

Some thoughts on light readout in LAr

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Preliminary questions on light RO in LAr

Primary scintillation is used mainly for trigger.

“physics” questions for ParisROC optimisation:

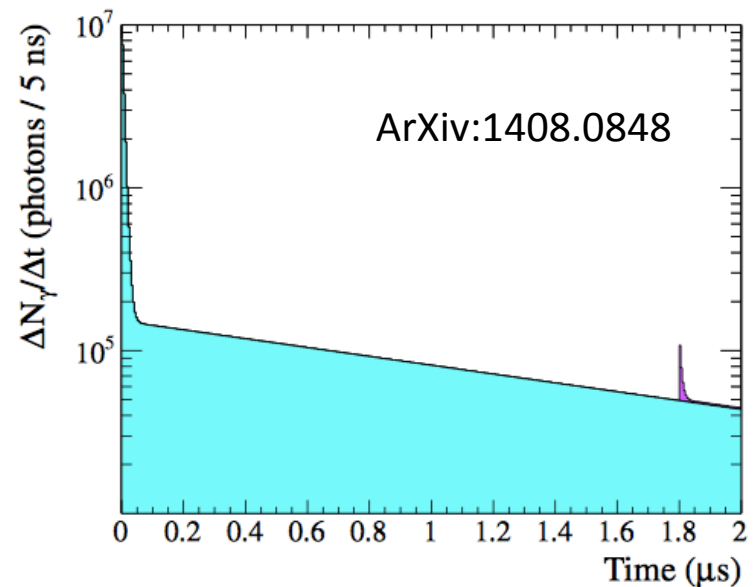
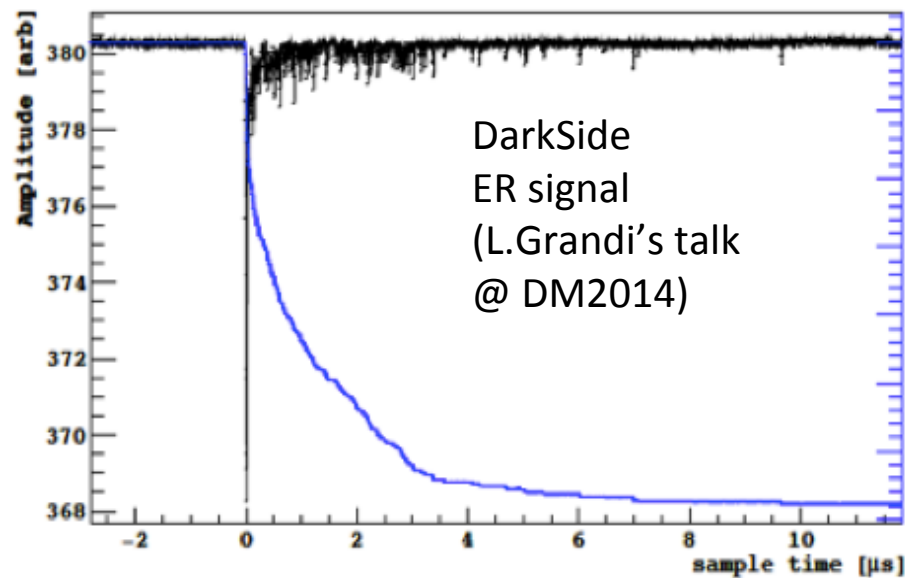
- timing of signals
- amplitude range
- is charge measurement necessary ?

Timing of signals

Primary scintillation in LAr :

- fast component (singlet) : $\tau_1=7\text{ns}$ ($\sim 23\%$ of light)
- slow component (triplet): $\tau_2=1.6\mu\text{s}$ ($\sim 77\%$ of light)

=> overall signal duration $\sim 5\mu\text{s}$



Amplitude of signals

1 GeV ν 's give $N_\nu \sim 1.6 \times 10^7$ [ArXiv:1408.0848] (not far from estimate with MIPs)

What is our light collection efficiency ?

- In ArDM, $\varepsilon = 4 \times 10^{-2}$
 - Extrapolation to WA105 :
 - optical coverage 68% \rightarrow 8% and only bottom $\rightarrow 1/17$
 - non-reflective walls: from ArDM geometry $\rightarrow 1/3$?
- $\Rightarrow \varepsilon \sim 8 \times 10^{-4}$ (need to check, with simulations for example)

So from 1 GeV ν 's, we should get ~ 10000 PE

- divide by 36 PMTs $\Rightarrow \sim 300$ PEs / PMT / GeV ν
- neutrino energies up to 8 GeV \Rightarrow up to ~ 2400 PEs/PMT
- MeV physics will be at < 1 PE/PMT

\Rightarrow Dynamic range : **1-3000 PEs**

Questions on light RO in LAr

Primary scintillation is used mainly for trigger.

“physics” questions:

- timing of signals

Fast component: $\tau_1=7\text{ns}$ (~23%)
Slow component: $\tau_2=1.6\mu\text{s}$ (~77%)
=> overall $\sim 5\mu\text{s}$



- amplitude range

from 1 PE (MeV physics) to
 ~ 3000 PE per PMT (GeV physics)



- is charge measurement necessary ?



Not strictly for trigger, but may be useful for calorimetry !
cfr M.Sorel, arxiv.org/pdf/1405.0848.pdf

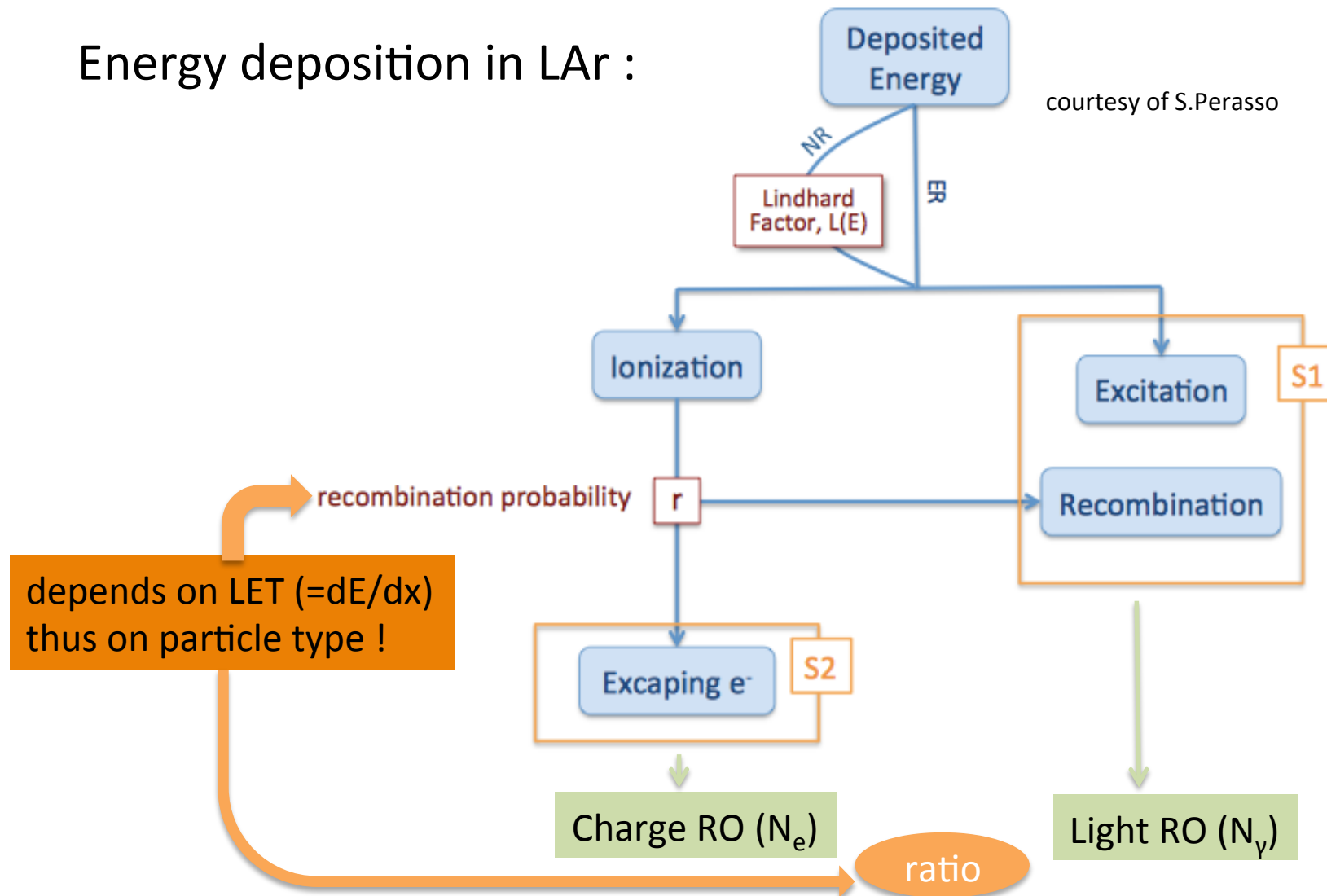
Neutrino energy measurement in LAr

- E_ν from lepton momentum and direction
good approximation only for CC-QE interactions
- E_ν from calorimetric energy reconstructions
suffers from fluctuations due to:
 1. nuclear effects in ν interactions
 2. leakage out of the active detector volume
 - 3. energy carried away by secondary ν 's**
 4. quenching of ionization and excitation
 - 5. electron-ion recombination**
 6. e- attachment to impurities
 7. electronic noise

ArXiv:1408.0848 => measurement of primary scintillation light can correct for 3. and 5.

Electron-ion recombination

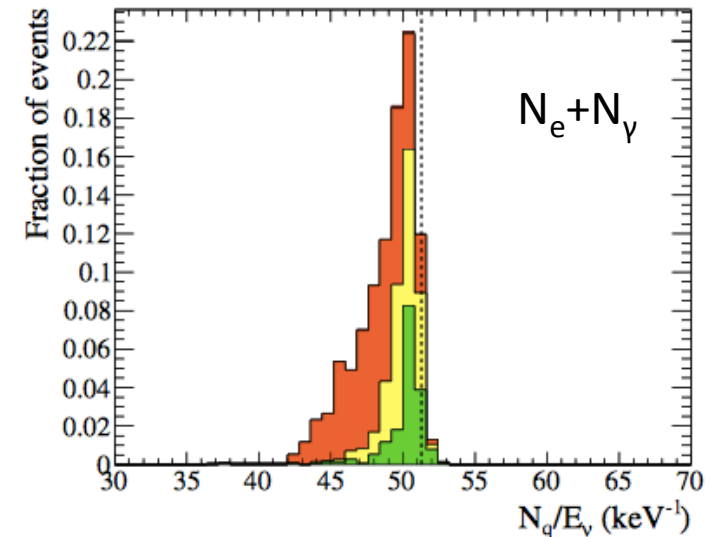
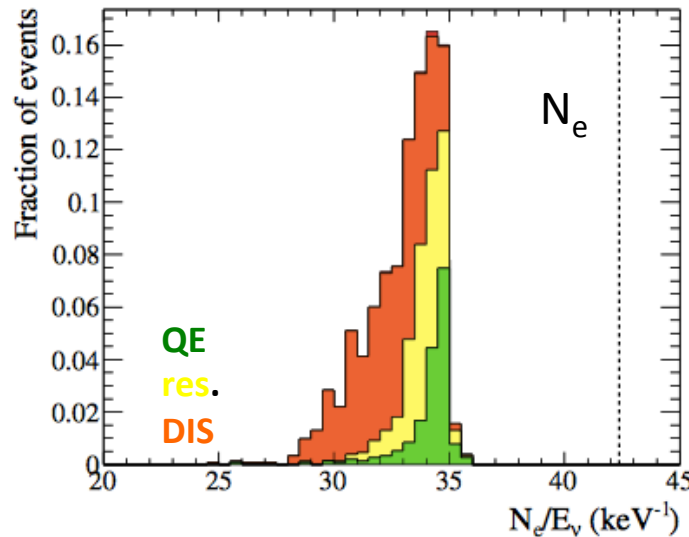
Energy deposition in LAr :



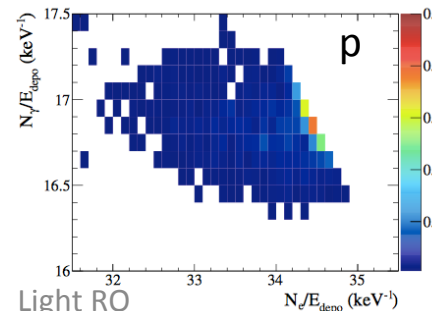
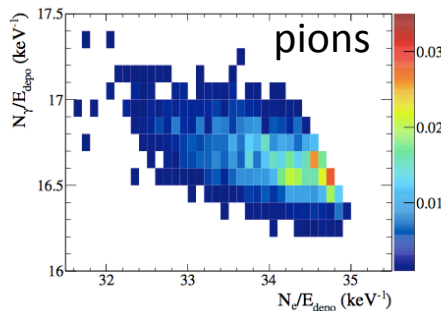
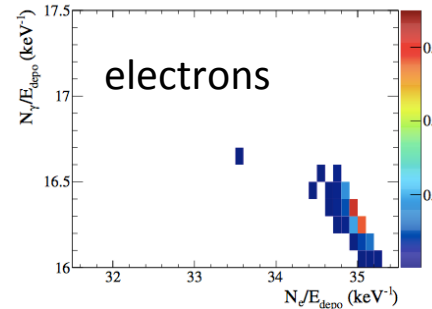
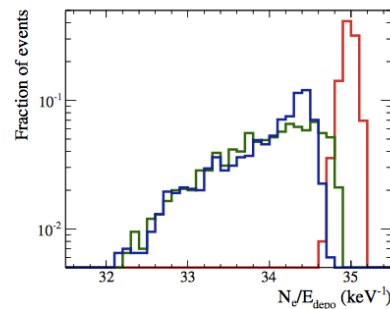
Electron-ion recombination

ArXiv:1408.0848

Resolution



Anticorrelation

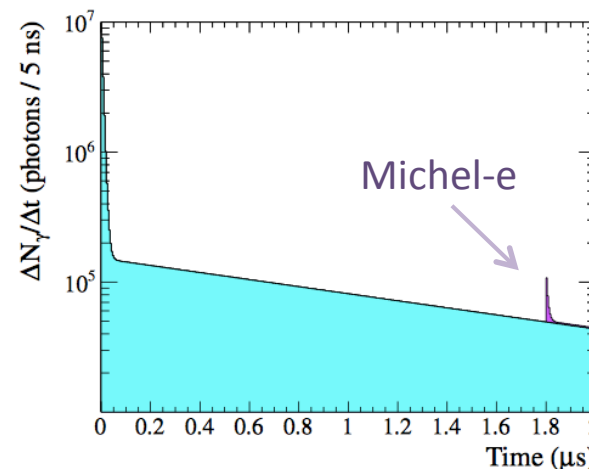


Conclusion :
Primary scintillation
+ ionisation
provides a better
measurement of ν
energy than
ionization alone

Missing energy due to secondary ν 's

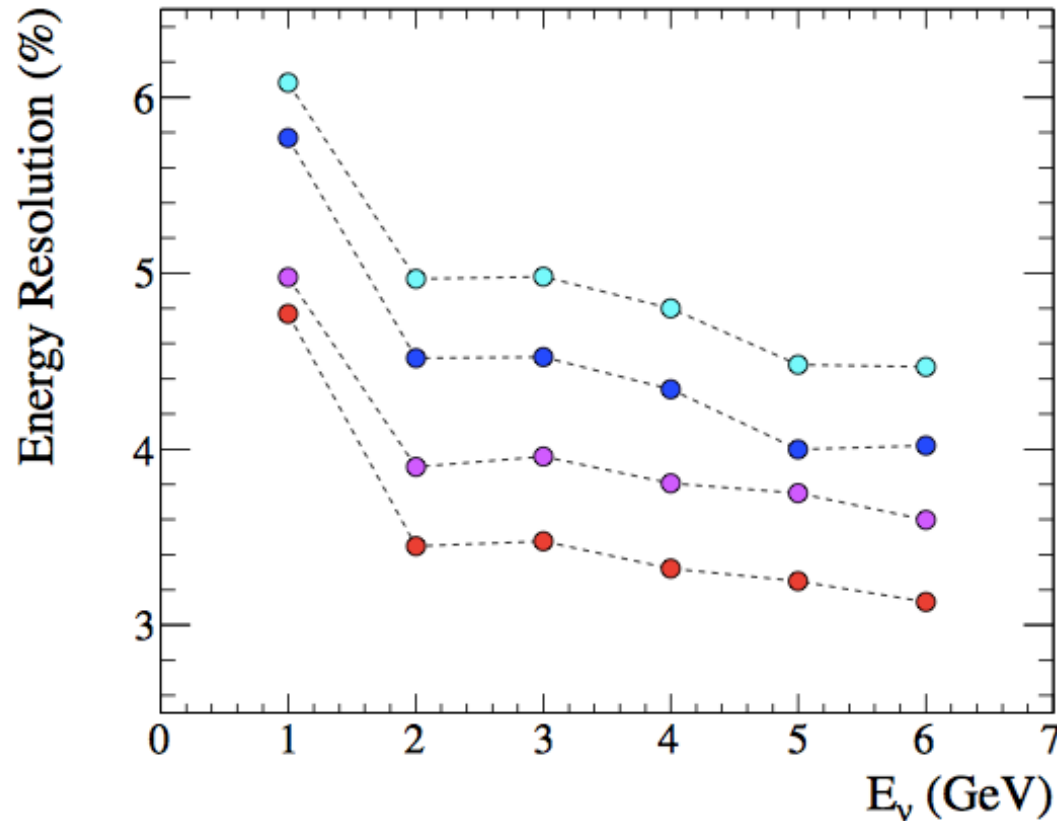
ArXiv:1408.0848

- Missing energy due to secondary ν 's from μ decays is a good estimate of total energy carried away by secondary ν 's.
- If a detector is capable to tag Michel electrons from μ decay at rest and to measure their energy, the total Emiss can be inferred
- Complication: μ lifetime
 \sim slow scintillation τ
- However, fraction of slow scintillation light decrease with energy and with impurities, so Michel-e tagging may be done with high efficiency (cfr ICARUS)



Improvement in calorimetric E_ν

ArXiv:1408.0848



Charge RO only

+ ionization corr. from light RO

+ Emiss from secondary ν 's

+ both corrections

Conclusion: primary scintillation measurement can improve ν energy measurement (complementary to PANDORA offline approach)
 \Rightarrow charge measurement in light RO is useful

Improvement in calorimetric E_ν

Detector requirements for light RO to be useful:

- average photon yield: $N_\gamma \sim 1.6 \times 10^7$ from 1 GeV ν 's
- need statistical fluctuations to be $< \sim 1\% \Rightarrow$ light collection efficiency $\epsilon > 6 \times 10^{-4}$

ArXiv:1408.0848

Our extrapolation to WA105 was $\epsilon \sim 8 \times 10^{-4}$: ok !
(need to check all this....)

Conclusion: primary scintillation measurement can improve ν energy measurement (complementary to PANDORA offline approach)
 \Rightarrow charge measurement in light RO is useful
 \Rightarrow tests in WA105 will be crucial

Summary

We have tried to ask some preliminary “physics” questions to define light RO specifications

- Signal timing: risetime \sim ns, total \sim 5 μ s
- Dynamic range: 1 - \sim 3000 PE
- Charge measurement in light RO can be useful for calorimetric measurement of E_ν ; WA105 has the appropriate requirements and can be an ideal test bench for the principle

Questions under discussion: impact of high rate in WA105 (cosmic μ \sim 7 kHz)

- overall readout time
- use of scintillation light for triggering (likely impossible in WA105, it will be just for test)
- ringing/blinding of PMTs ?