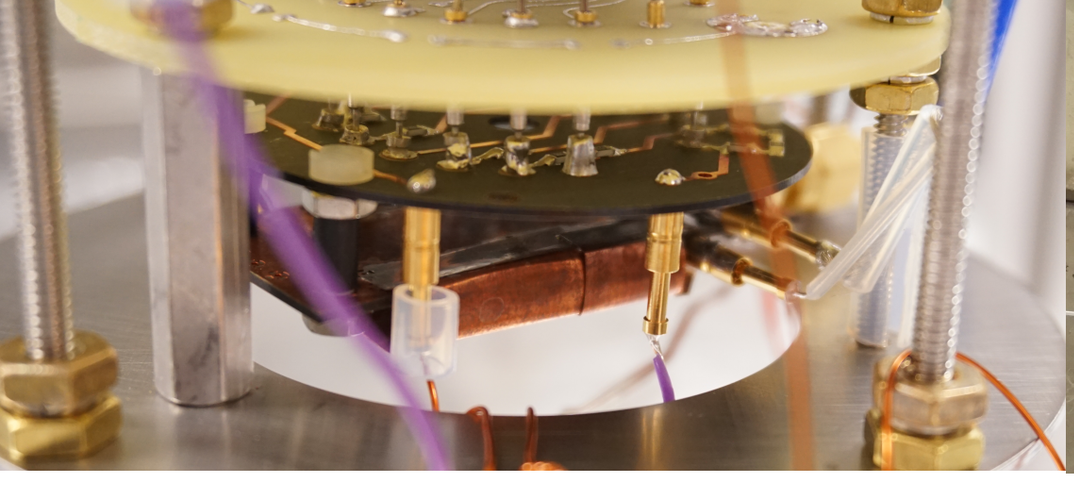
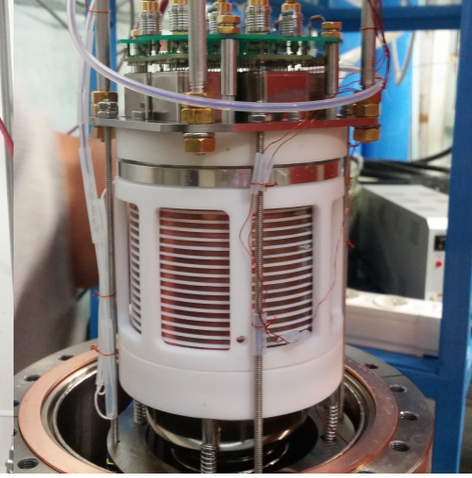


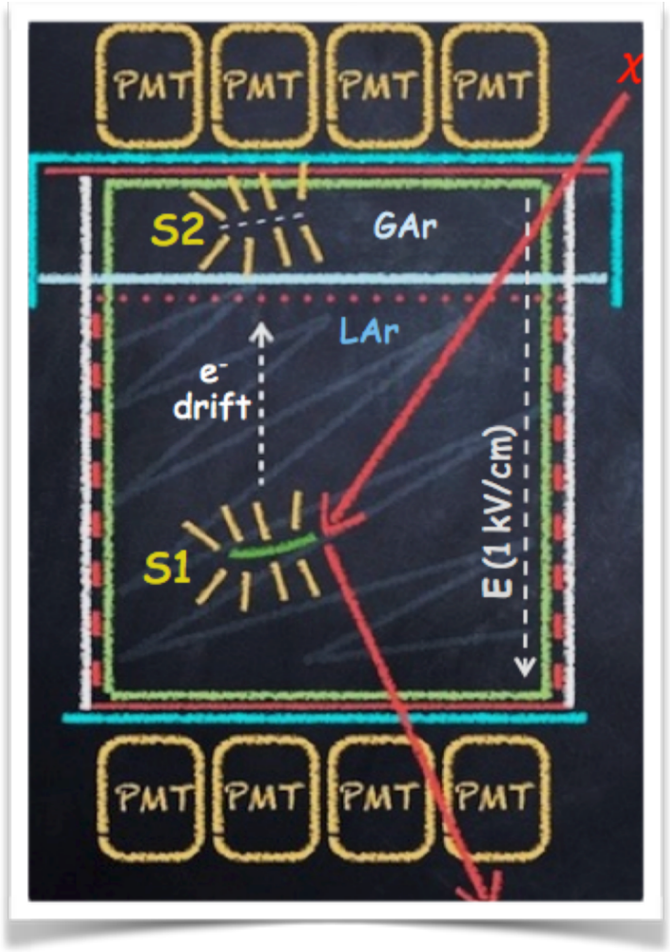


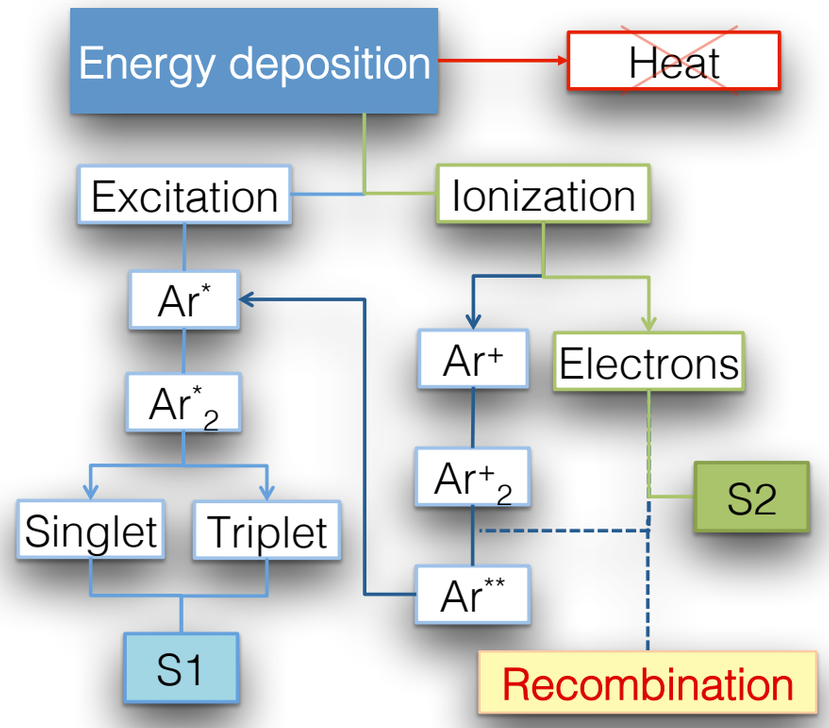
Results from the ARIS experiment

Anyssa Navrer-Agasson

30th Rencontres de Blois - June 5, 2018

Direct dark matter search with liquid argon





Uncertainties on the response of LAr to nuclear and electronic recoils are a major source of systematics

Energy scale in LAr

Recoil energy

NR quenching

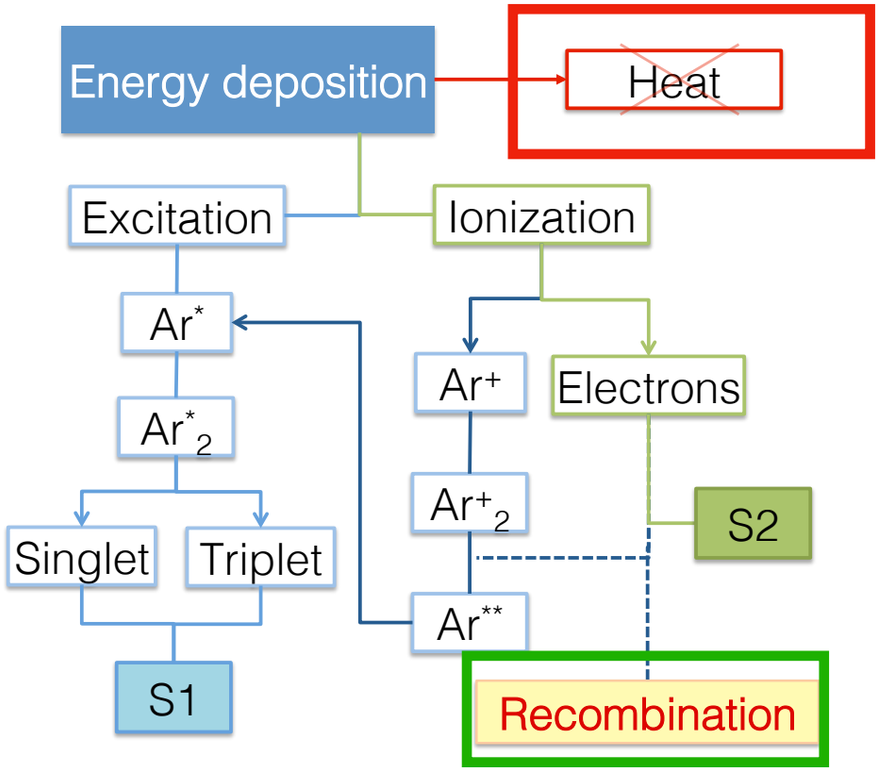
$$S1 = E_R * LY * L_{eff}(E_{NR})$$

Measured signal

Light yield (dependance on electric field via recombination)

Depends on :

- ➡ Particle nature (ER/NR)
- ➡ Particle energy
- ➡ Electric field



Need to determine experimentally :

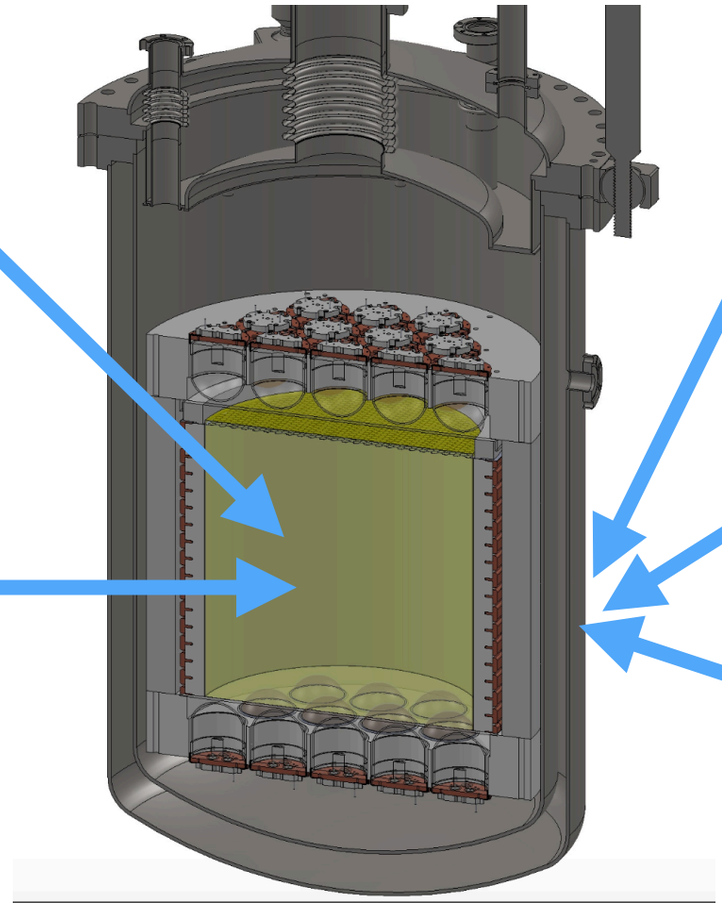
- **Photoelectron yield** of electronic recoils as a function of energy
- **Effect of electric field** on scintillation output
- **Relative scintillation efficiency** (L_{eff}) between electronic and nuclear recoils

Measurements methods

Natural internal source (^{39}Ar, ^{127}Xe)
Uniformly distributed
Limited number of sources

Injected gaseous source (^{83m}Kr)
Direct measurement
Uniformity of the distribution ?

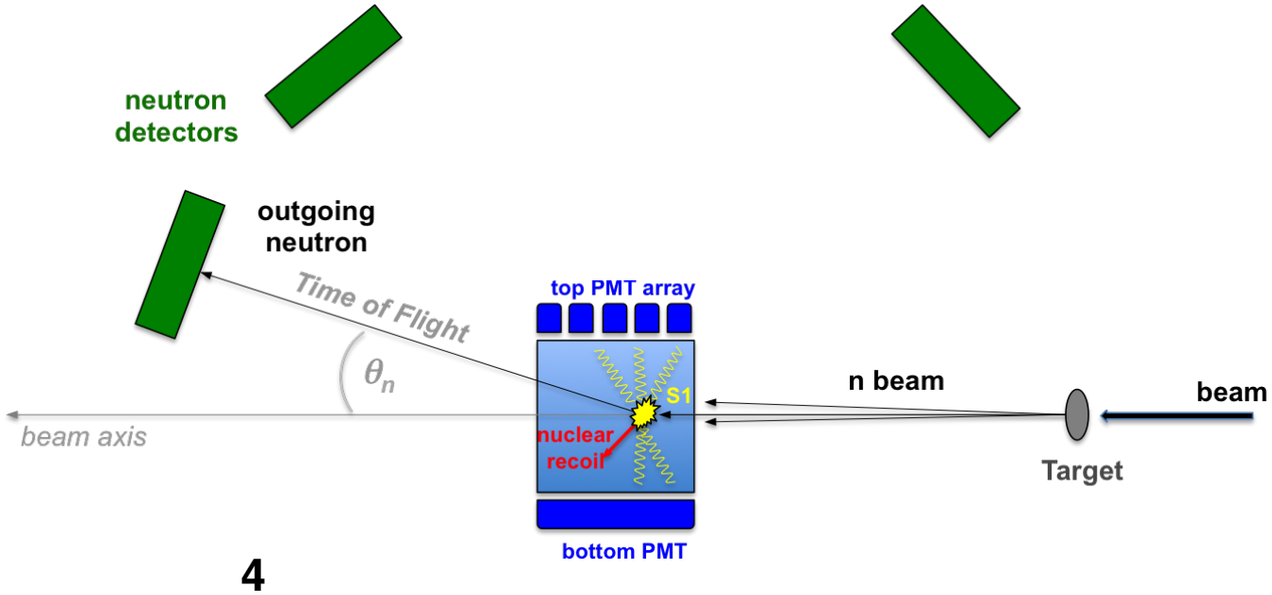
External calibration
Precise recoil energy reconstruction
Indirect measurement



External neutron source (AmBe)
Direct measurement
Non-monochromatic

D-D gun in the veto
Monochromatic neutrons
Recoil energy reconstruction

External gamma source (^{241}Am, ^{133}Ba)
Known energy
Events close to the borders

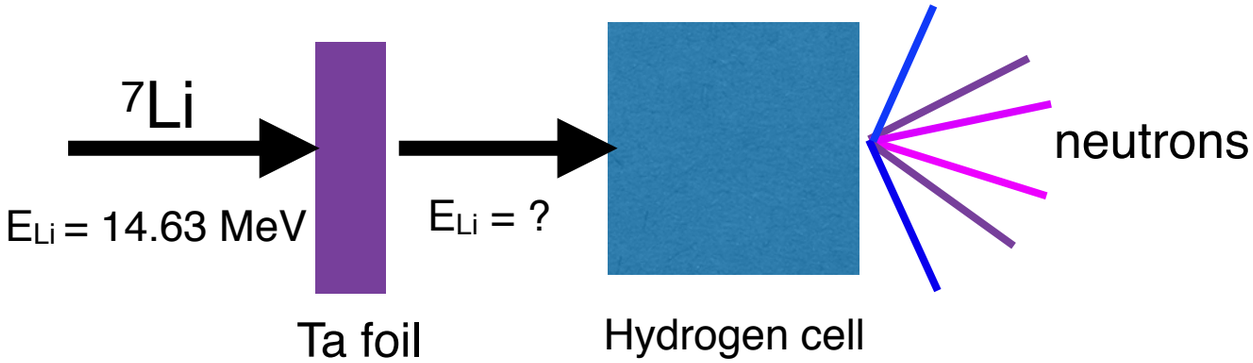


http://aris.in2p3.fr

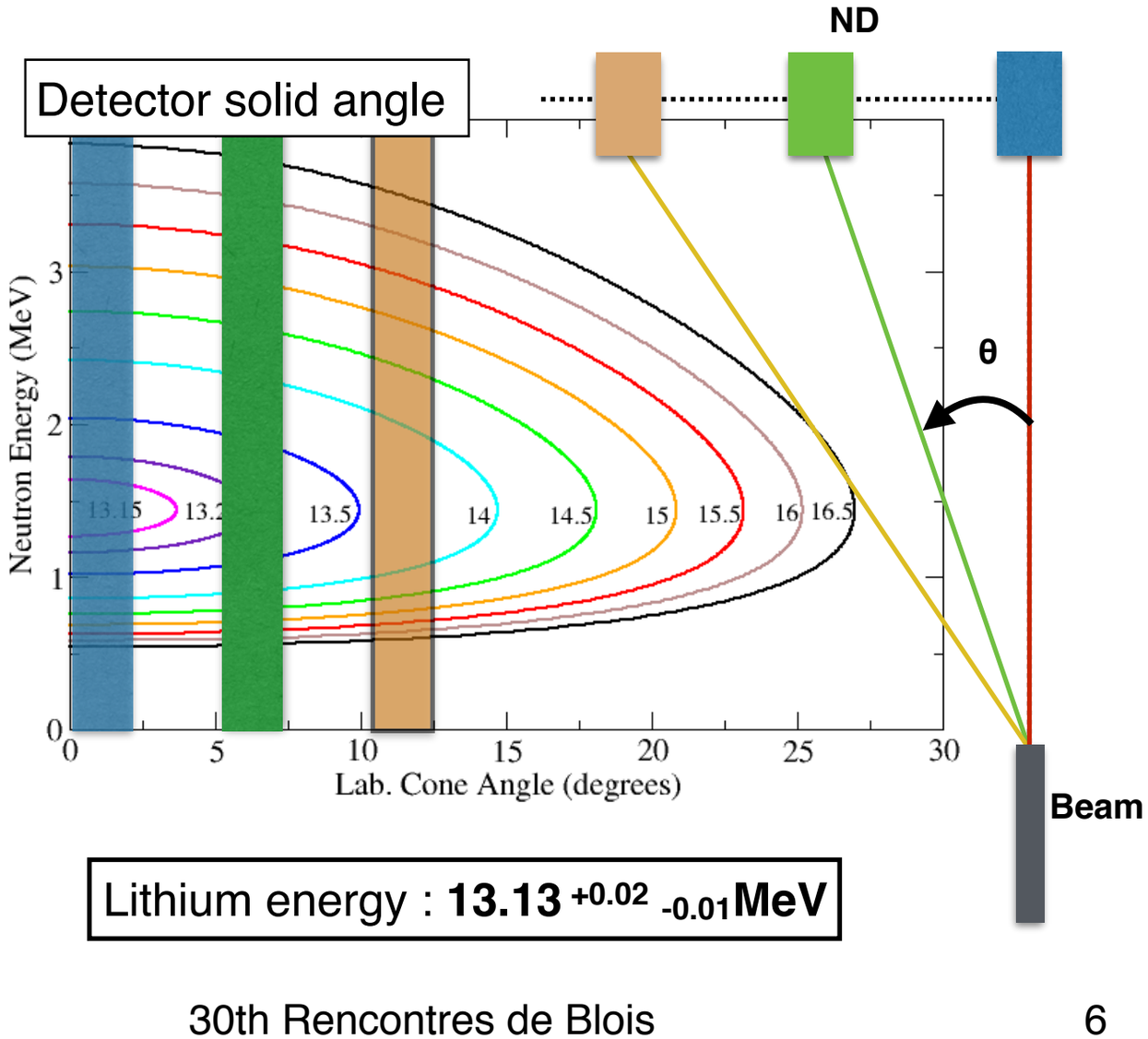
The ARIS experiment

LICORNE beam kinematics

Neutron production: $^{1}\mathrm{H}(^{7}\mathrm{Li}, n)^{7}\mathrm{Be}^{*}$

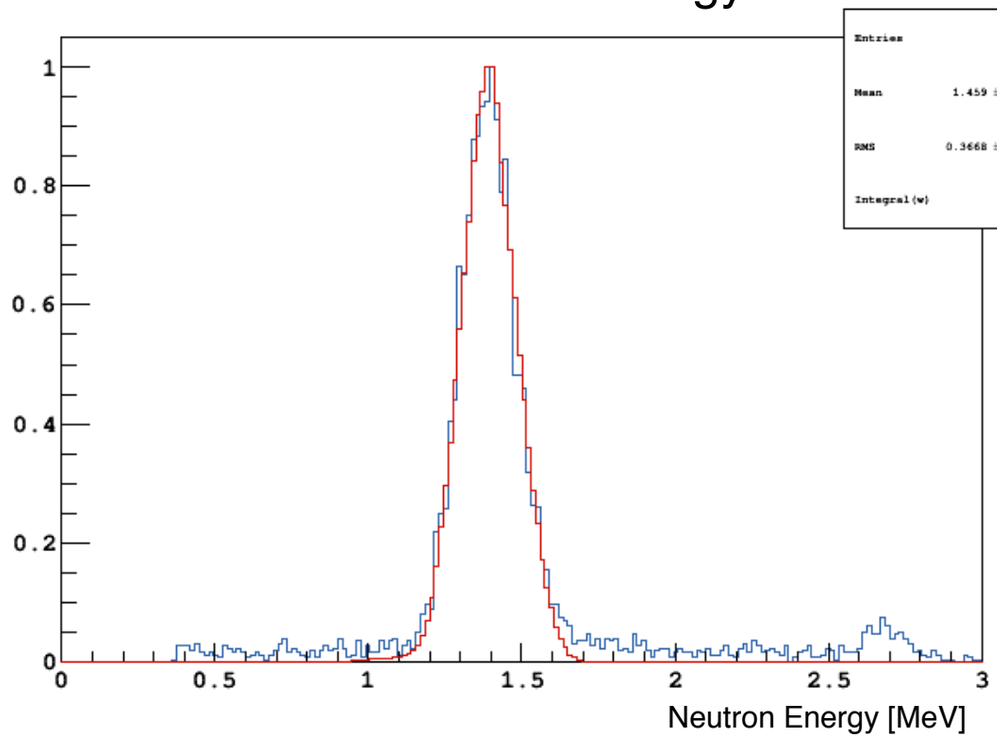


Detector solid angle



Lithium energy : **13.13** $^{+0.02}_{-0.01}$ **MeV**

TOF -> Neutron energy



Neutron energy: **1.45 ± 0.08 MeV**

Beam characteristics:

- ⇨ 1 pulse / 400 ns
- ⇨ Beam pulse width: 1.5 ns
- ⇨ Neutron flux on TPC : ~ 10^4 Hz

Advantages:

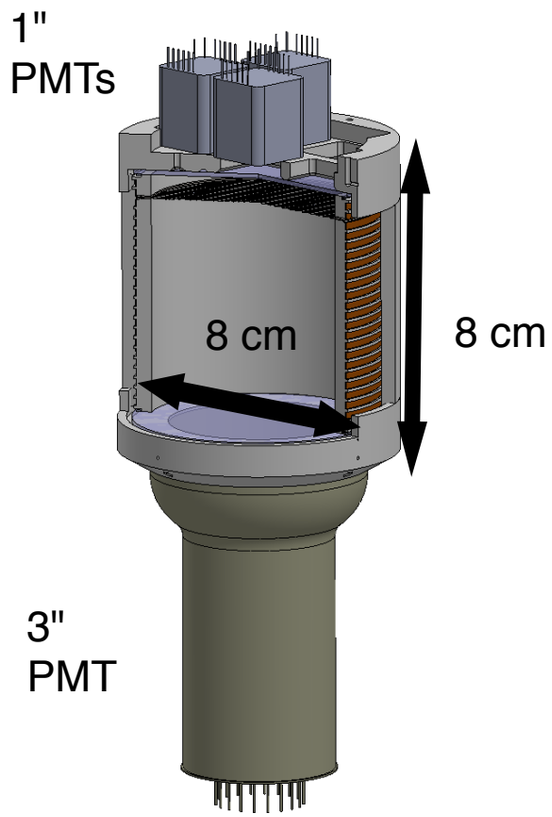
Lithium energy near production threshold

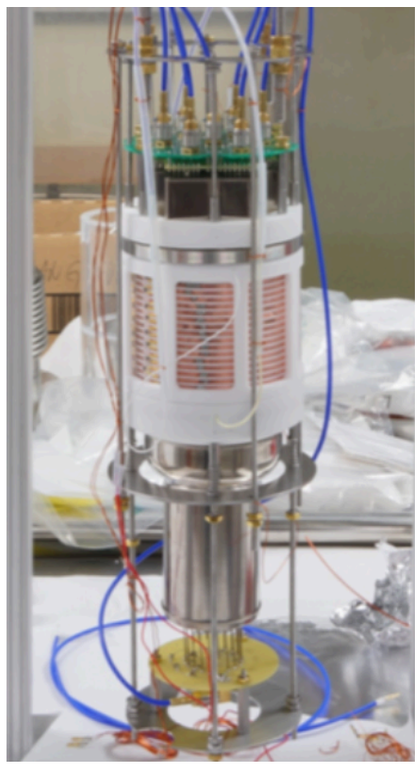
- ⇨ **highly collimated** beam
- ⇨ **high neutron flux** on the TPC

Mono-energetic

The ARIS setup

Small scale TPC ⇨ single scatter events





8 neutron detectors:

- NE213 liquid scintillator
- 20 cm diameter
- 5 cm height
- Signal pulse shape discrimination available

TPC:

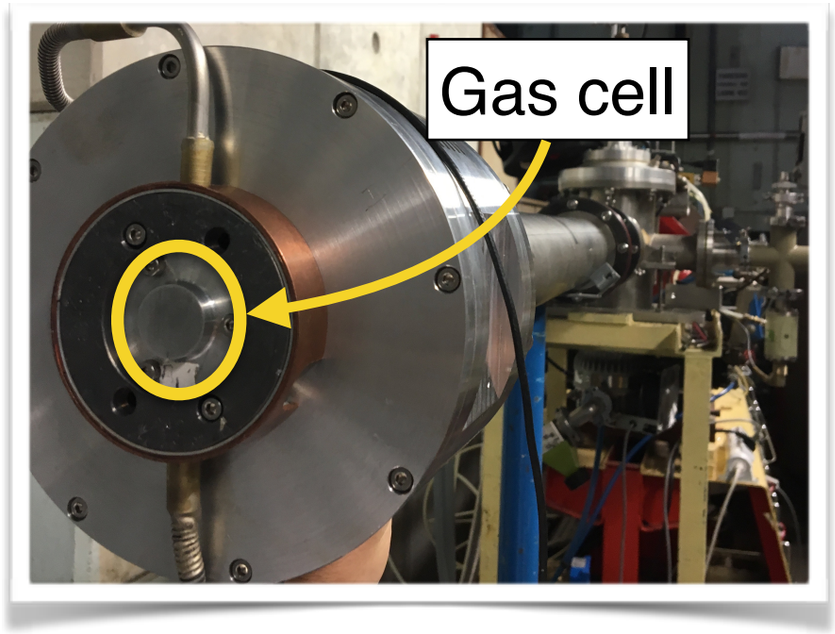
- ~0.5 kg of LAr
- PTFE reflector with TPB coated surface
- 7 Hamamatsu 1” PMTs on top, one 3” PMT on bottom
- Single phase mode (high statistics)

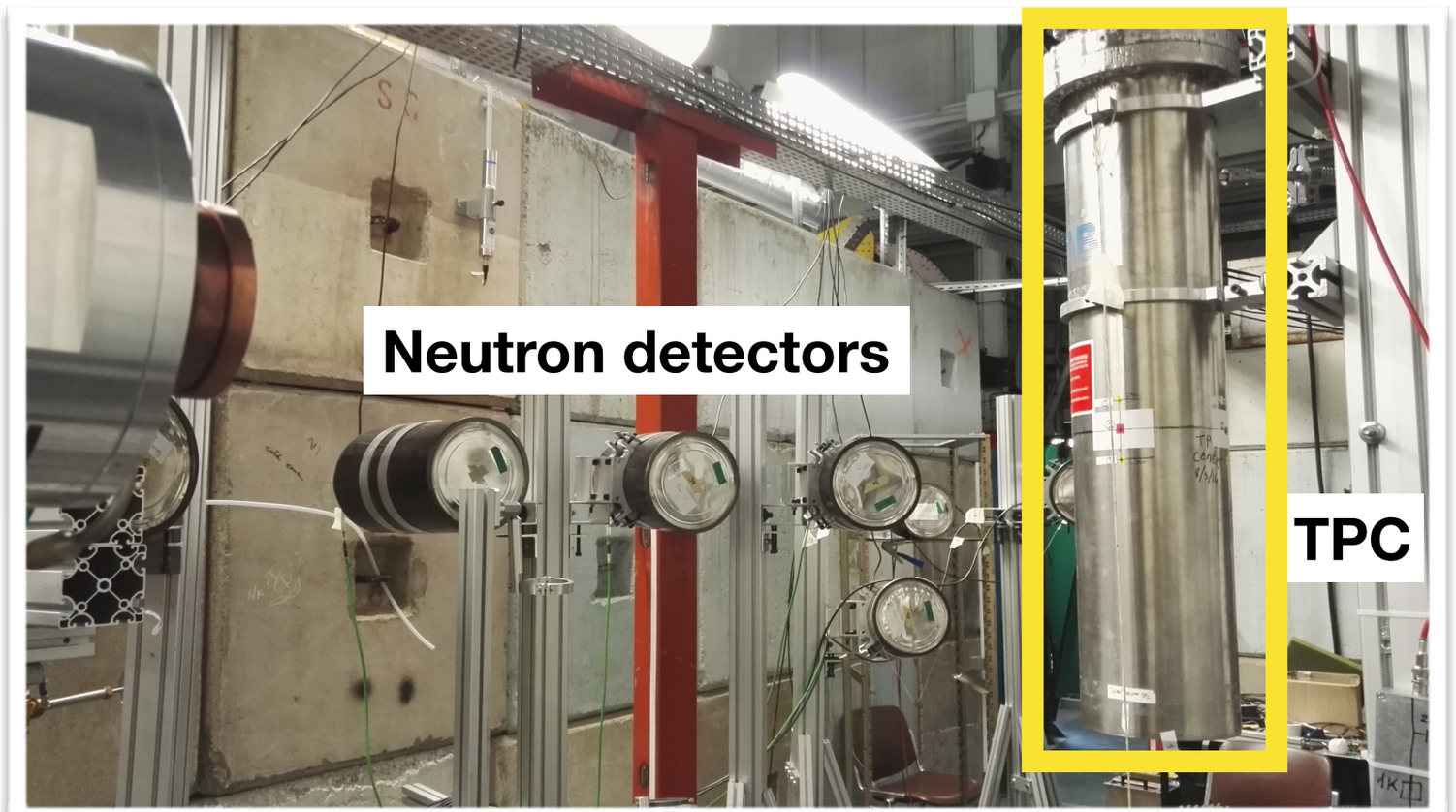
Probed recoil energies

	Scattering Angle [deg]	MC Determined Mean NR Energy [keV]
A0	25.5	7.14
A1	35.8	13.72
A2	41.2	17.78
A3	45.7	21.69
A4	64.2	40.45
A5	85.5	65.37
A6	113.2	98.14
A7	133.1	117.78

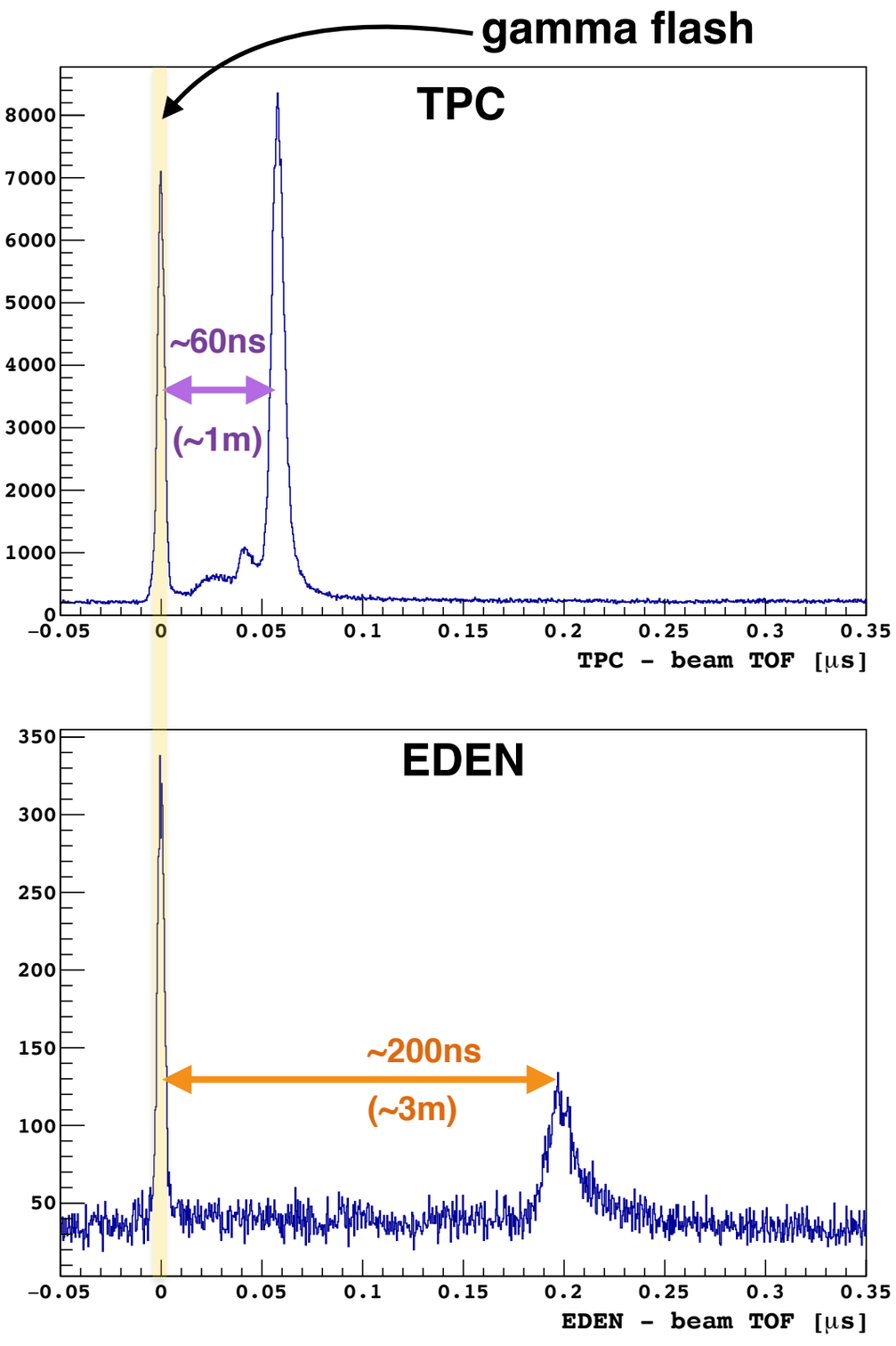
ARIS experiment : data taking at Licorne

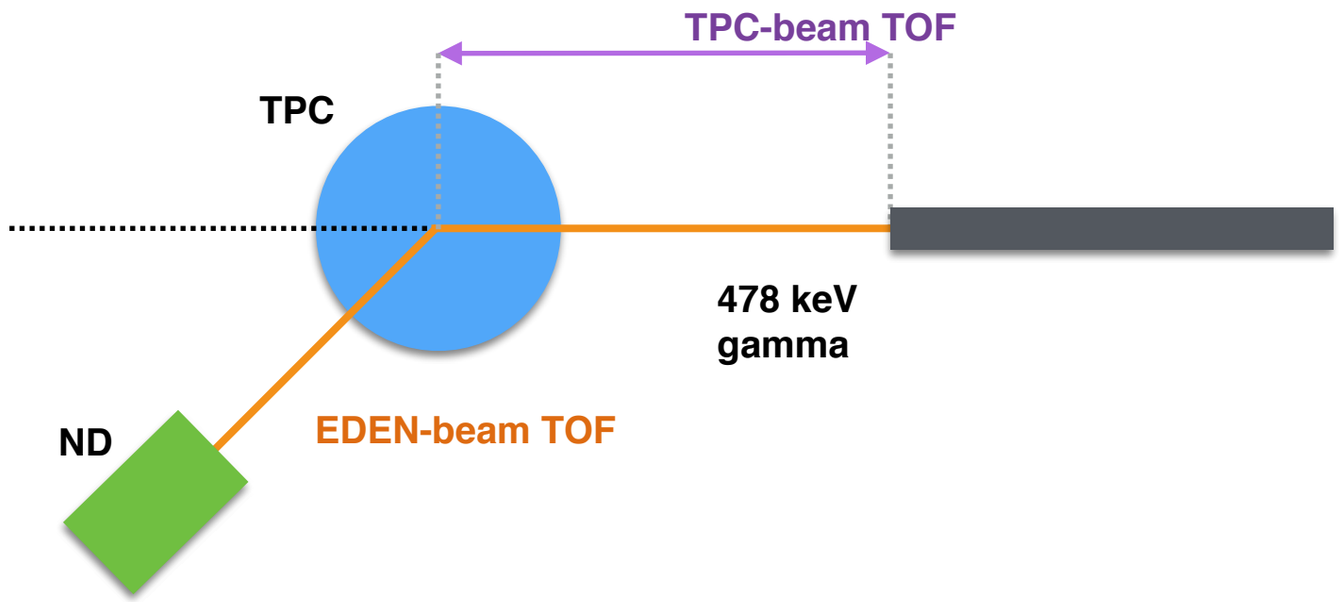
12 days of data taking
in October 2016





TOF distributions





Emission of 478 keV gammas ($^{7}Li^{*}$ de-excitation)

→ γ-flash

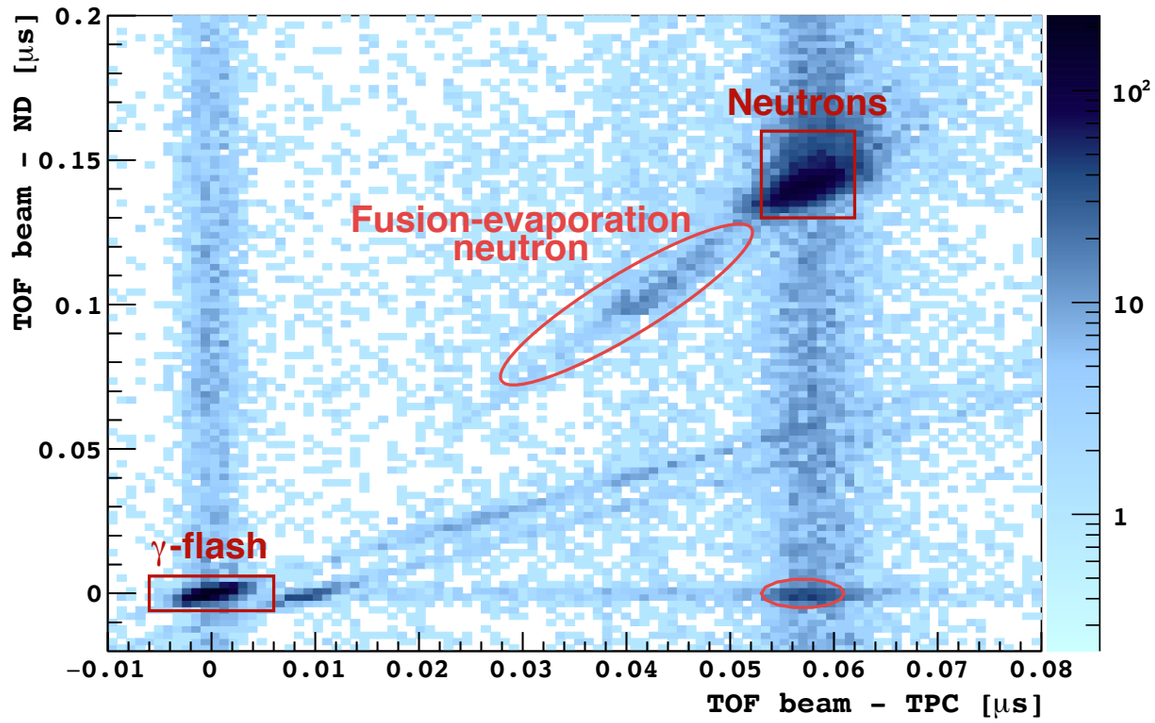
TOF Resolutions:

TPC = ~1.8 ns
EDEN: ~1.6 - 3 ns (depending on the detector)

Data selection

4 populations

- Neutrons from $^{1}H(^{7}Li,n)^{7}Be$ reaction
- Compton scattered beam-correlated γ from 7Li* de-excitation
- Neutrons from fusion evaporation reactions
- Accidental coincidences between a neutron in the TPC and a γ in the ND



Cuts on TOF, ND charge and ND PSD

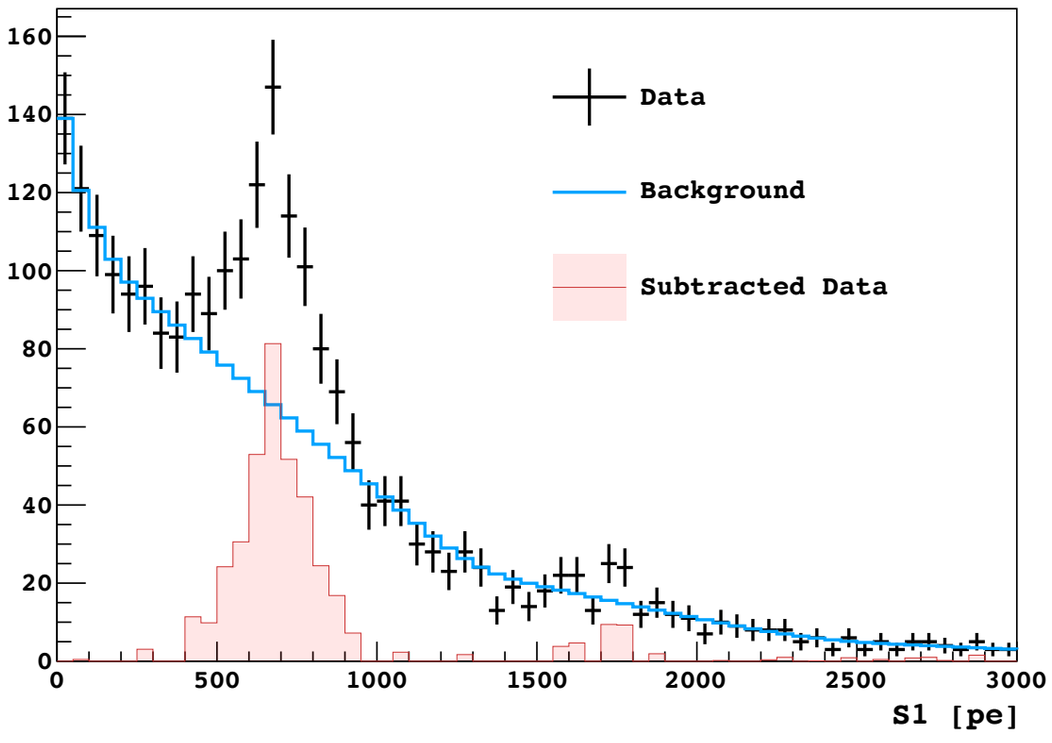
Exploitable samples of both ER and NR with well defined energies

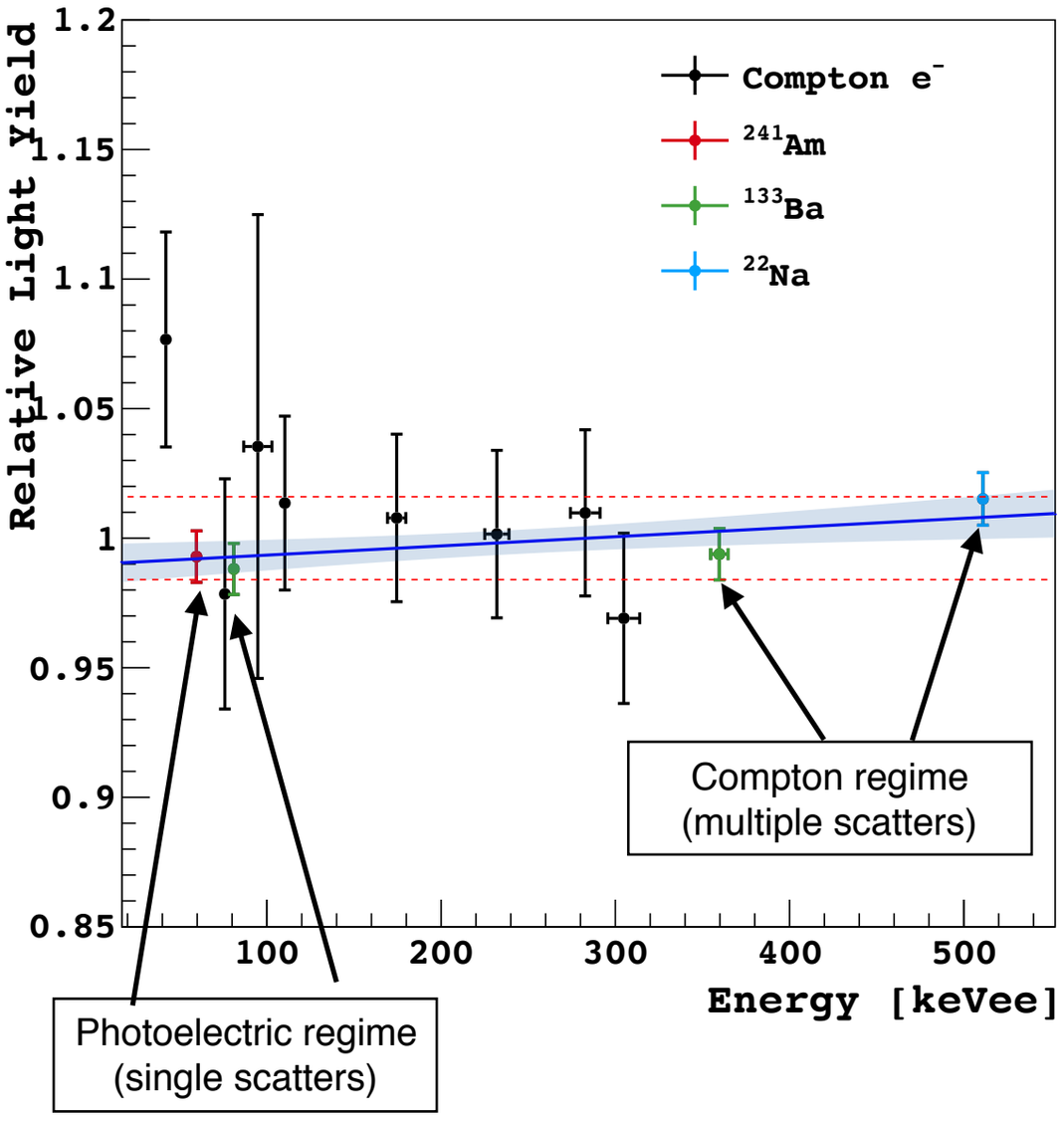
Light yield linearity at null field

Sources

➡ ^{133}Ba, ^{241}Am, ^{22}Na

➡ 478 keV γ from 7Li* de-excitation provide a pure sample of Compton single scatters





Light yield proven to be constant within 1.6% fitting all sources (42 to 511 keV)

Recombination probability in LAr: ER

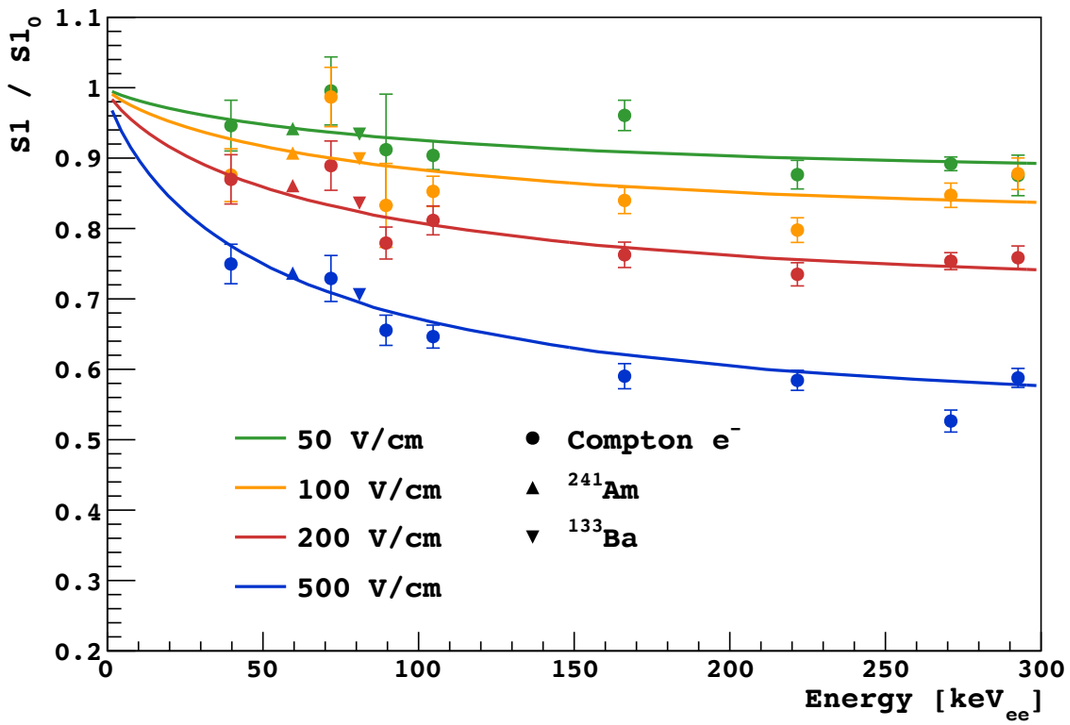
$$\frac{\mathrm{S1}_{field}}{\mathrm{S1}_{null\_field}} = \frac{R + \alpha}{1 + \alpha}$$

extracted from **ER** data

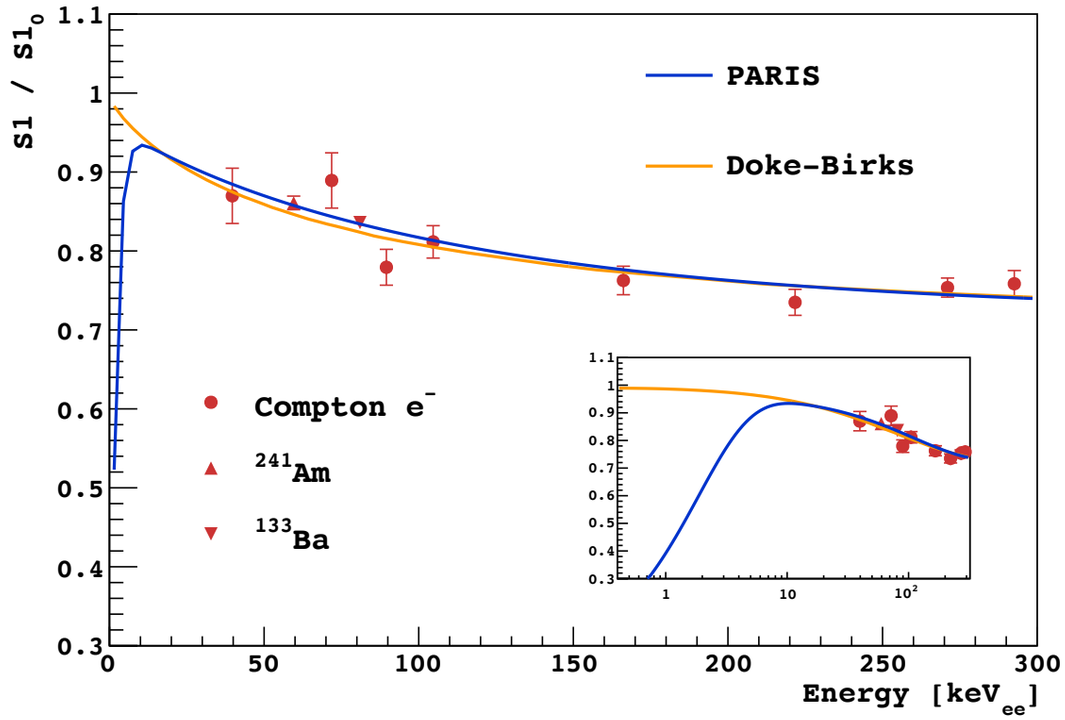
$$\left(\alpha = \frac{N_{ex}}{N_i} = 0.21 \text{ for ER} \right)$$

Fit by Doke-Birks model

(tuned to account for field dependance)



Comparison to prediction of PARIS model



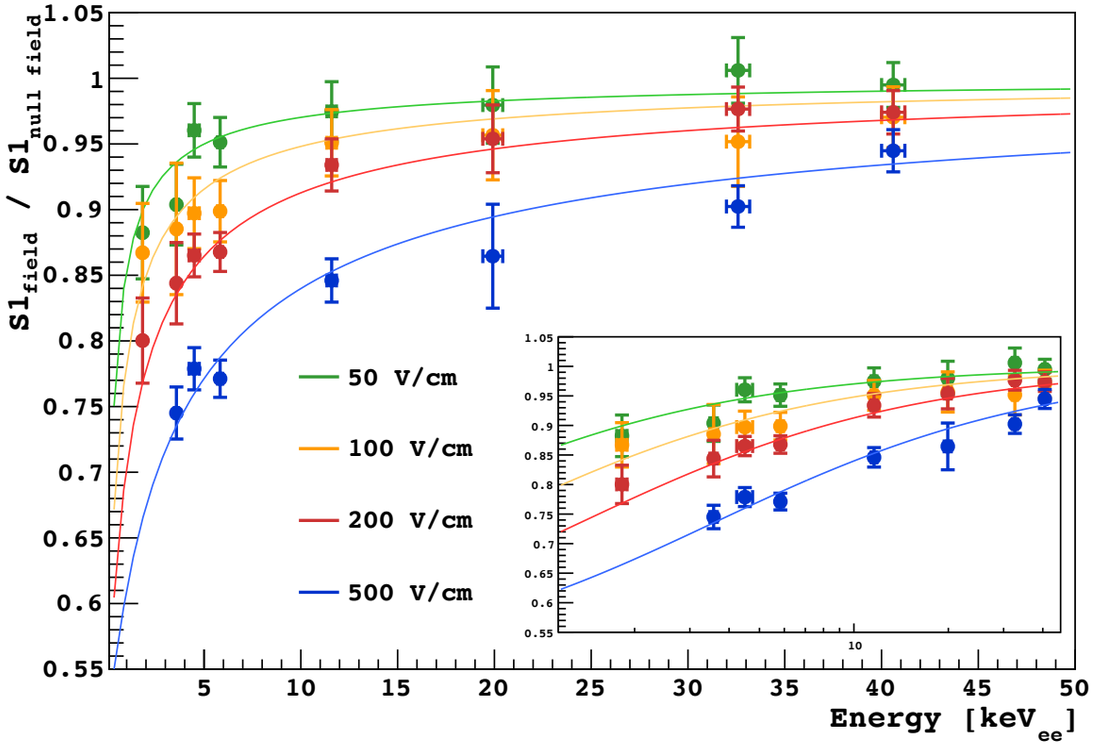
Doke-Birks' R goes to 1 at low energies while data shows that R should decrease

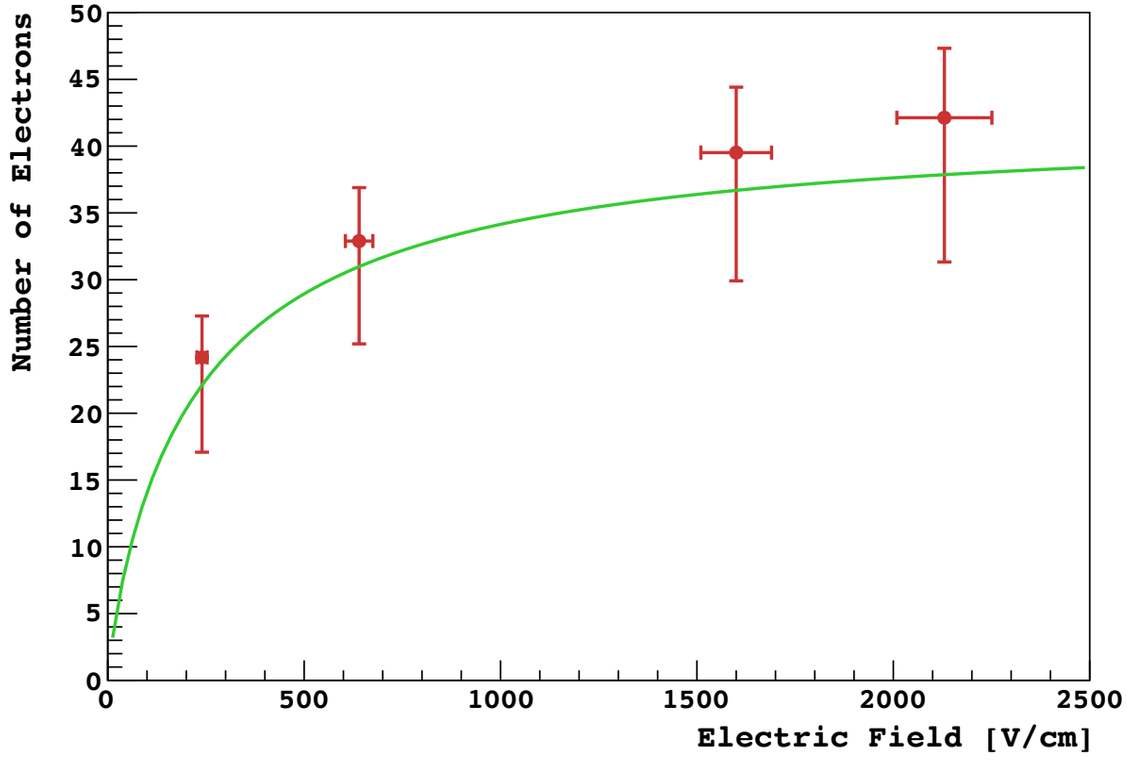
PARIS model consistent with ARIS ER data at 200 V/cm

Recombination probability in LAr: NR

Fit $S1_{null}/S1_{null\_field}$ data for NR with Thomas-Imel model (assuming $\alpha = 1$)

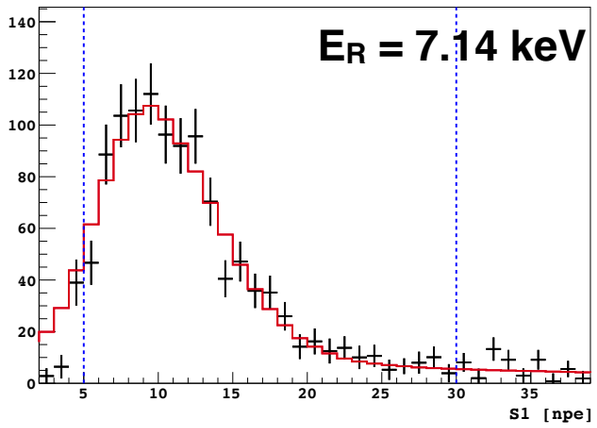
Tuned model compared to S2 at 6.7 keV data from Joshi et al. as a cross check

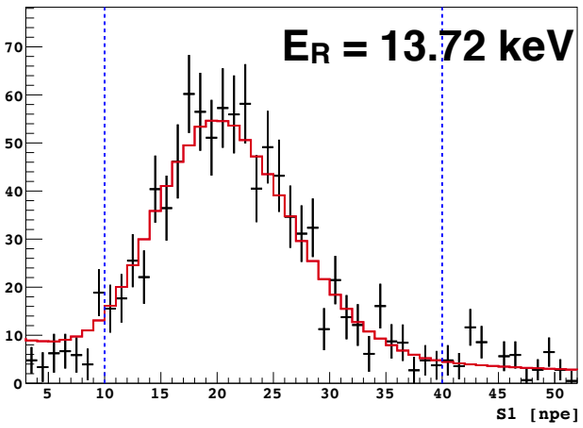


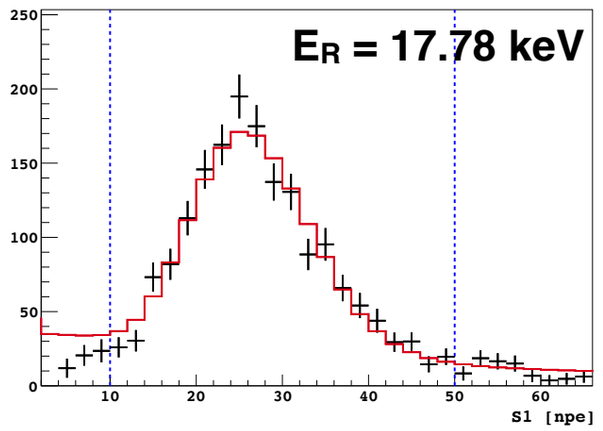


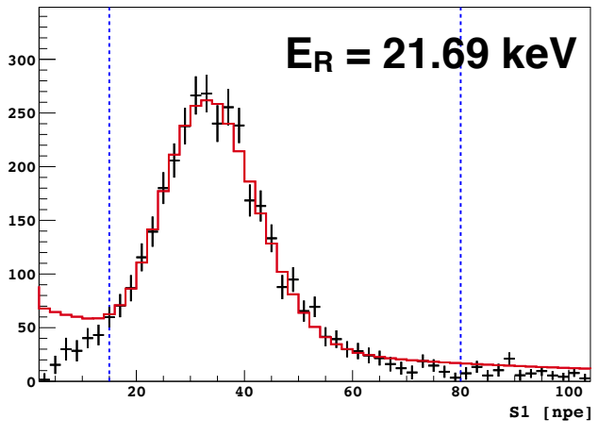
Thomas-Imel model reproduces both NR S1 and S2 (6.7 keV) at different drift fields

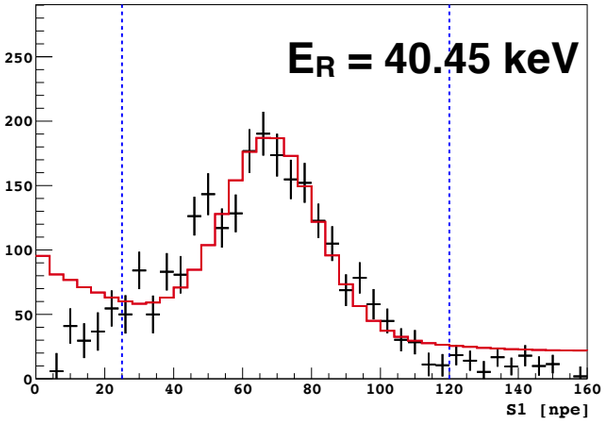
Fitted NR spectra

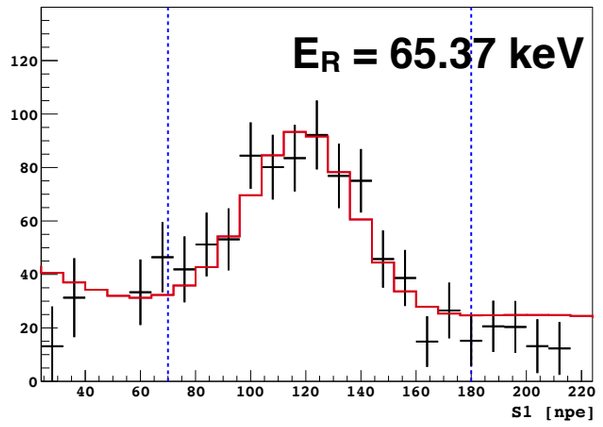


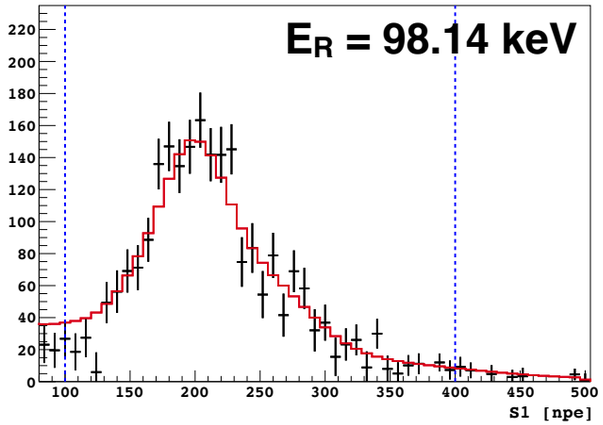


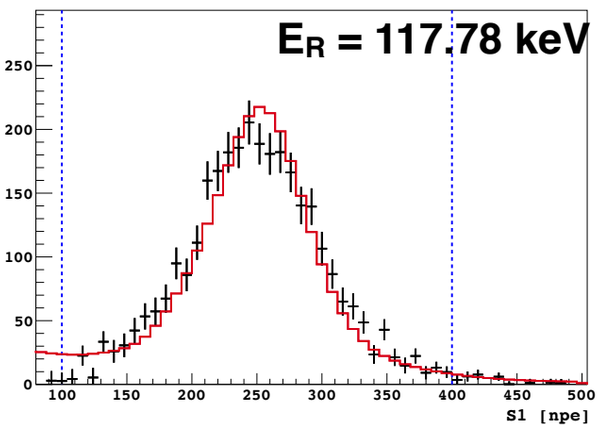








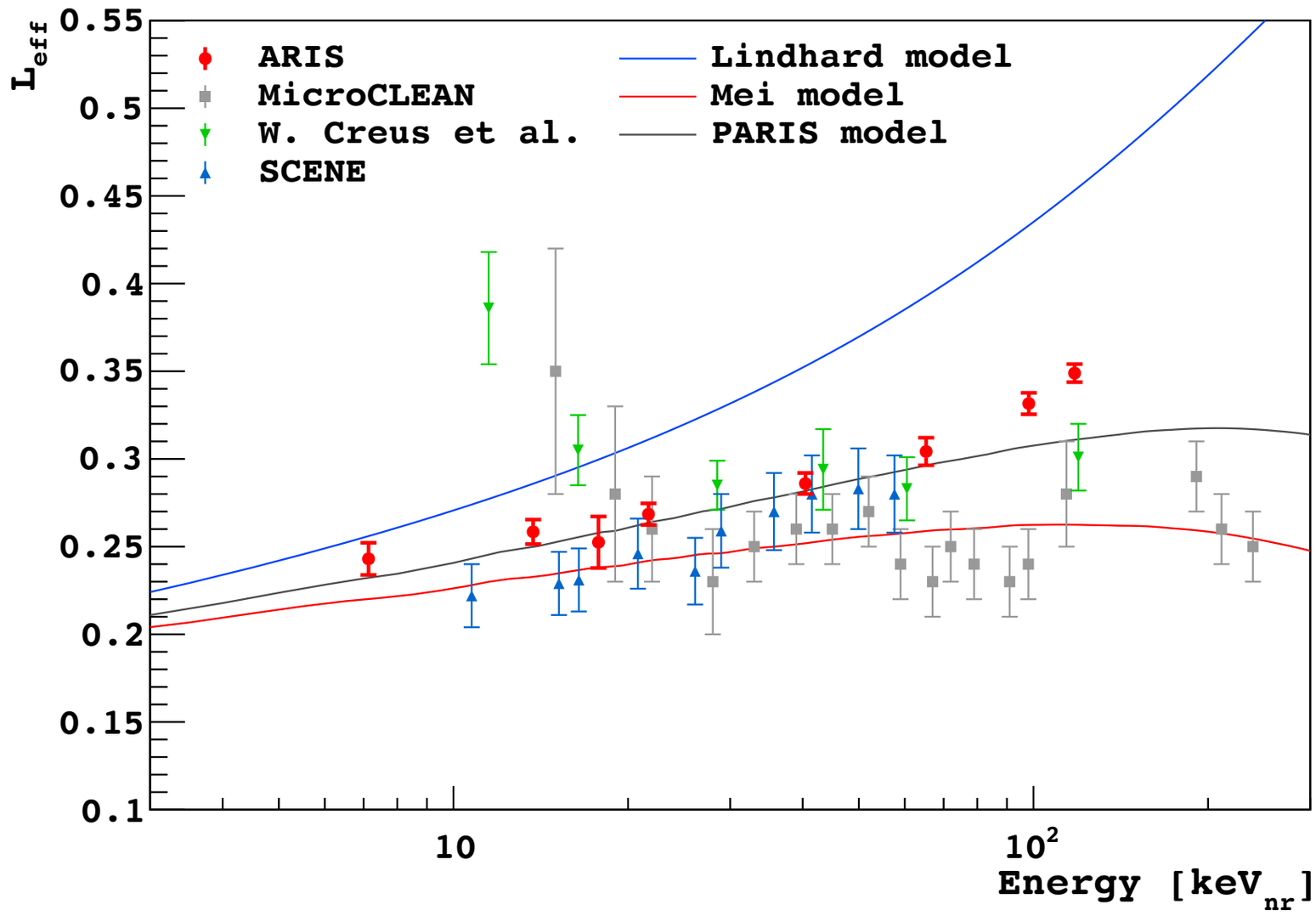




Data is **background subtracted**.
Fit performed with **L_{eff} as free parameter**

Quenching of NR

Most precise measurement of L_{eff} and lowest energy point

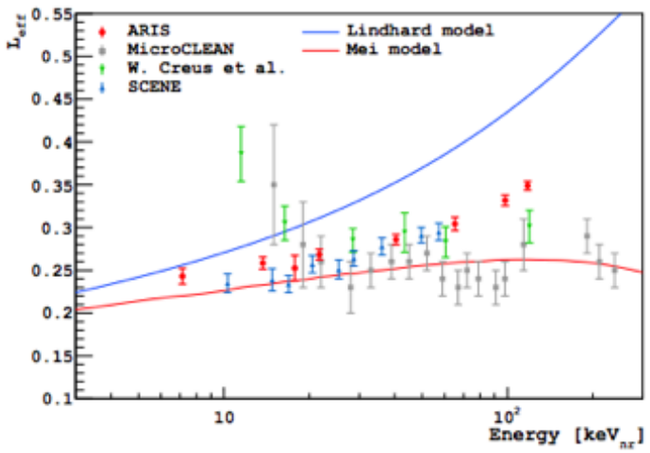


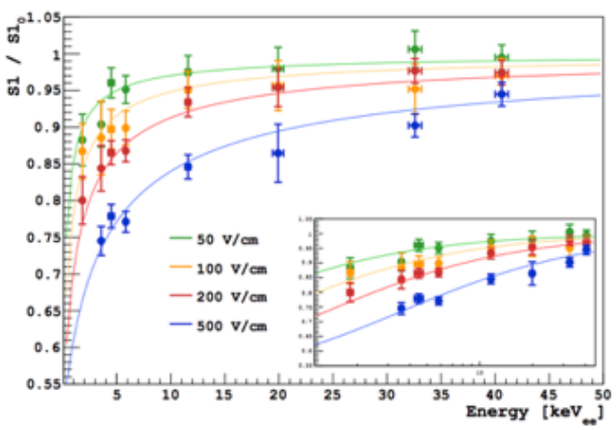
Good agreement with PARIS model up to 60 keV_{nr}

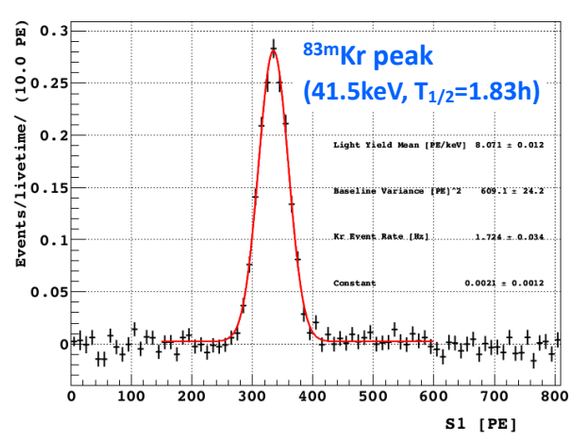
Ionization yield in DarkSide-50

$$S1_{DS50}(Enr) =$$

$$Leff = S1^{0V} / (E_{nr} \times LY_{ARIS}) \quad \times \quad S1^{200V}/S1^{0V} \times E_{nr} \quad \times \quad LY^{0V}_{DS50}$$







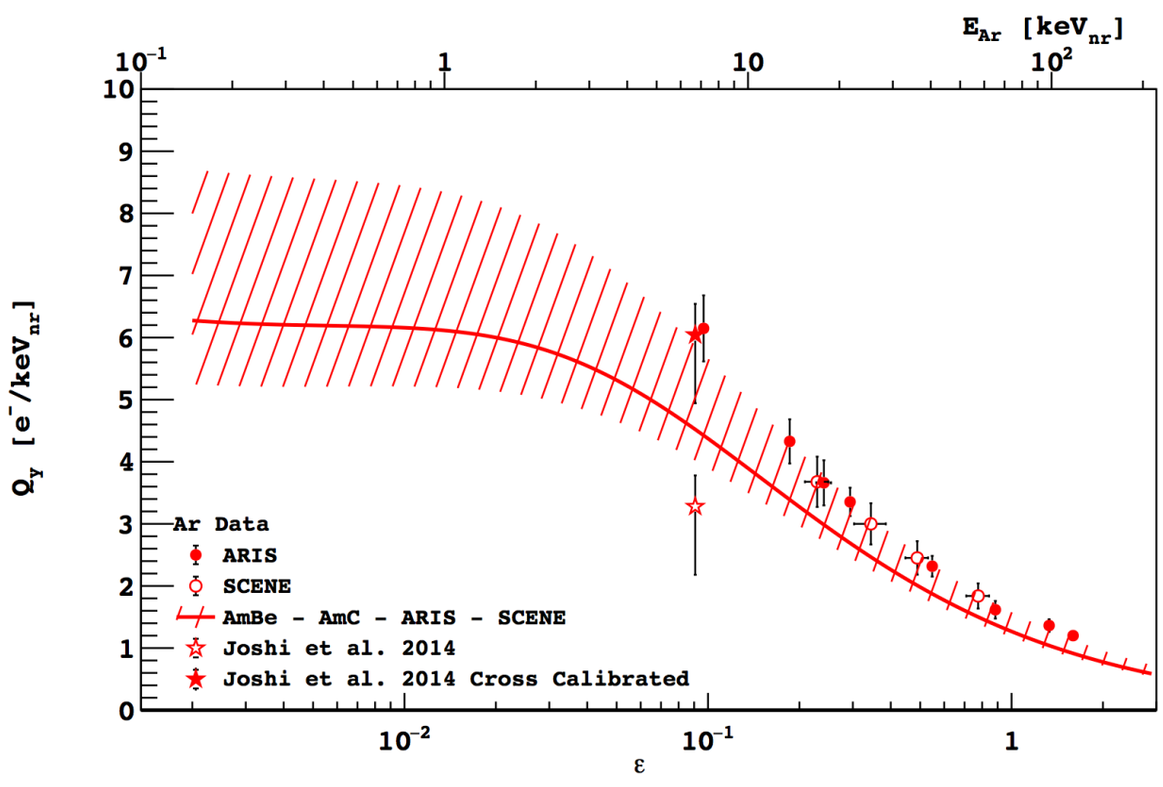
S1 in DS-50 reconstructed using ARIS L_{eff}

↓

S2 derived from S2/S1 vs S1 from AmBe in DS50 data

↓

Electron yield in DS-50



Conclusions

- **Scintillation yield** :
  - Linearity demonstrated within 1.6% in the [40, 511] keV_{ee} range

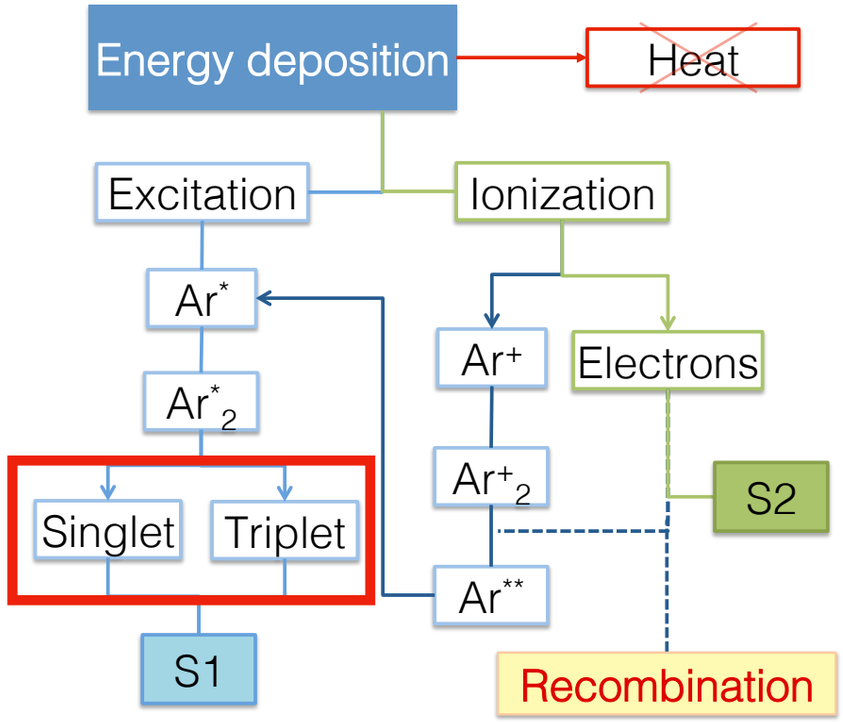
- **Measure of L_{eff}** in the [7, 120] keV_{nr} range:
  - Most accurate and lowest energy measure of L_{eff}

- Tuning of parametrization of **recombination probability** for ERs and NRs at different drift fields

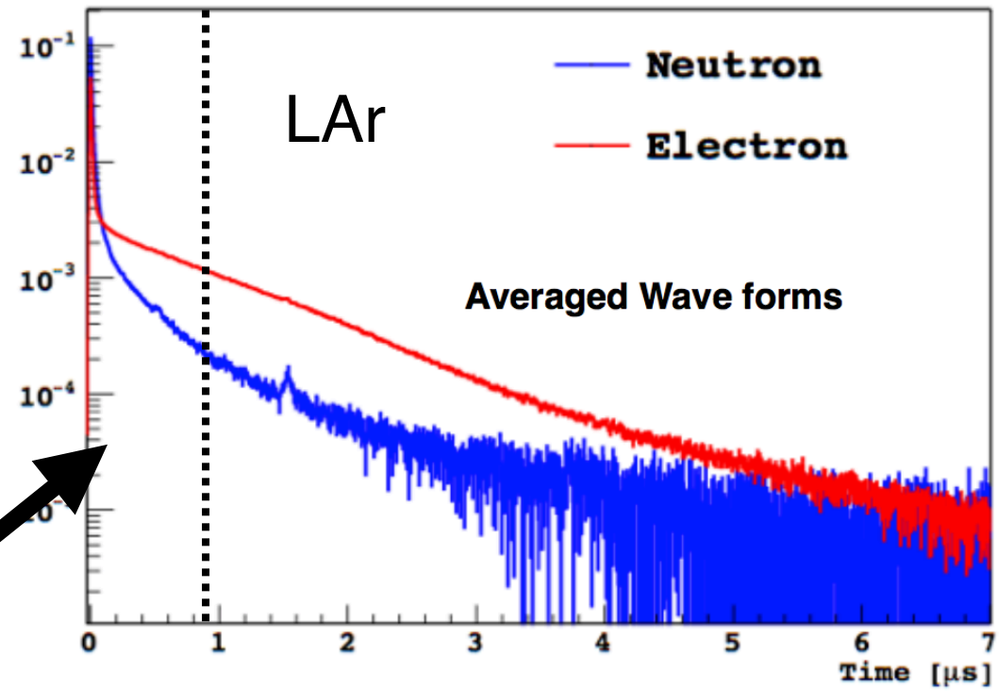
- Included in **DarkSide-50 low mass WIMP search** to extract the electron yield at low energies

Backup slides

ER/NR discrimination

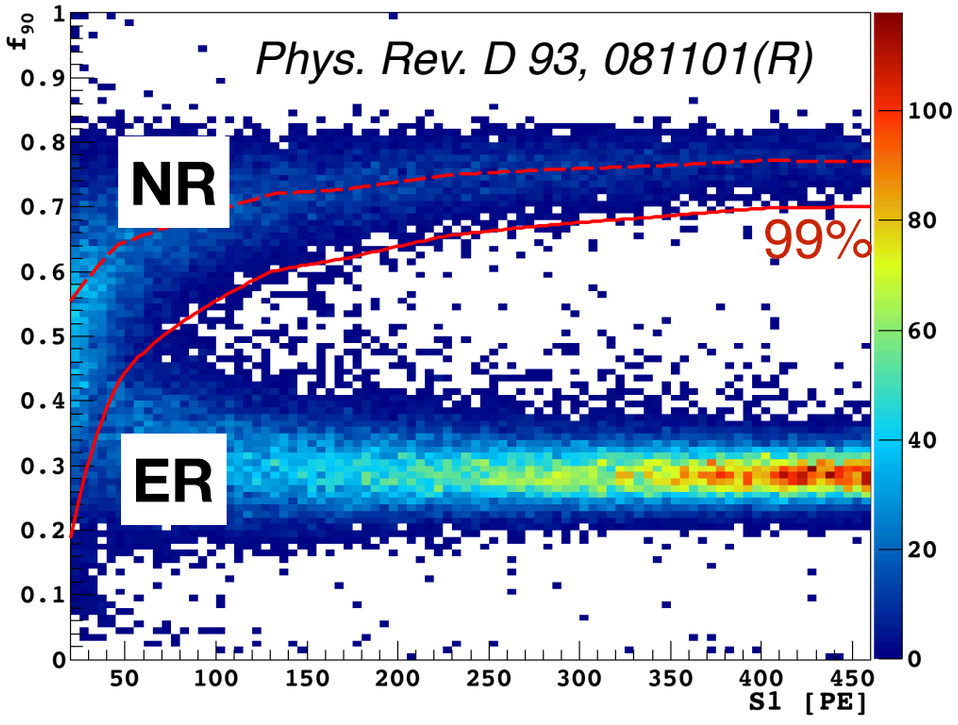


Pulse Shape Discrimination



PSD parameter **f_{90}** :
fraction of light seen in the **first 90 ns**

	Singlet	Triplet
Time constant	~7 ns	~1.6 μs
Population ratio for Electron ionizing	33%	67%
Population ratio for Nucleus ionizing	75%	25%

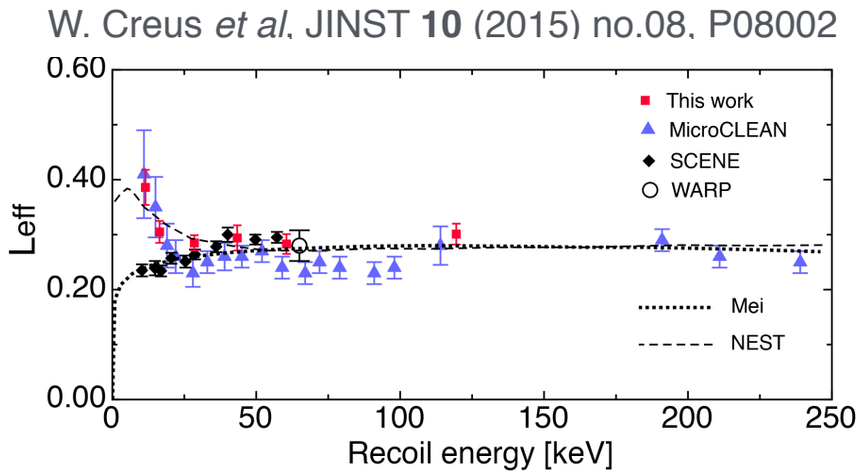


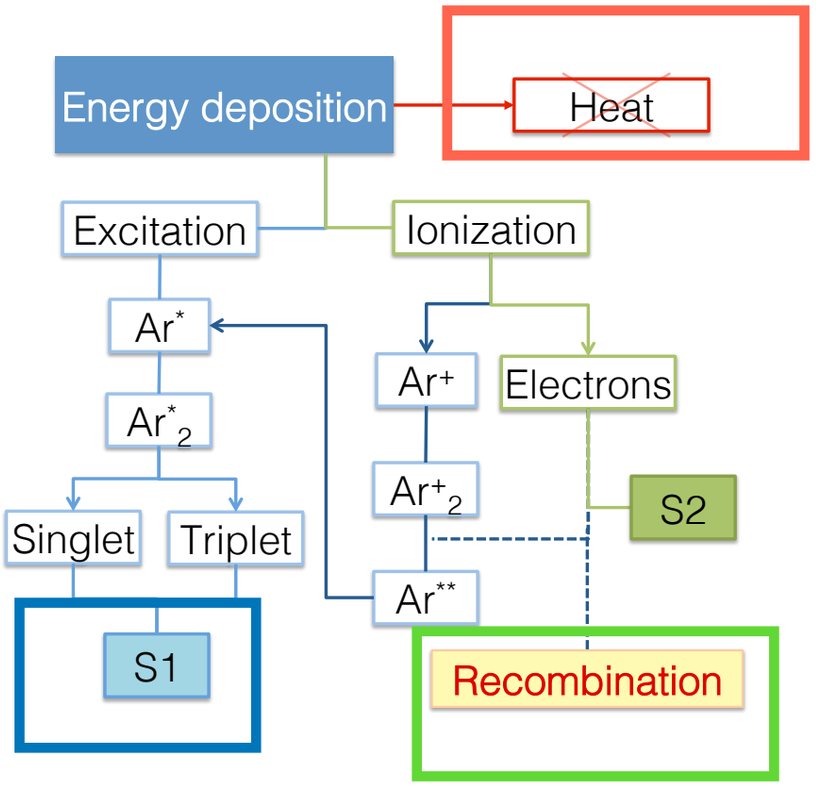
Liquid Ar ER rejection factor: ~10^8

WARP Astr. Phys 28, 495 (2008)

Energy scale calibration

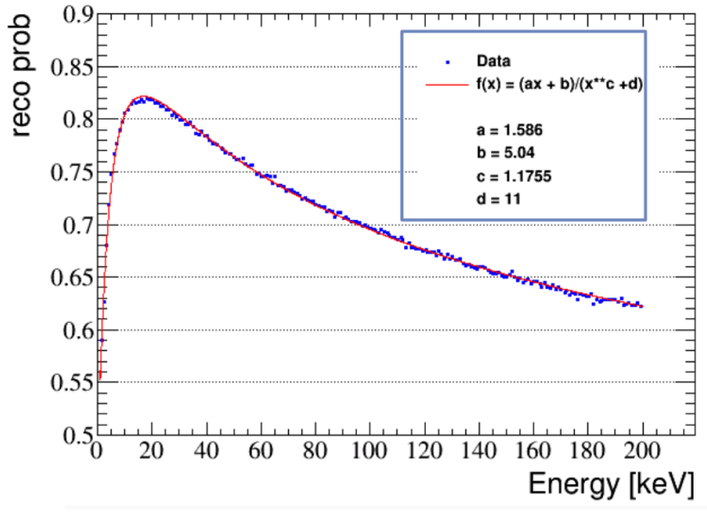
NR quenching





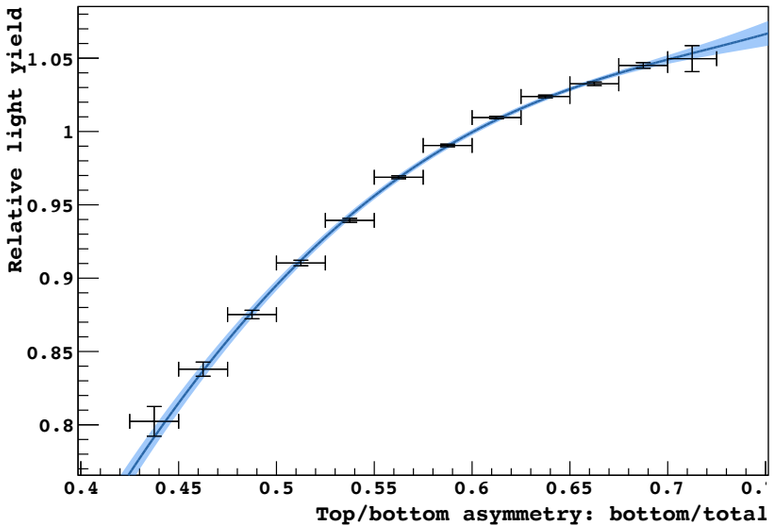
Light yield

Recombination probability



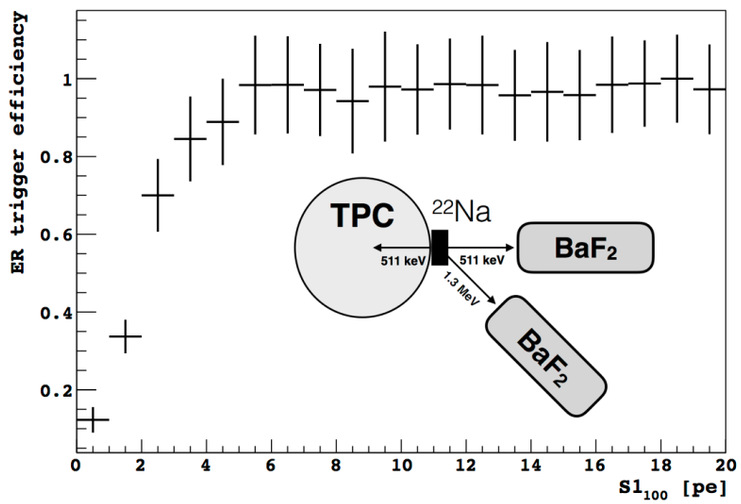
TPC calibration

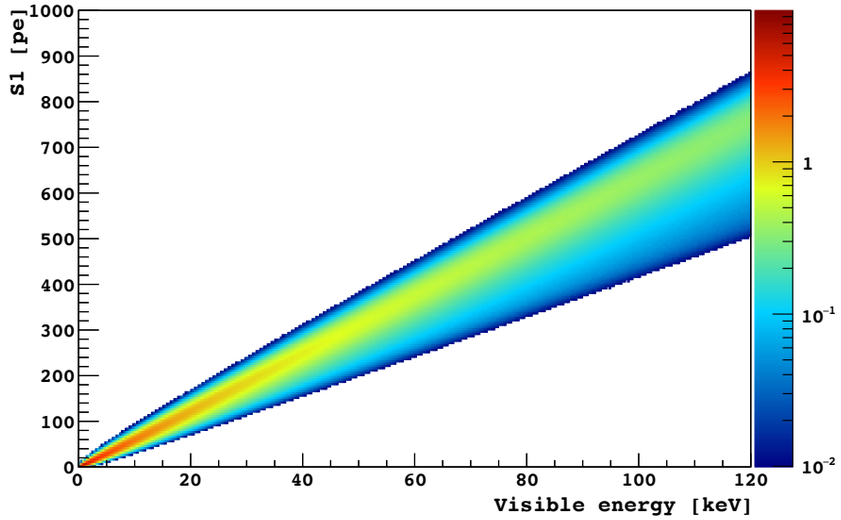
Top/bottom asymmetry



Efficiency ~ 1 for S1 > 15 PE

Trigger efficiency

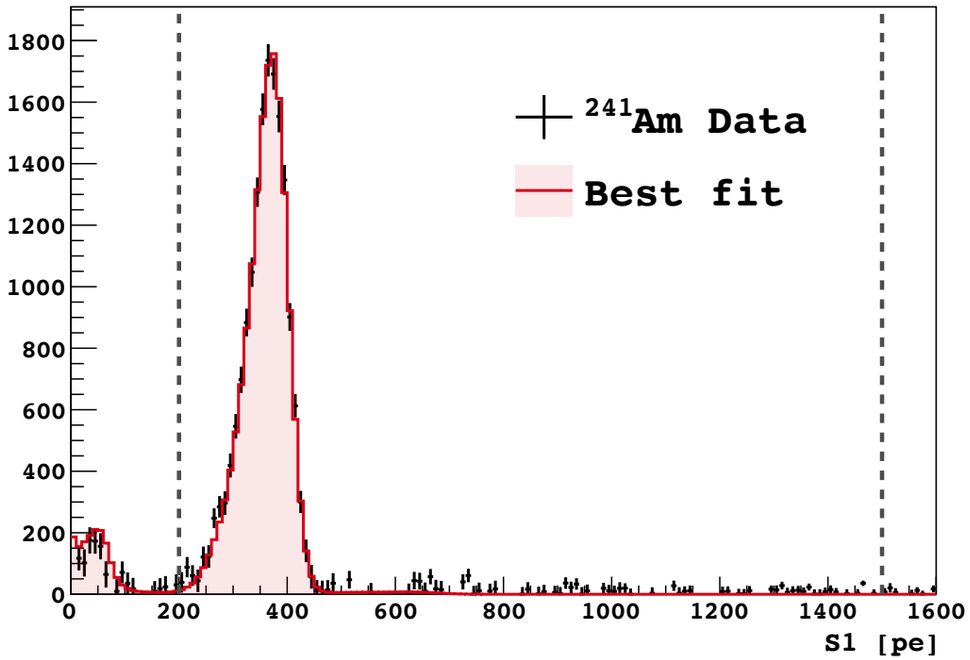


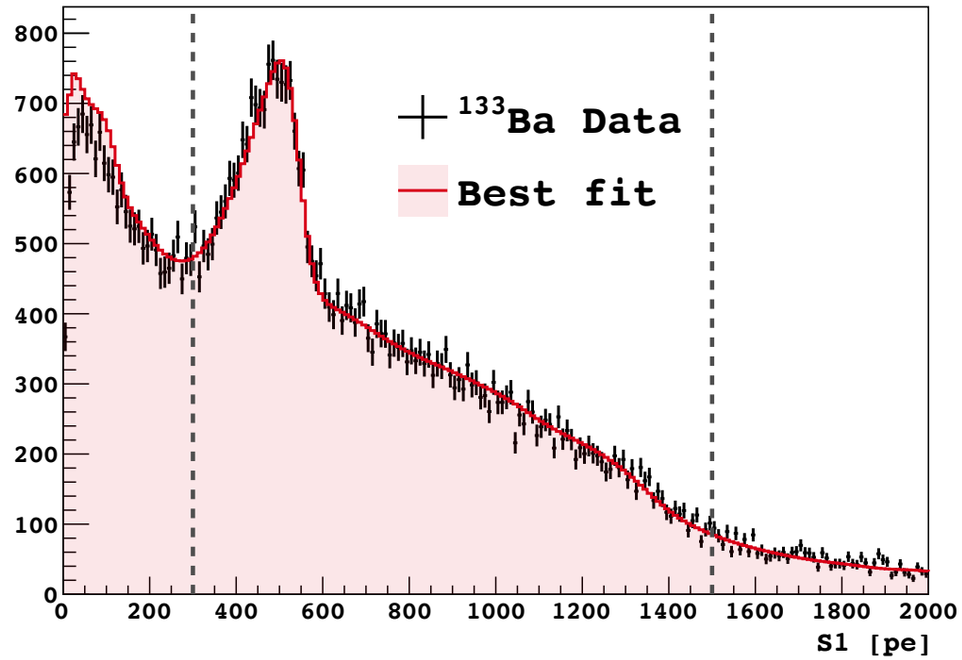


Response map to model detector response

Light yield in LAr

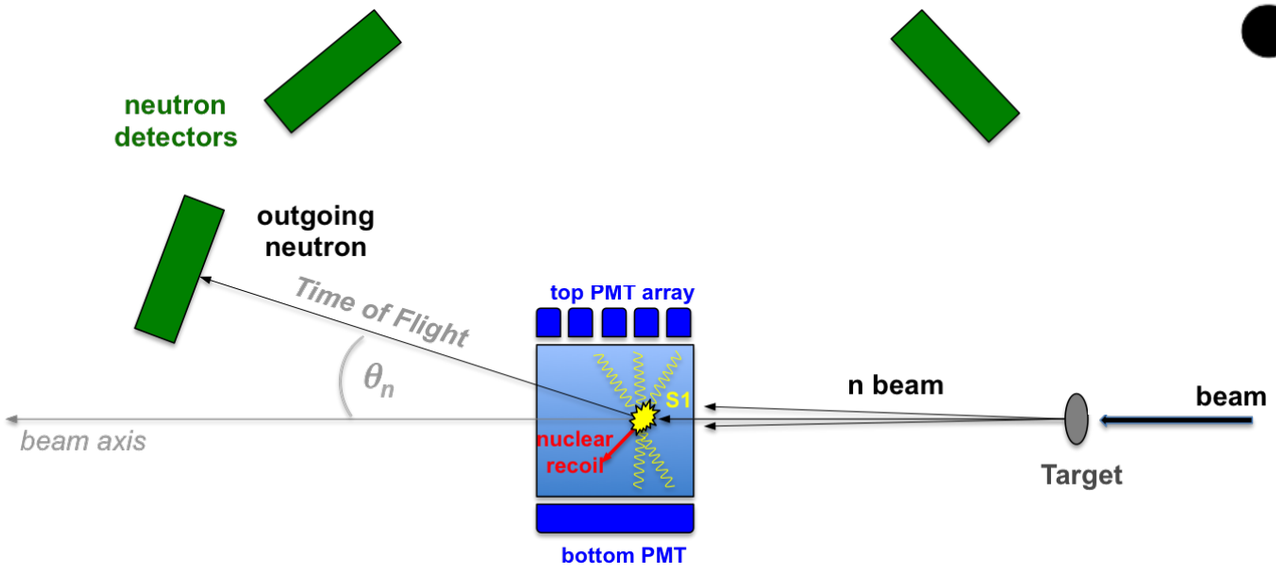
Light yield extracted using data from ^{241}Am and ^{133}Ba sources

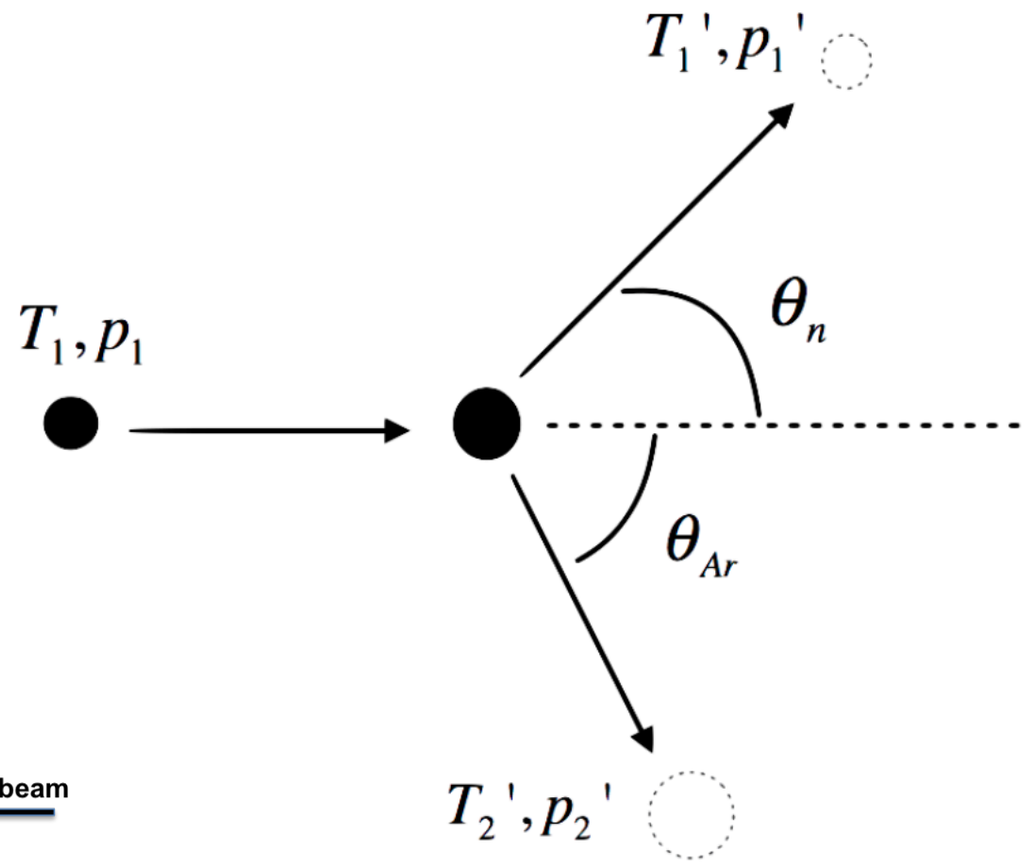




Combined average light-yield: 6.35 ± 0.05 pe / keV

Scattering angle/ recoil energy relation





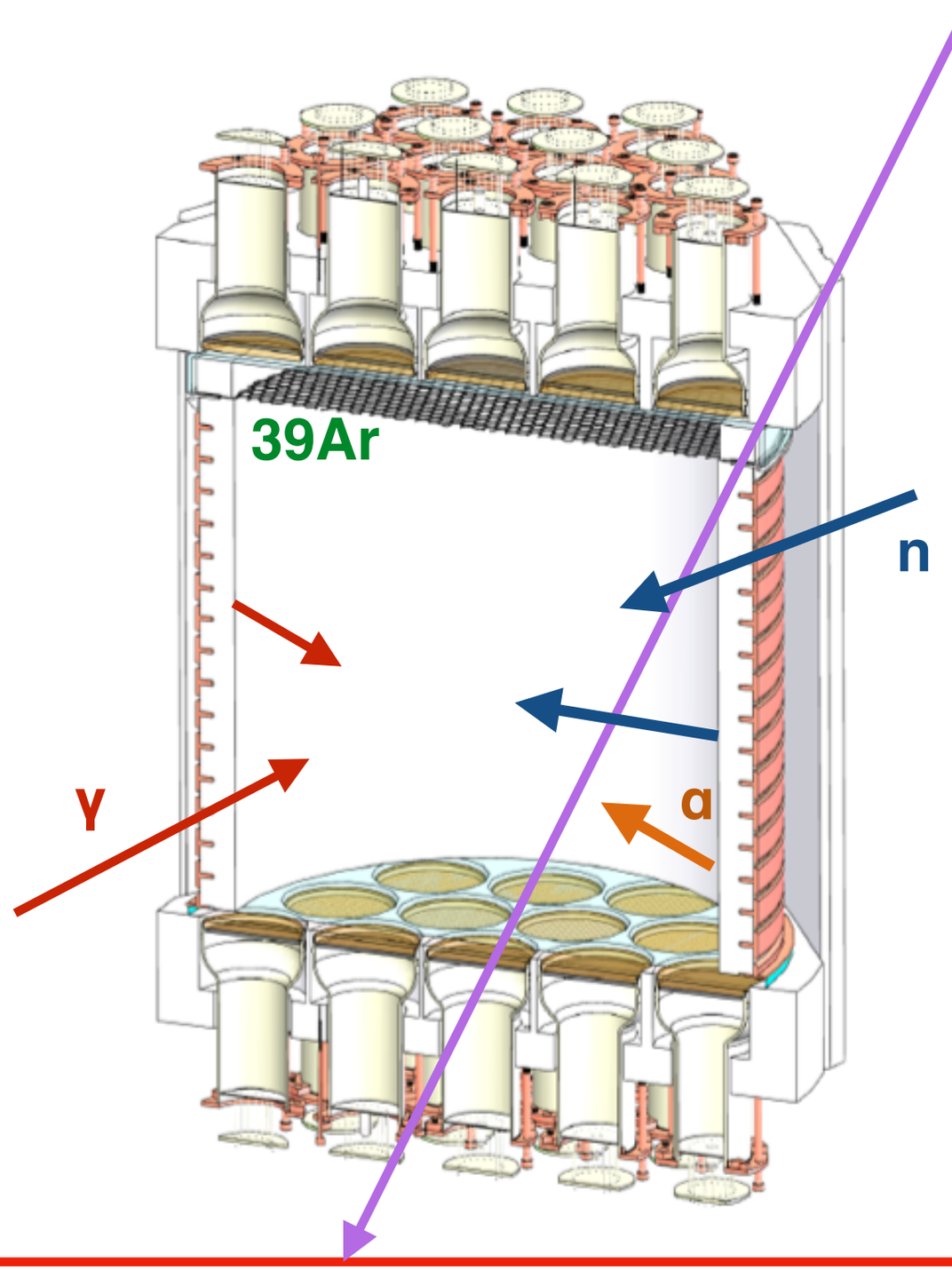
$$T_2' = T_1 \frac{2A}{(1+A)^2}(1-\cos\theta_n)$$

LAr TPC backgrounds

Electron recoils

^{39}Ar
~9x10^{4} evt/kg/day

γ
~1x10^{2} evt/kg/day



Nuclear recoils

Radiogenic neutrons
~6x10^{-4} evt/kg/day

Alpha particles
~10 evt/m^{2}/day

100 GeV, 10^{-45}cm^{2} WIMP Rate ~ 10^{-4} evt/kg/day