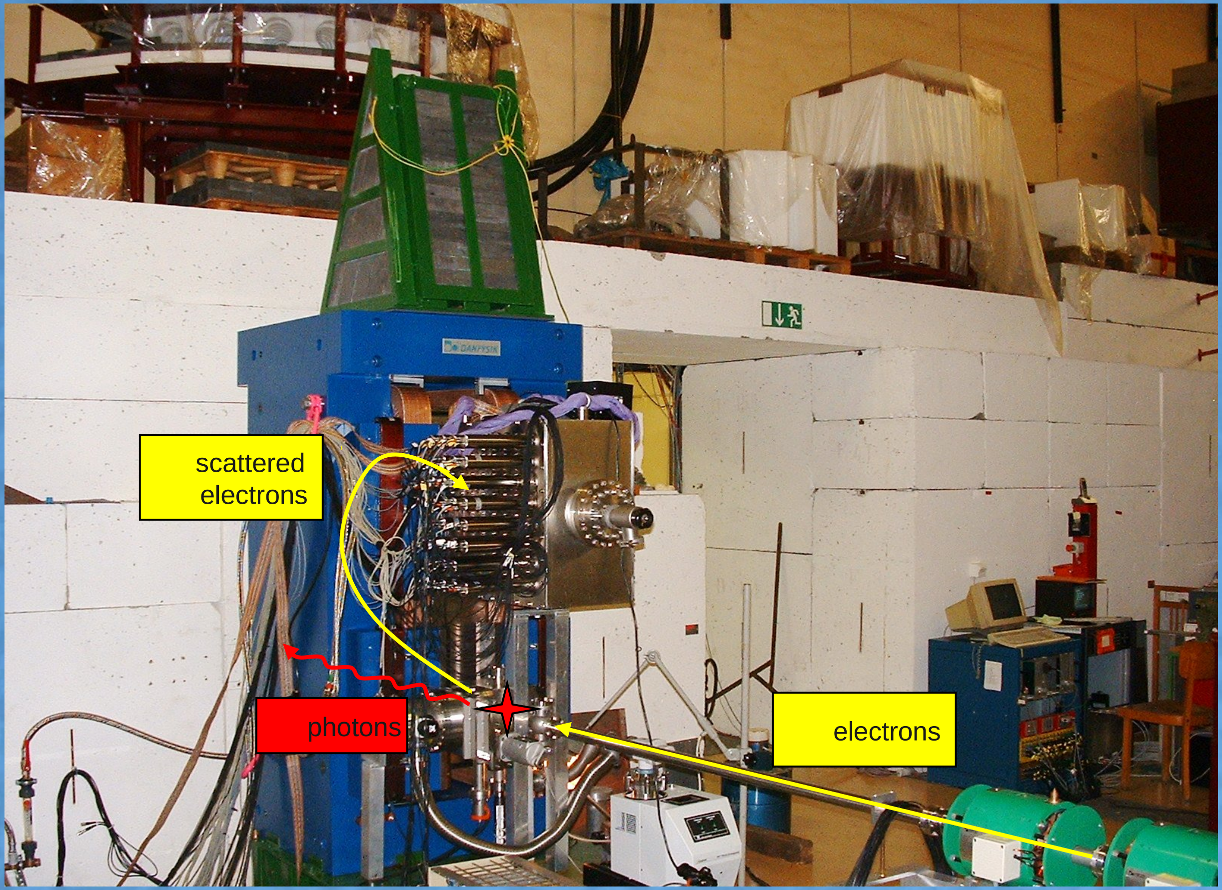
- Photons are produced by electrons emitting bremsstrahlung
- Idea: determine energy of electron to deduce photon energy



- Conservation of energy:
- $E_\gamma = E_0 - E_e$
- tagging via time relation



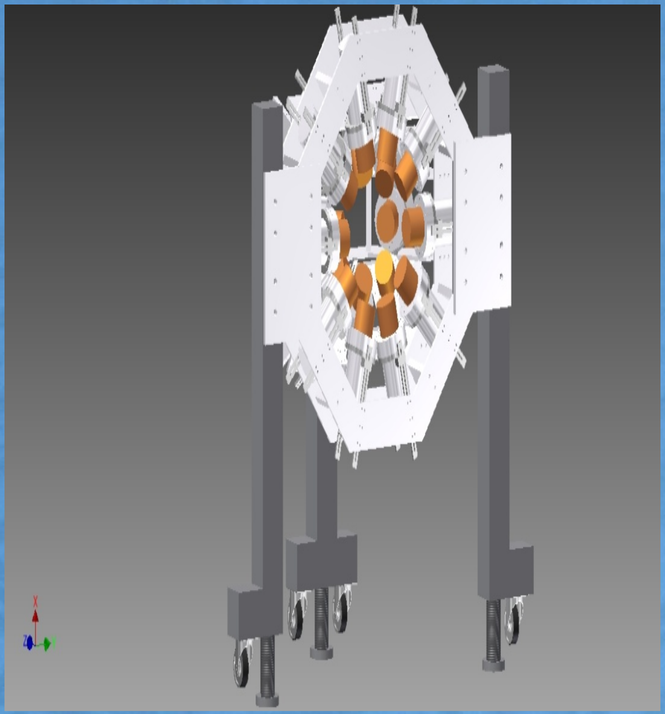
NEPTUN Setup



Picture from Linda Schnorrenberger

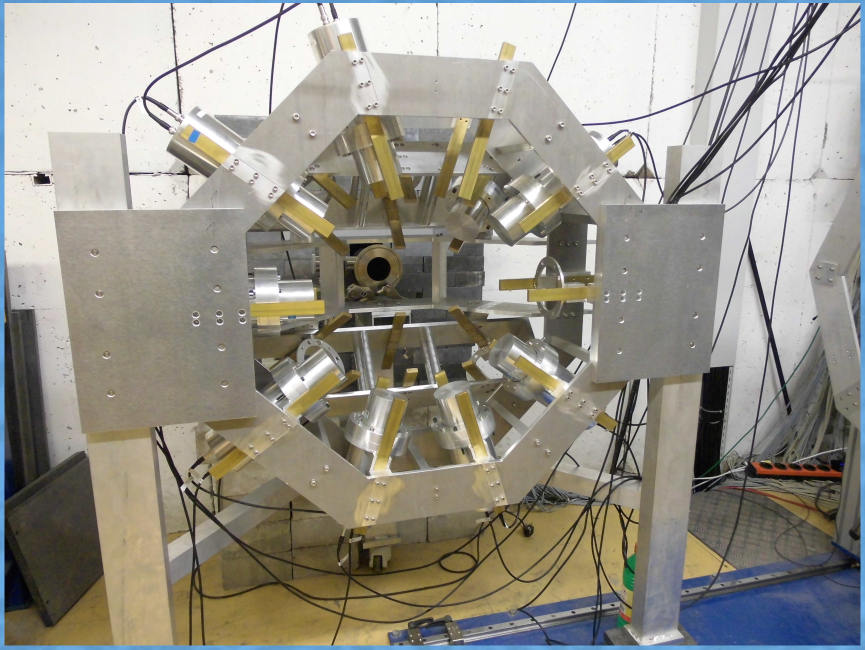
- Measure the momentum of the electrons with scintillating fibers
  - Resolution: 1 mm $\hat{\approx}$ 25 keV
- Electron target: Gold foil
  - 4,8 µm to 20 µm
- γ target:
  - ^{112}Sn, ^{116}Sn, ^{120}Sn, ^{124}Sn planed
  - S used as test for commissioning

NEPTUN Setup

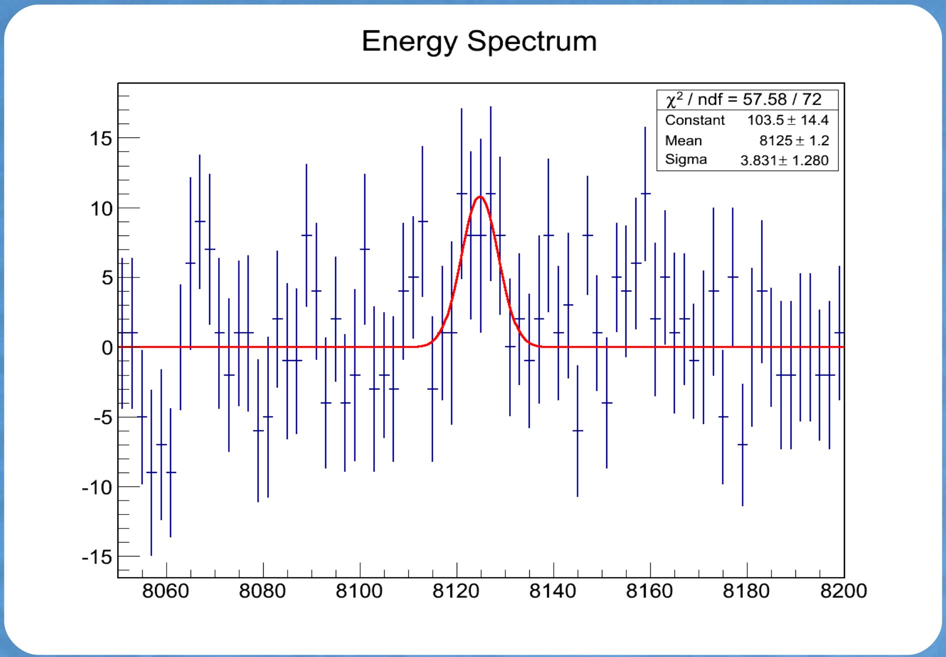


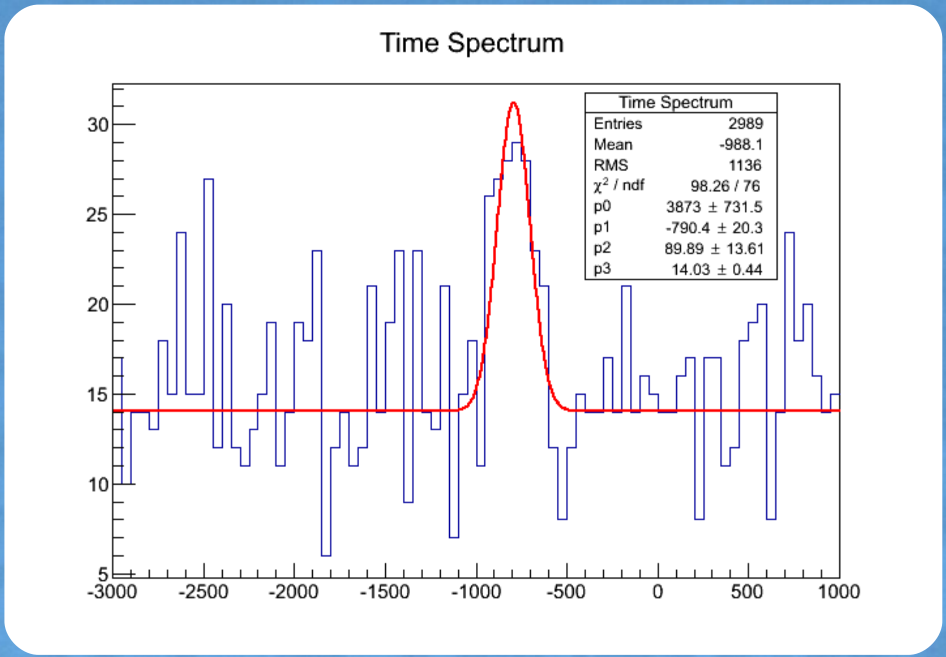
Graphic from Christopher Walz

- Detect scattered gammas with the GALATEA LaBr array
  - For calibrating we also use a HPGe detector
- Detect neutrons with organic scintillators
  - Not implemented, yet
  - Test planned for next beam time



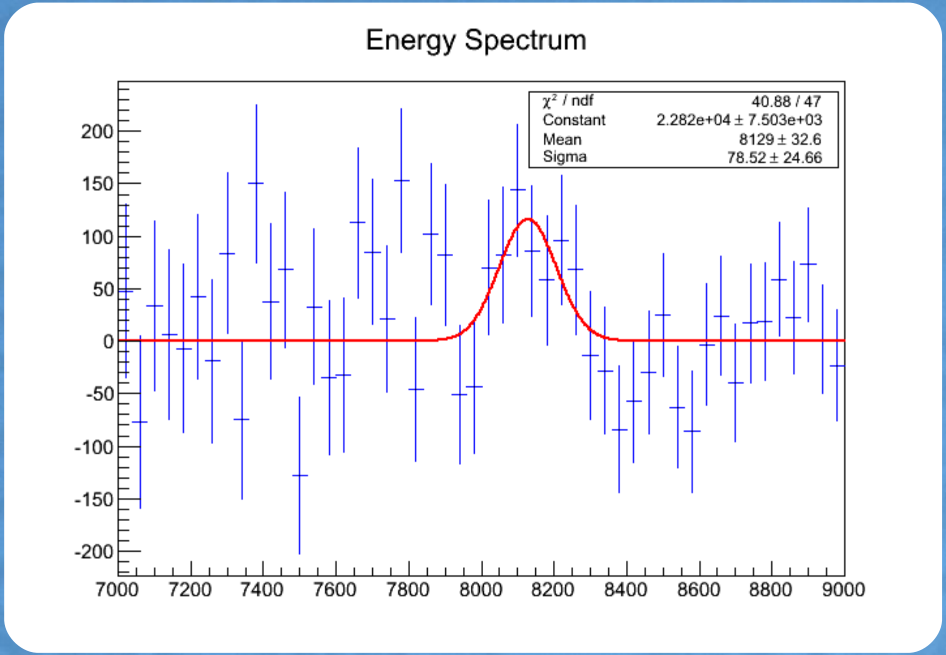
Sulfur Peak in HPGe

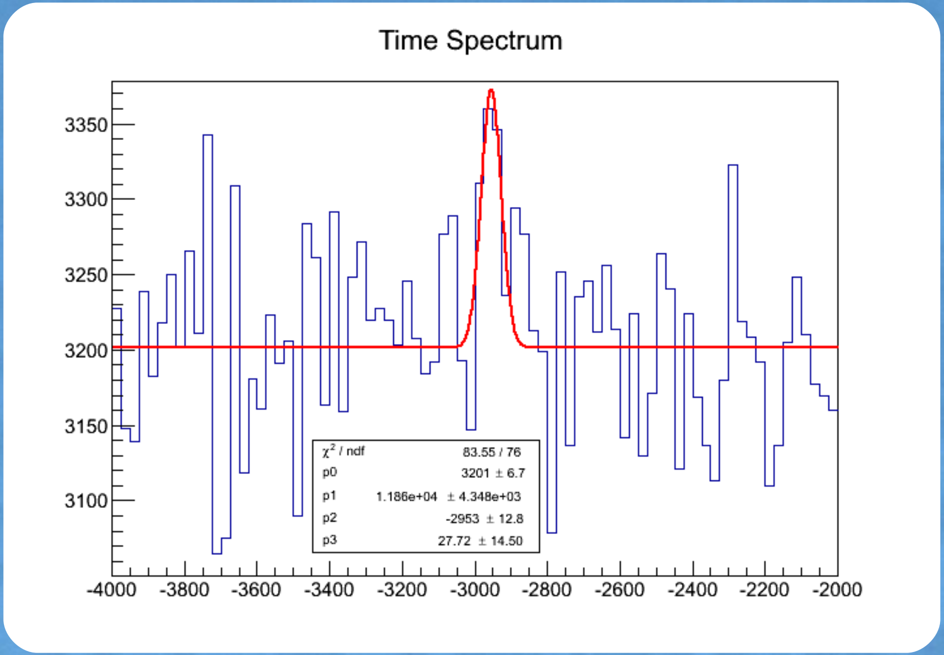




- Energy resolution: 1.2 keV
- Time resolution: 9 ns
- Number of events:
  - 52 ± 7 events in energy peak
  - 66 ± 14 events in a 3σ environment of time
- Significance: 3.2σ (Statistical hint)

Sulfur Peak in LaBr





- Worse energy resolution: 79 keV
- Better time resolution: 2.8 ns
- More events but also higher background:
  - 643 ± 209 events in a 3σ environment of energy
  - 571 ± 19 events in a 3σ environment of time
- Same significance: > 3σ (We had problems with the calibration)

Conclusion

- Using tin isotopes we will provide the pygmy strength over a large A/Z range from 2.24 to 2.64
- Data combined from 4 facilities
- ^{124}Sn used as benchmark in all experiments
- Will hopefully lead to a better understanding of the pygmy dipole resonance

Experiment	Facility	Status	Isotopes
γ^3	HIγS	In analysis	^{124}Sn only
CoulEx	R^3B @ GSI	In commissioning	Radioac. Beams
(α,α')	RIKEN	To be done in October	Radioactive Beams
NEPTUN	S-DALINAC	Commissioning in October	Stable Isotopes only

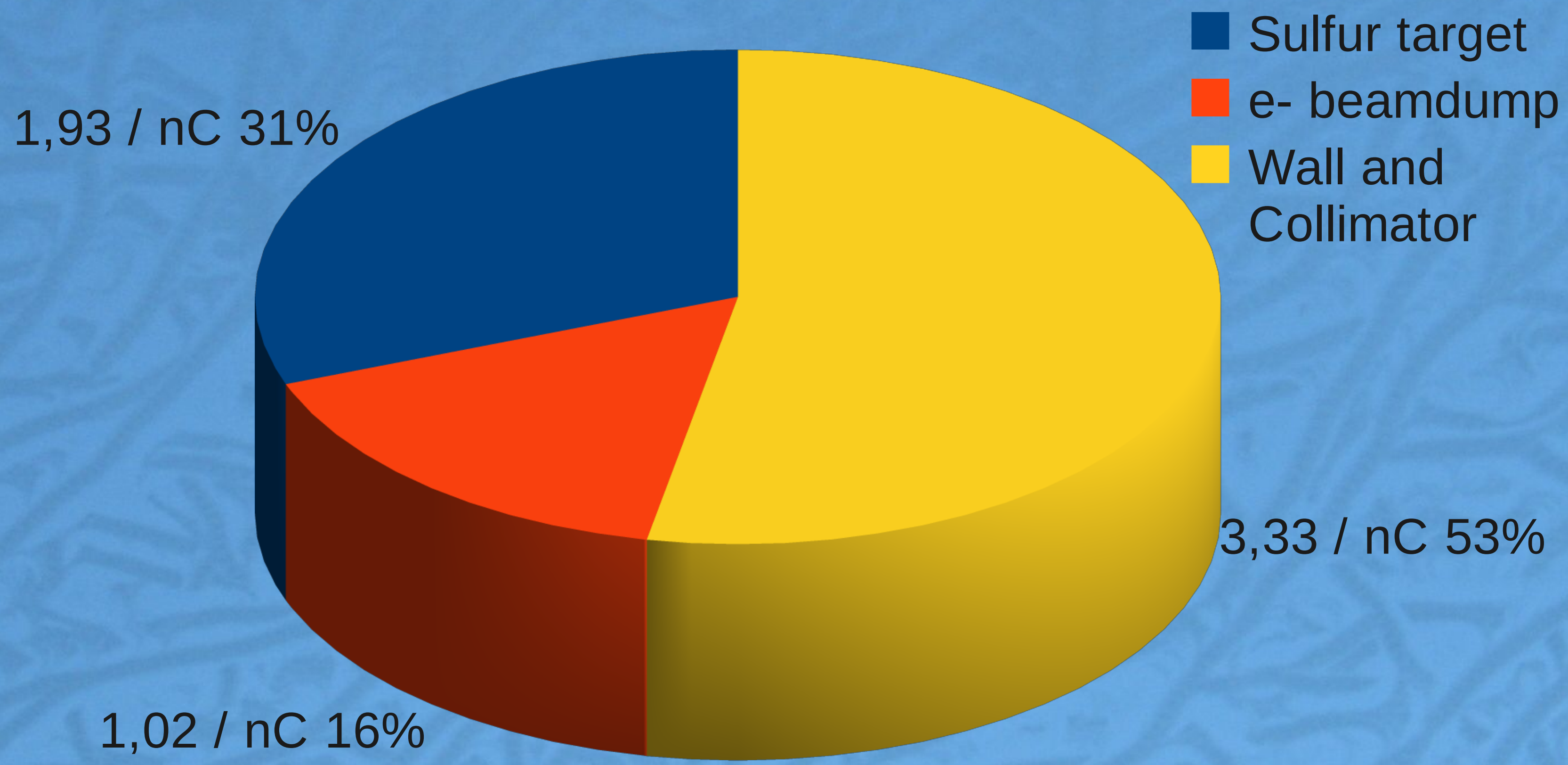
Thanks to my collaborators: Thomas Aumann, Christopher Bauer, Martin Baumann,Michael Beckstein, Jacob Beller, Alexander Blecher, Nebojsa Cvejin, Marc Duchene, Florian Hug, Julian Kahlbow, Michael Knörzer, Kathrin Kreis, Christoph Kremer, Ronan Lefol, Bastian Löher, Philipp Ries, Christopher Romig, Heiko Scheit, Linda Schnorrenberger, Dmytro Symochko, Christopher Walz

Extra Slides

- Start
- The Pygmy Dipole Resonance
- Experiments below and above Sn
- Overview about the full project
- Photon Tagging
- NEPTUN Setup
- Sulfur Peak in HPGe
- Sulfur Peak in LaBr
- Conclusion

- Background Sources
- Problems
- Outlook to Beam Time in 2014
- NEPTUN - Facility
- Background Sources

Background Sources



Problems

- Fiber rates are partially higher than expected
  - Probably due scattering of electrons in the magnet
- Still much background
  - May be less with new tungsten collimator
  - Gamma-beam-dump wanted
  - Neutron shield for e^- beam-dump
- Lot of things to do until next beam time

Outlook to Beam Time in 2014

- Switch to Digital DAQ
- Readout Fibers Individually
- Carbon Fiber Beam Pipe
- Gamma Beam Dump
- Improve shielding
- More Probes
- Gamma Monitor
- Automatic Picture Taking
- And many small changes

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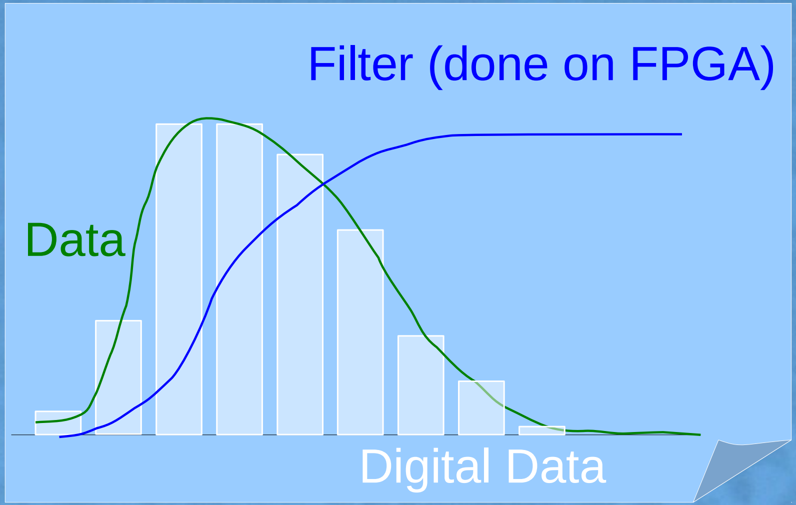

- Better time resolution $\sigma = 1.2$ ns instead of 5.4 ns
- Factor 4.5 less Background
- Energy readout possible

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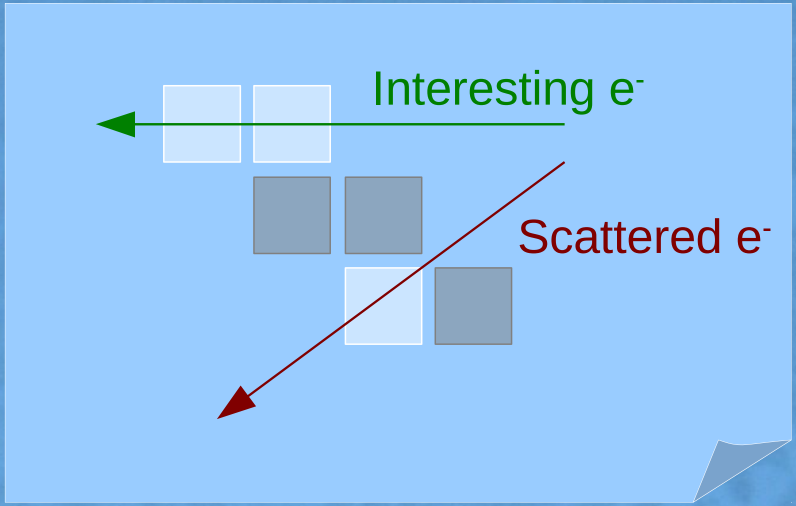

- Distinguish between interesting and scattered electrons
- Hope to remove up to an other factor 2 background

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Photo goes here

- High transparency
  - For gammas
  - and for neutrons
- Low Z materials ($Z \leq 6$)
- Only 1.2 mm thickness
- Stability against air pressure

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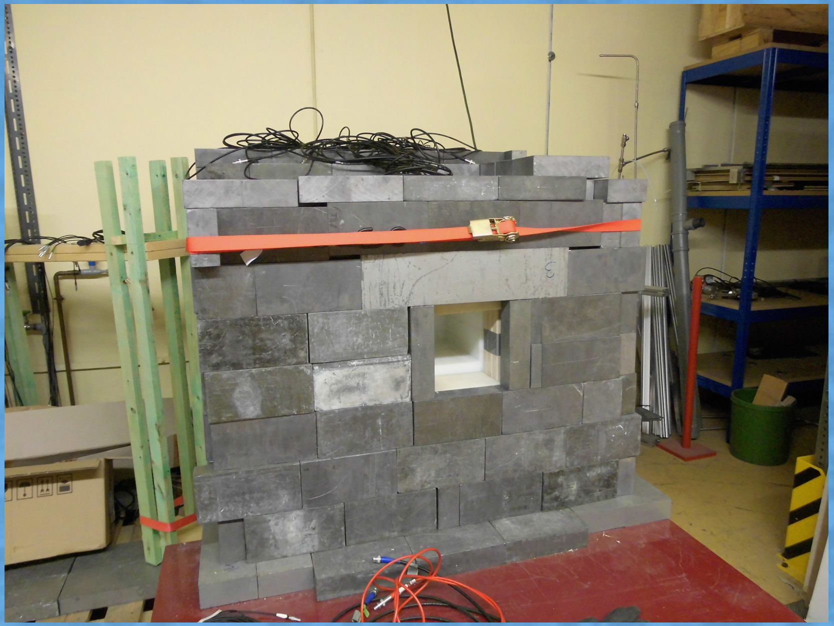
- Avoid backscattering
- Made from borated Polyethylene to absorb neutrons
- Lead cover to absorb gammas
- Gamma monitor included



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- Cares about the biggest part of the background
- Several changes needed:
  - Polyethylene at the gamma beam pipe and the electron beam dump to absorb neutrons
  - Stuffed holes in the wall
  - Optimized the position of the concrete blocks
- Too less beam time to evaluate all changes individually

Outlook to Beam Time in 2014

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- Gamma Monitor
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- Hall probe
  - Foreseen from the beginning
  - Monitor magnetic field
  - Changes of ‰ will affect resolution dramatically
- Temperature probe
  - Will add the chance to debug for temperature dependencies

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Photo goes here

- Provides a 2D image from gamma beam
- Used to debug beam

Outlook to Beam Time in 2014

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- Gamma Monitor
- **Automatic Picture Taking**
- And many small changes

Photo goes here

- Raspberry Pi camera
- Takes a picture from the setup at each run
- Excludes human failure in protocoling

Outlook to Beam Time in 2014

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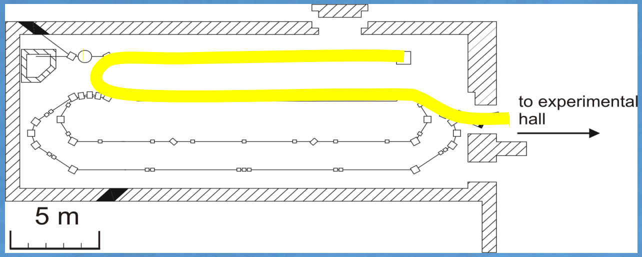
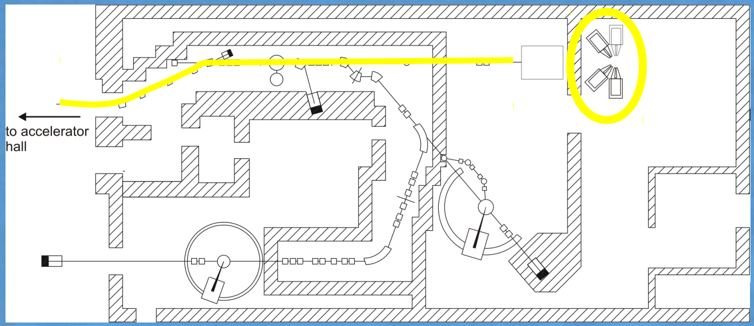
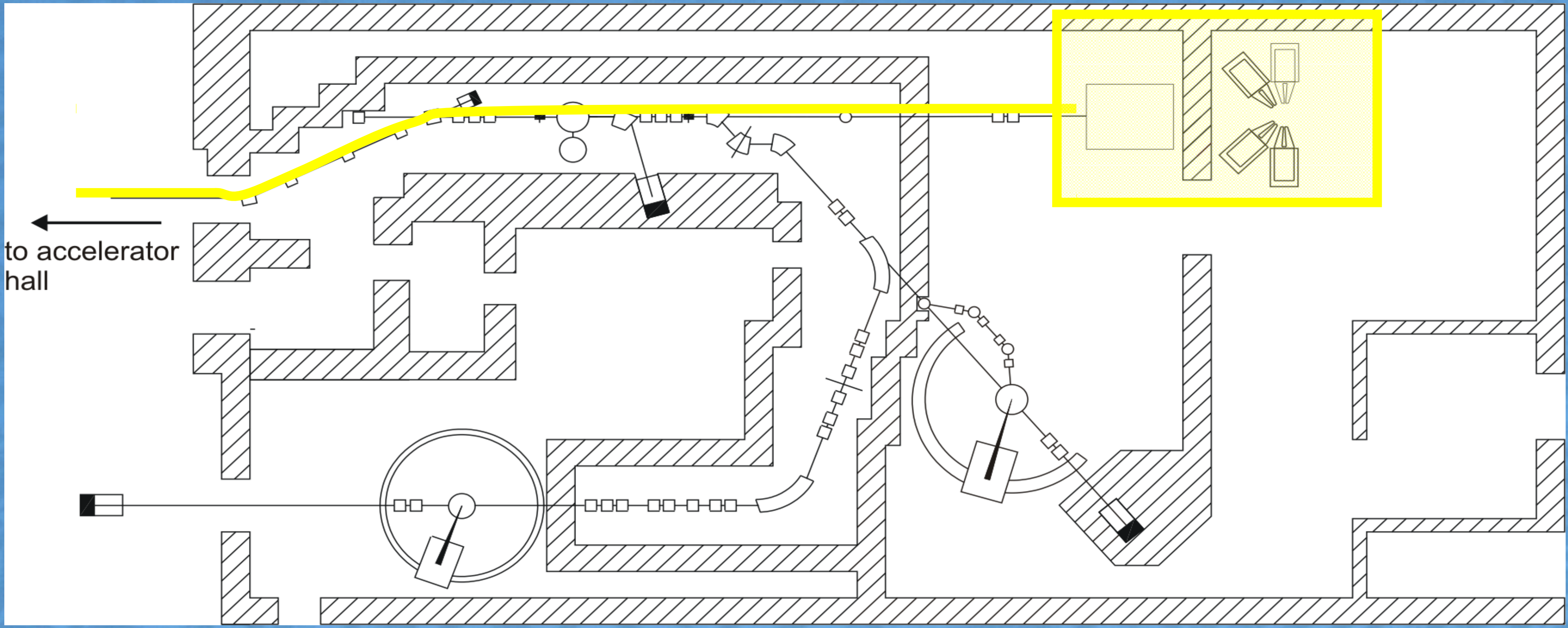
NEPTUN Facility







Background Sources

Test	Difference			Cmp Run	Run
Air in the beam pipe	18.76%	±	0.91%	28	29
Lead between beam pipe and detector and table	13.64%	±	1.10%	28	30
More lead between beam pipe and table	-12.02%	±	0.72%	30	31
PE shielding closer to the beam pipe	-3.00%	±	0.53%	31	33
Lead stones in front of HPGe	-7.10%	±	1.47%	33	34
Wrapped lead instead of wall	-28.64%	±	2.18%	33	37
Added lead wall in front and on top of the detector	-51.76%	±	2.65%	37	39
HPGe threshold changed from 1,1 to 2,2 at discriminator	14.05%	±	2.23%	58	50
Without Sulfur Target	-18.84%	±	0.92%	56	54
With air in the gamma beam pipe	3.69%	±	0.59%	56	55
Full target 10 µm	-4.02%	±	0.57%	56	61 & 63
Full target 1 µm	-18.73%	±	0.76%	56	62
PET at opposite wall	-5.70%	±	0.81%	56	64
PET bricks on the top of lead shielding of HPGe	-12.59%	±	1.05%	64	65