DSNB detection in liquid scintillators?

Background considerations

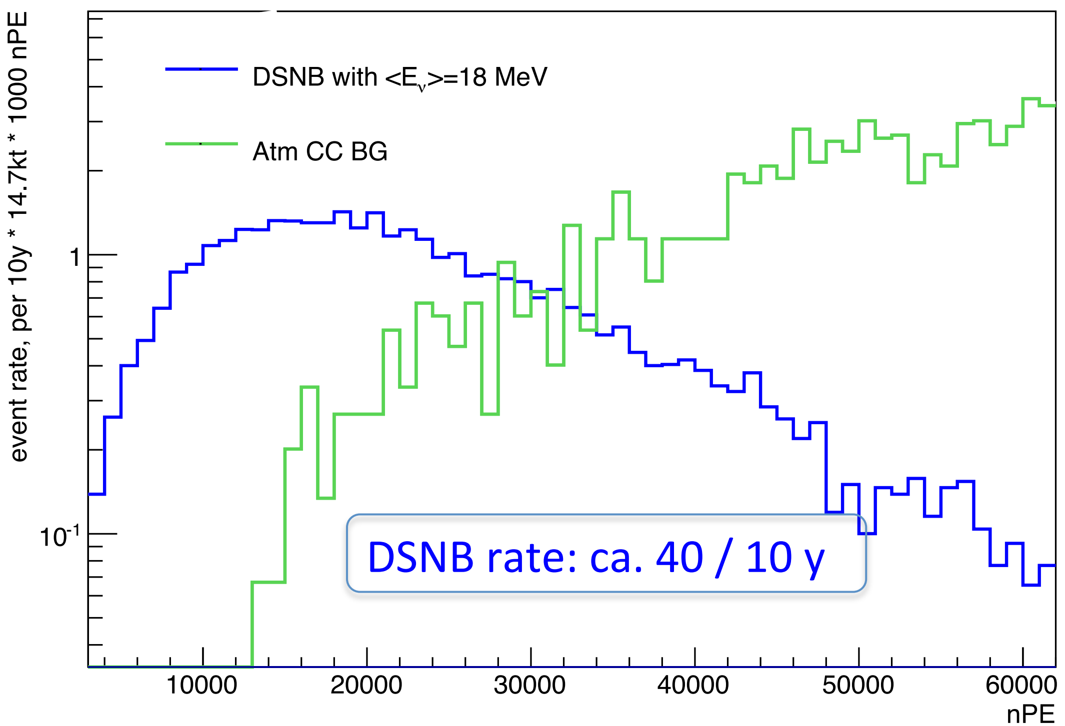
Atmospheric neutrino nc – reactions

The quest for pulse-shape-discrimination

Background considerations

Monte-Carlo simulations for JUNO - PhD by Julia Sawatzki (TUM) – for the JUNO experiment

1. Irreducible background: atmospheric neutrino cc - reactions



DSNB in liquid scintillator:

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

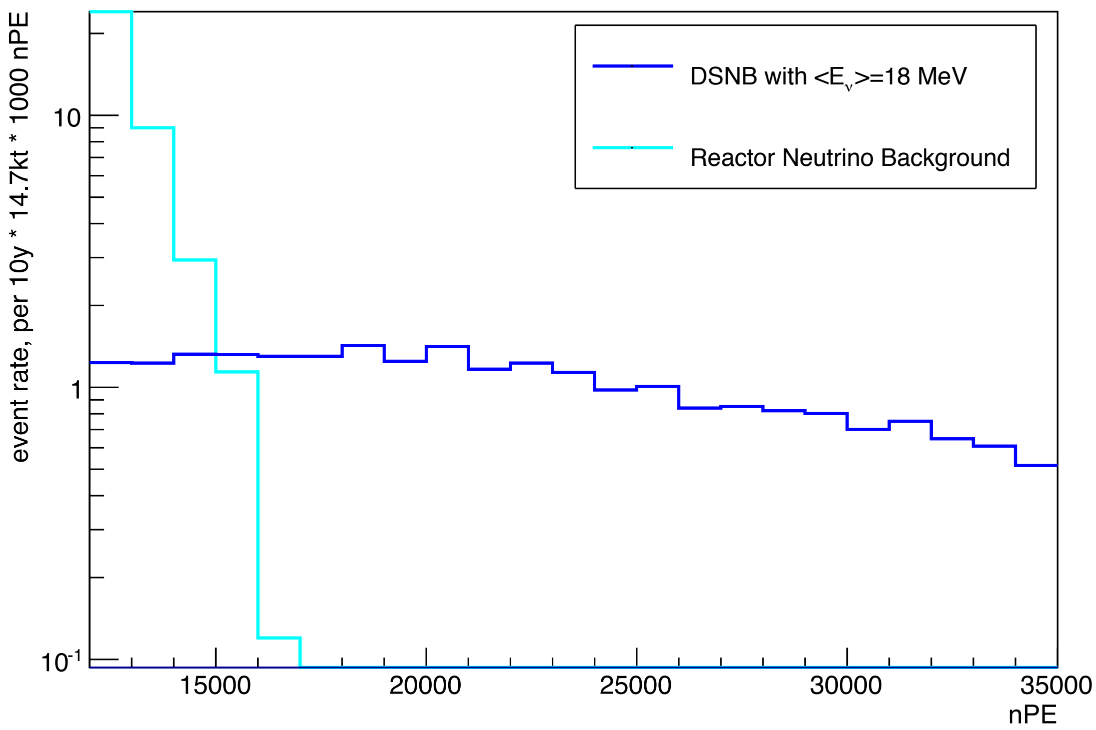
Positron provides prompt signal

Neutron capture on p and 2.2 MeV gamma provides delayed signal

Fid.Vol. 14.7 kt

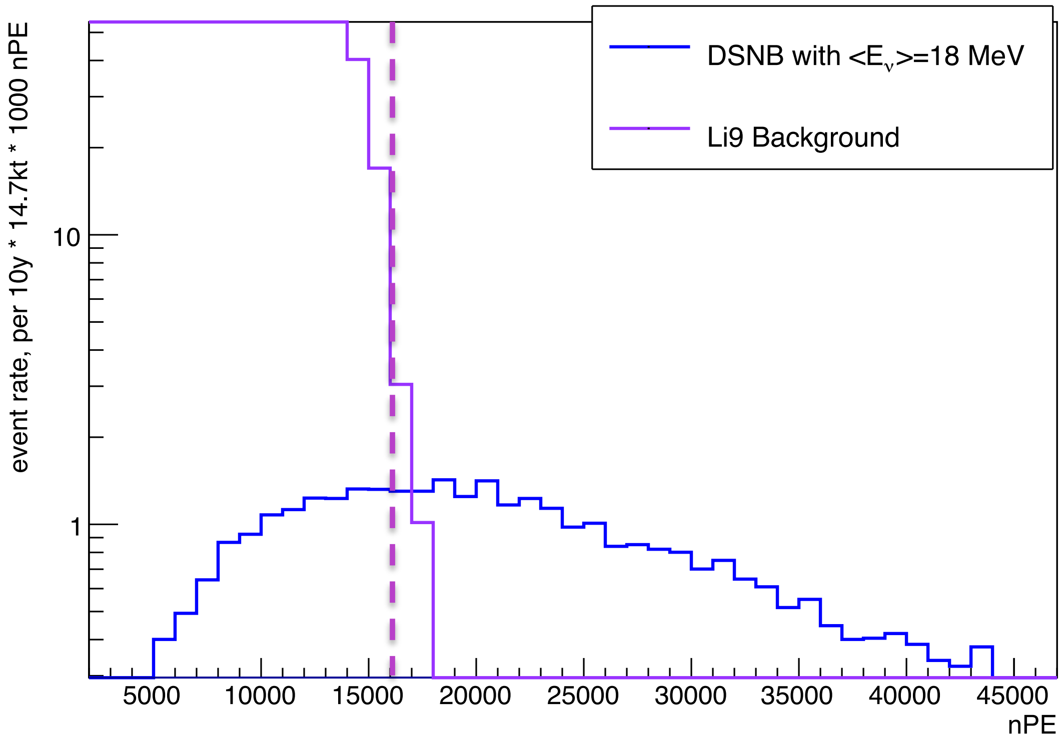
Background considerations

2. Irreducible background: reactor neutrinos



Background considerations

3. cosmogenic background: ^{9}Li – production via cosmic muons

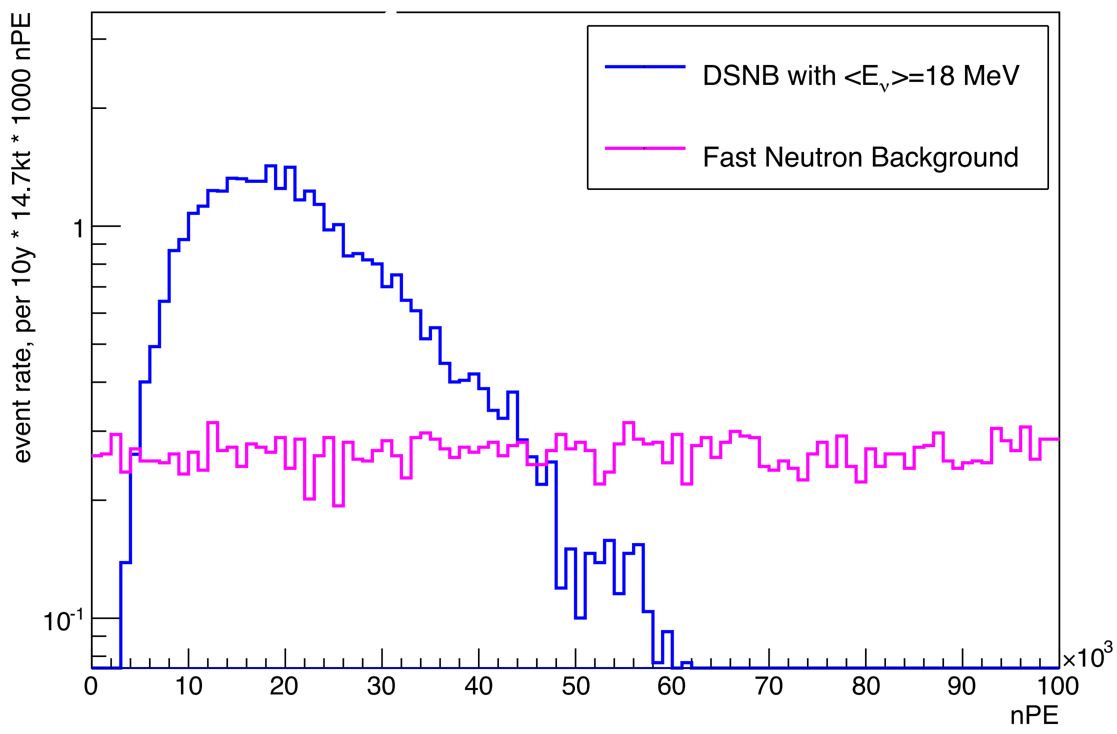


Tagging can be applied

Still 9-Li determines lower energy threshold

Background considerations

4. cosmogenic background: fast neutron production via cosmic muons



Cut @ 16m radius

Fid.Vol
14.7 kt

Self shielding is effective

Background considerations

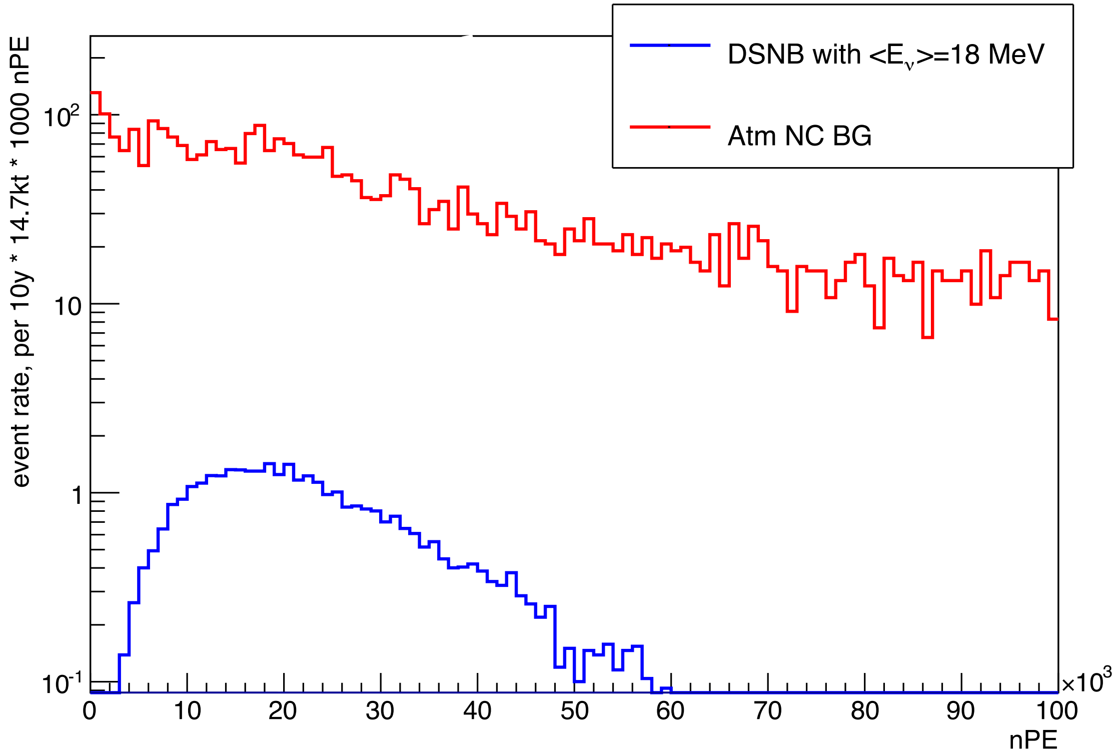
5. Atmospheric neutrino nc – reactions on C-nuclei

Reaction channel $\nu_x + {}^{12}C \longrightarrow \nu_x +$									ratio in %
(1)	n					+	^{11}C		35.7
(2)	n	+	p			+	$\mathbf{^{10}B}$		26.0
(3)	n	+	2p			+	$\mathbf{^{9}Be}$		11.5
(4)	n	+	p	+	^{2}H	+	^{8}Be		8.7
(5)	n	+	p	+	α	+	$\mathbf{^{6}Li}$		8.2
(6)	n	+	3p			+	^{8}Li		2.8
(7)	n	+	4p			+	^{7}He		1.0
(8)	n			+	α	+	$\mathbf{^{7}Be}$		0.8
(9)	n	+	2p	+	α	+	^{5}He		0.8
(10)	n			+	^{2}H	+	^{9}B		0.7
(11)	n	+	2p	+	^{2}H	+	$\mathbf{^{7}Li}$		0.7
(12)	n			+	^{3}He	+	^{8}Be		0.7
(13)	n	+	5p			+	^{6}H		0.5
(14)	n	+	p	+	^{3}H	+	^{7}Be		0.5

- Inelastic neutrino scattering and production of a **fast neutron** inside the scintillator volume
- Excited nuclei plus recoil of neutron on protons => prompt signal
- Neutron capture => delayed signal

Background considerations

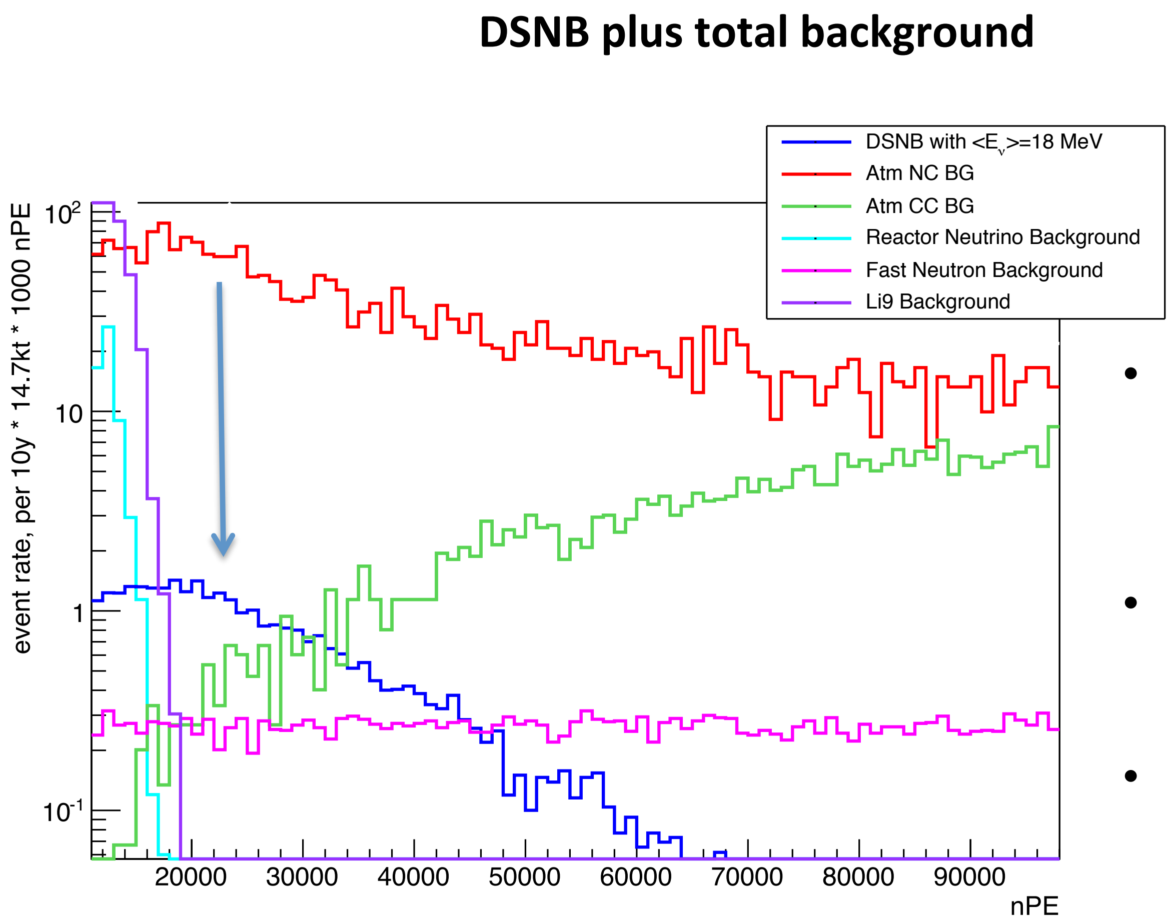
5. Atmospheric neutrino nc - reactions



Possibility of ^{11}C tagging not included here

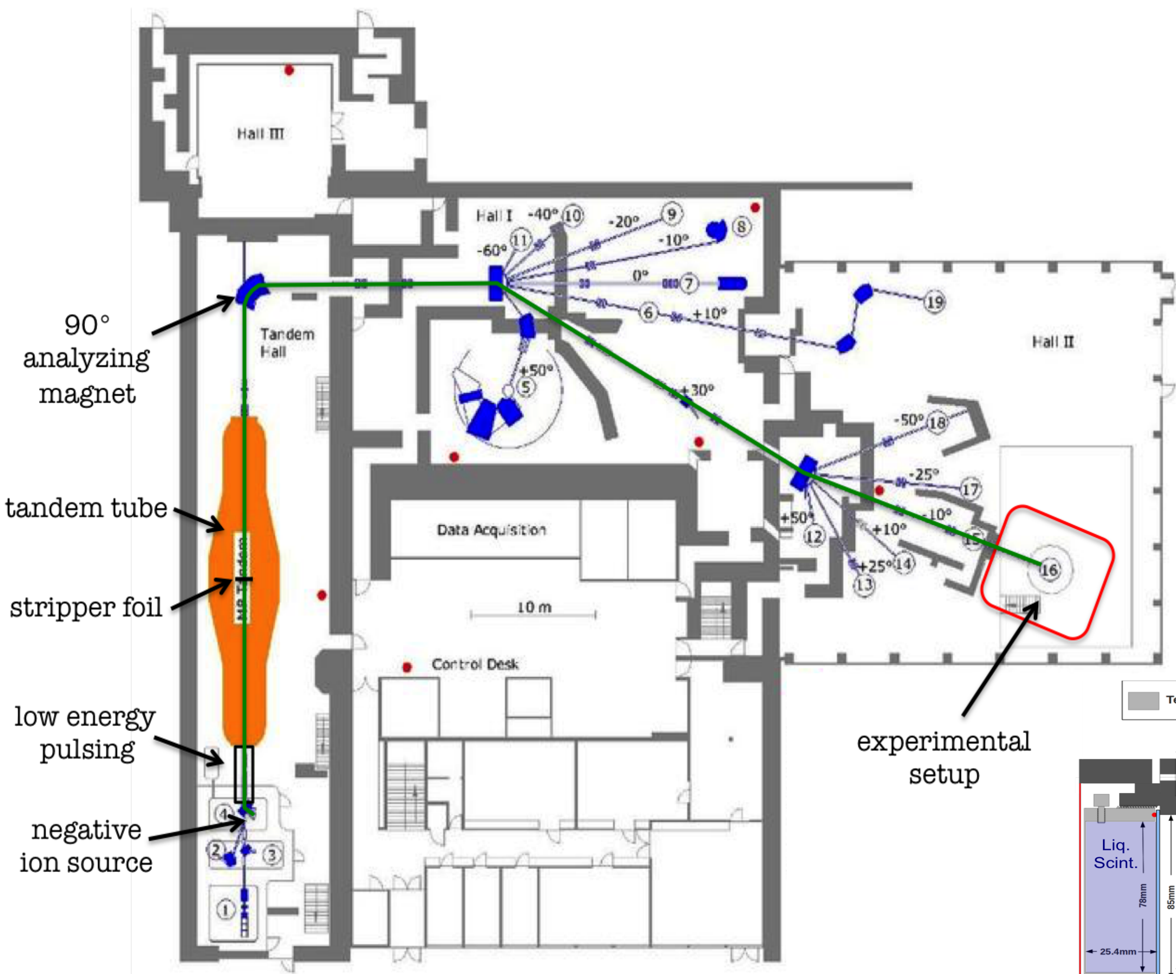
LENA studies: bg reduction of ca. 40%

Background considerations



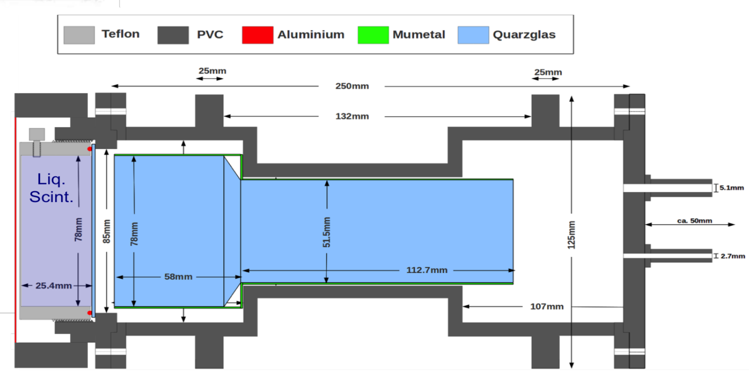
- Main problem: neutrons from atmospheric neutrino nc – reactions
- Can we identify them via pulse-shape discrimination (PSD)?
- Reduction factor required: ca. 20 – 50 (depends on ^{11}C tagging)

PSD measurements at TUM

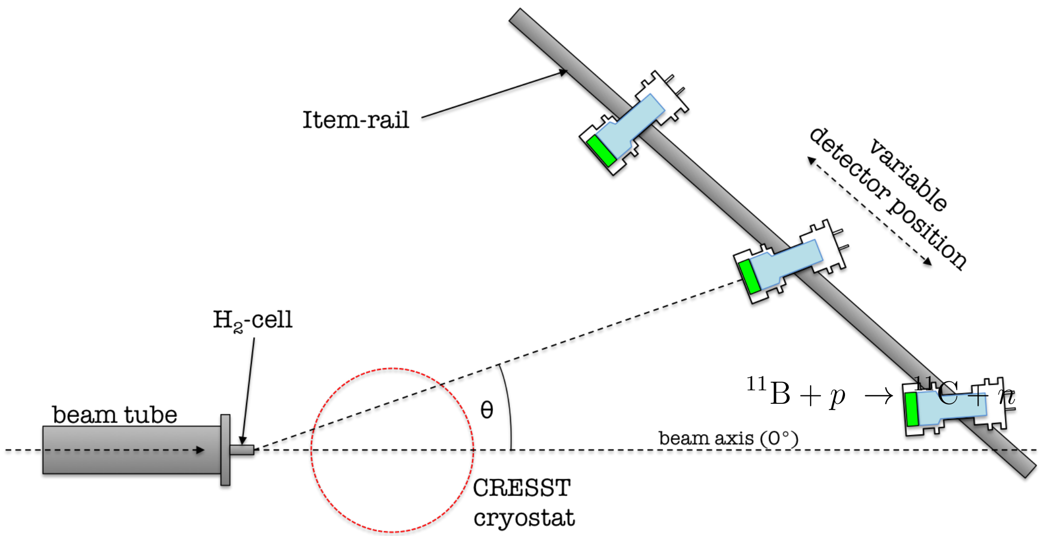


- Pulsed neutron beam
- T = 11 MeV
- Inclusive measurement (all scattering angles)
- Gamma/neutron separation via ToF measurement

detector



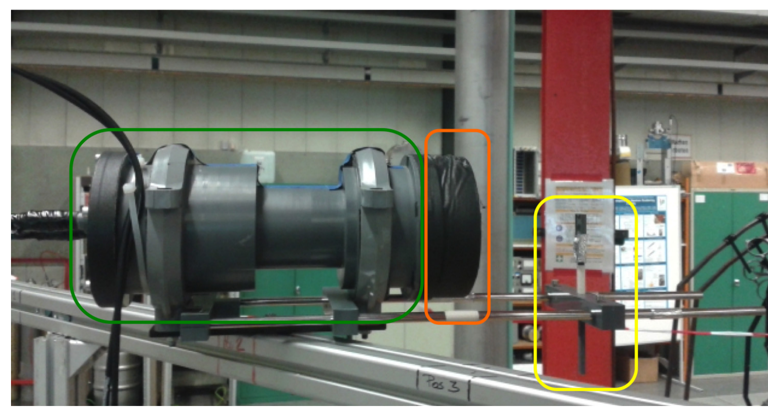
PSD measurements at TUM



$$^{11}\mathrm{B} + p \rightarrow {}^{11}\mathrm{C} + n$$

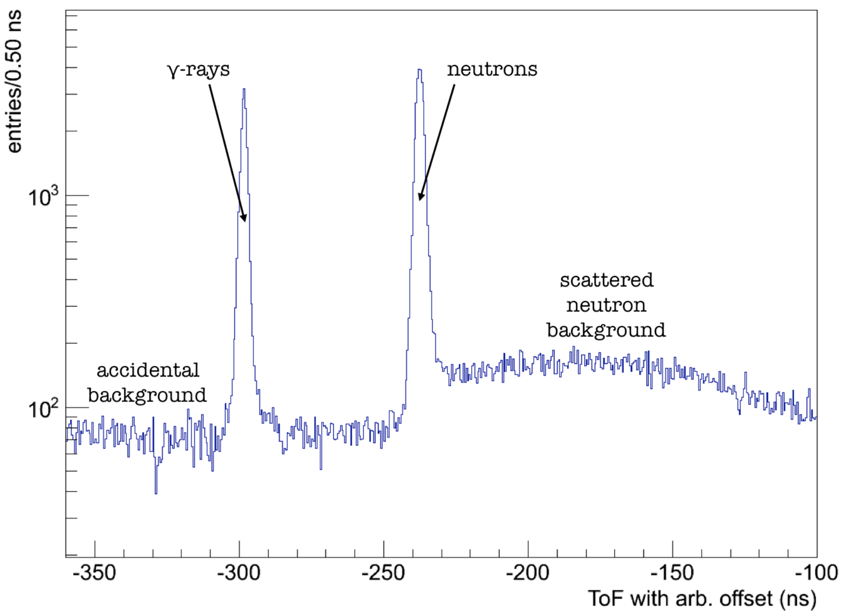
Off-axis measurements for choosing neutron energy (range between ca. 5 and 11 MeV)

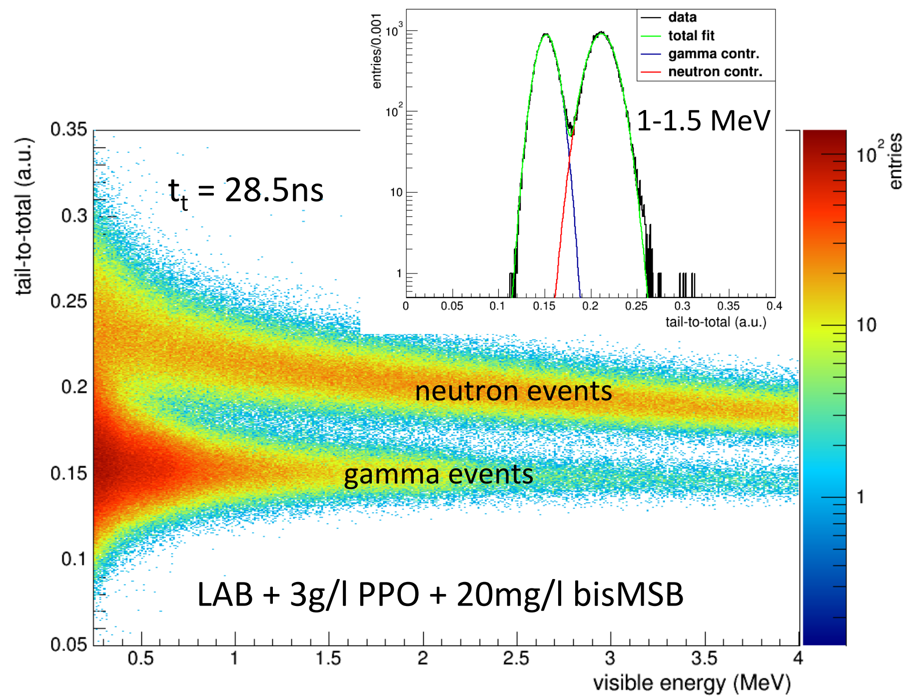
Final detector assembly at MLL with calibration device



PSD measurements at TUM

Pulsed neutron beam at 11 MeV



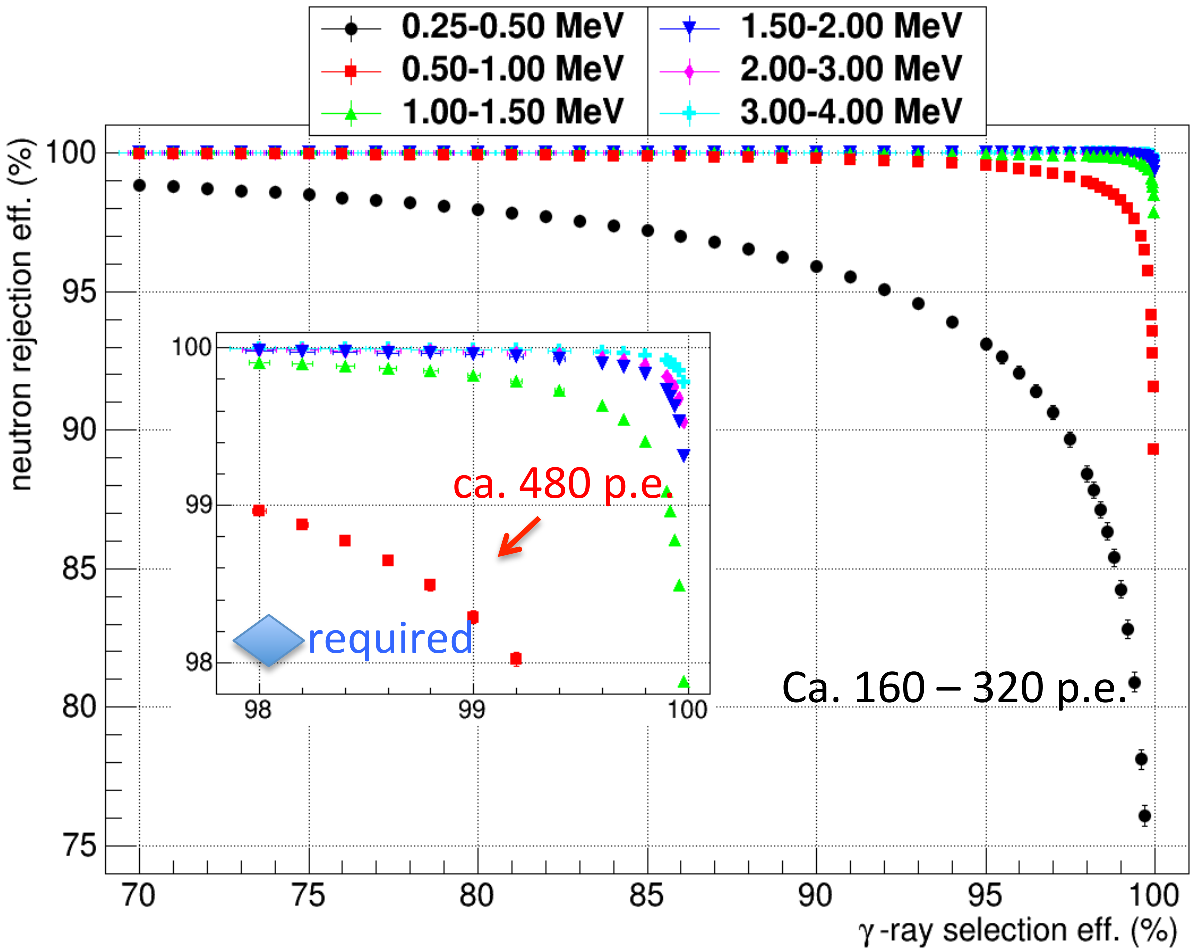


LAB scintillator exhibits excellent PSD behavior

PhD-thesis V. Zimmer, TUM

Similar results from B. von Krosigk et al. (Univ. Dresden), Eur.Phys.J. C73 (2013) 4, 2390

PSD measurements at TUM



Neutron rejection vs gamma acceptance

Light yield @ TUM measurement:
628 ± 40 p.e. / MeV

LAB + ppo + bis/MSB (JUNO type)

This is a promising result, but not the end of the story...

Neutron energies are higher and de-excitation has to be considered

Conclusions

- Inverse beta decay opens a window for DSNB measurement with liquid scintillator detectors
- Atmospheric neutrino nc – reactions on C-nuclei with neutron emission provide the most severe background contribution
- Identification of those events via pulse shape discrimination required
- LAB based scintillator provide this opportunity
- Further experimental studies and simulation necessary
- Borexino exposure is (after 10 years of data taking) large enough to study atmospheric neutrino nc - reactions