Some thoughts on light readout in LAr

APC / LAPP / Omega

Ongoing activity for light RO in LAr

1) Preliminary questions on light-RO in LAr [A.T.]

Primary scintillation is used mainly for trigger.

"Physics" questions for ParisROC optimisation:

- time properties of signals
- amplitude range
- is charge measurement necessary ?

2) High event rate in WA105:
what consequences for light-RO ? [A.T.]

3) Latest ideas on RO chip installation [N.N.]

4) Plans for tests of ParisROC [N.N.]

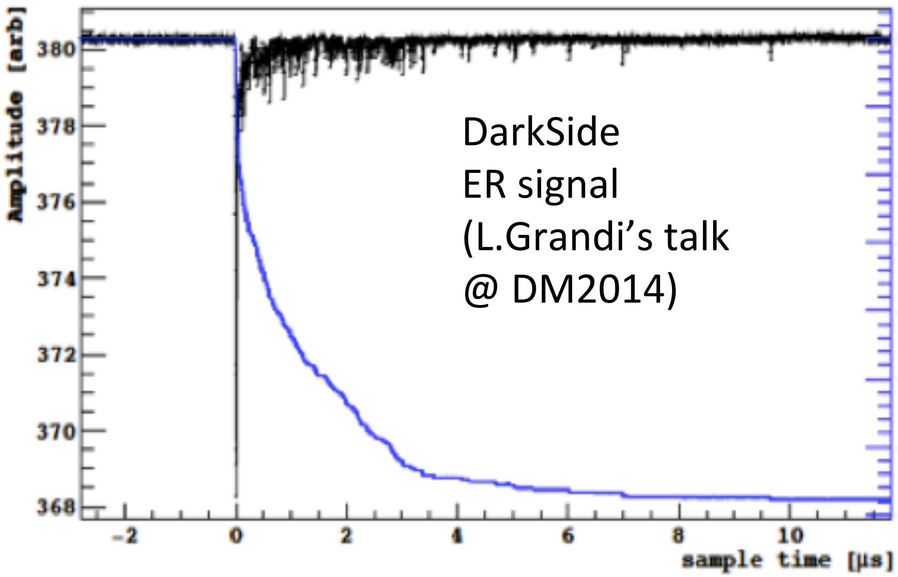
1) Preliminary physics questions

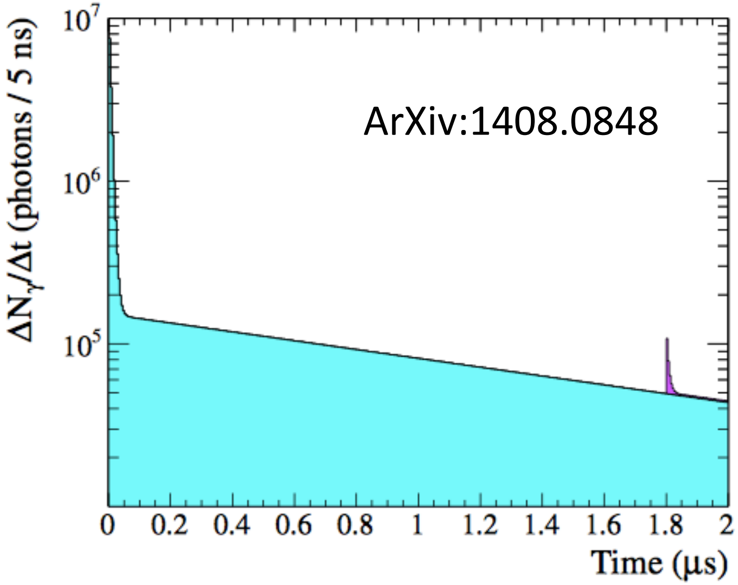
Time properties of signals

Primary scintillation in LAr :

- fast component (singlet) : τ_1=7ns (~23% of light)
- slow component (triplet): τ_2=1.6μs (~77% of light)

=> overall signal duration ~5μs





Amplitude of signals

1 GeV ν's give N_γ~$1.6x10^7$ [ArXiv:1408.0848] (not far from estimate with MIPs)

What is our light collection efficiency ?

- In ArDM, $\varepsilon = 4x10^{-2}$
- Extrapolation to WA105 :
  - optical coverage 68% -> 8% and only bottom -> 1/17
  - non-reflective walls: from ArDM geometry -> 1/3 ?

  => $\varepsilon \sim 8x10^{-4}$ (need to check, with simulations for example)

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

- divide by 36 PMTs => ~ 300 PEs / PMT / GeV ν
- neutrino energies up to 8 GeV => up to ~2400 PEs/PMT
- MeV physics will be at O(1 PE/PMT)

=> 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: τ_1=7ns (~23%)
  Slow component: τ_2=1.6μs (~77%)
  => overall ~5μs

  ✔

- 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

- Eν from lepton momentum and direction

  good approximation only for CC-QE interactions
- Eν from calorimetric energy reconstructions

  suffers from fluctuations due to:

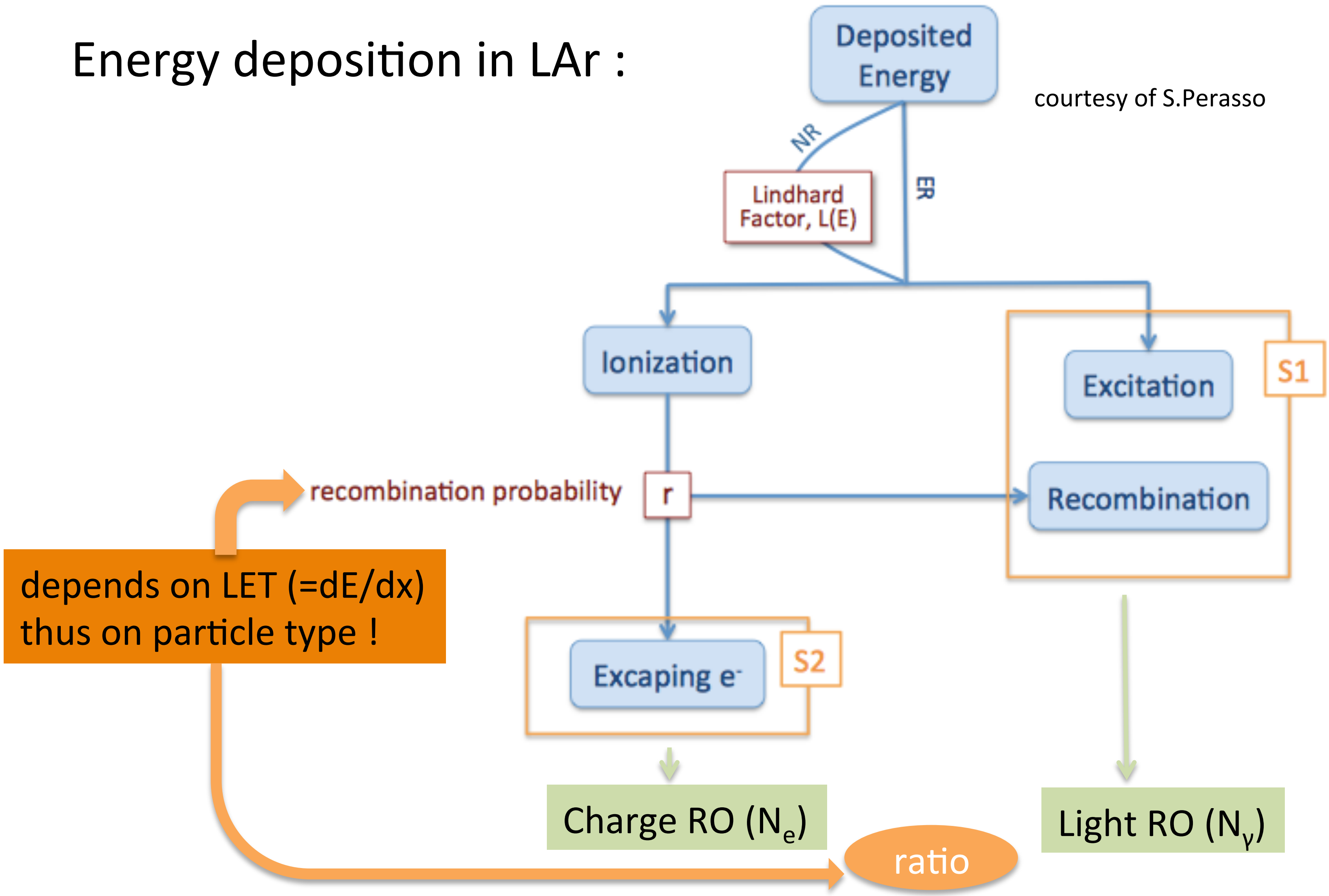
  1. nuclear effects in ν interactions
  2. leakage out of the active detector volume
  3. **energy carried away be secondary ν's**
  4. quenching of ionization and excitation
  5. **electron-ion recombination**
  6. e- attachment to impurities
  7. electronic noise

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

Electron-ion recombination

Energy deposition in LAr :

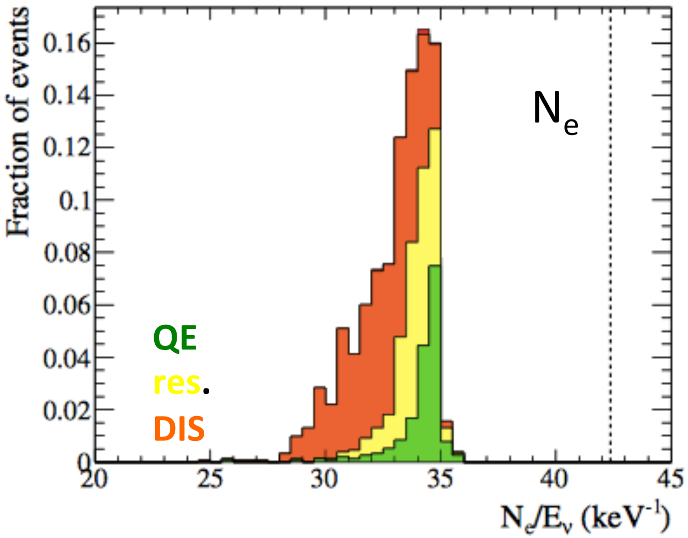
courtesy of S.Perasso

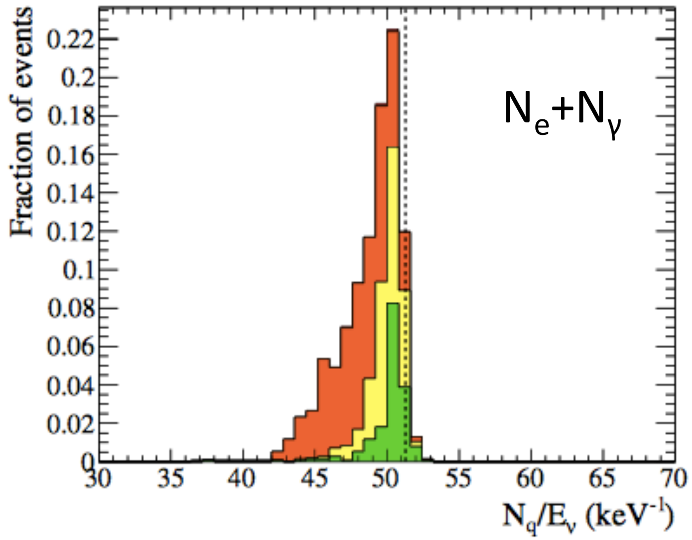


Electron-ion recombination

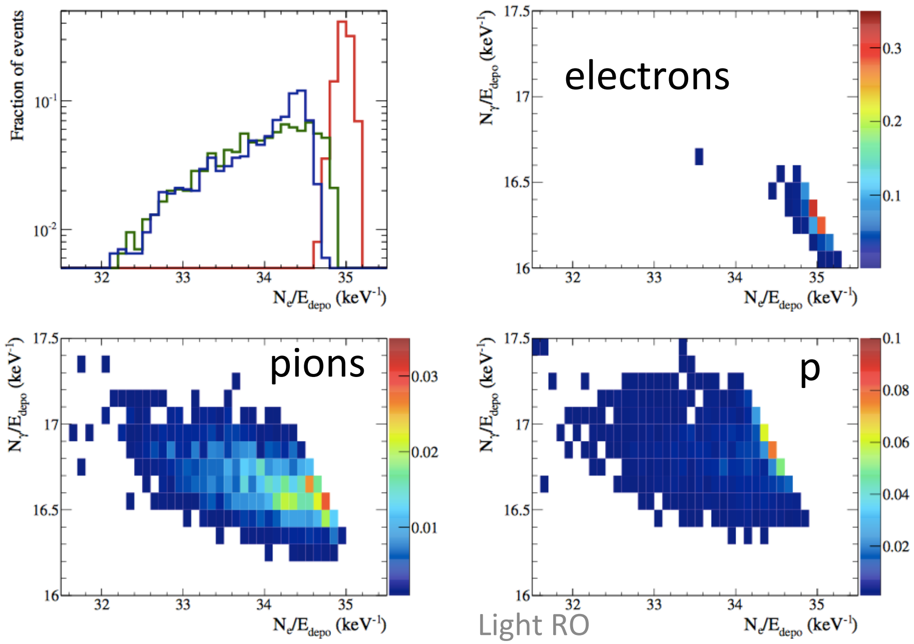
ArXiv:1408.0848

Resolution





Anticorrelation

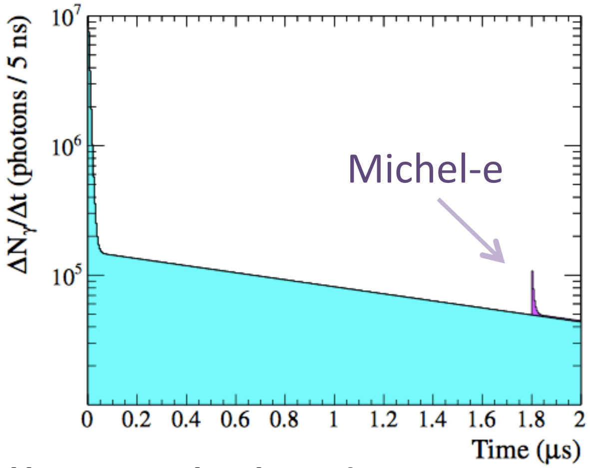


Conclusion :
Primary scintillation
+ ionisation
provides a better
measurement of ν
energy than
ionization alone

Missing energy due to secondary ν's

ArXiv:1408.0848

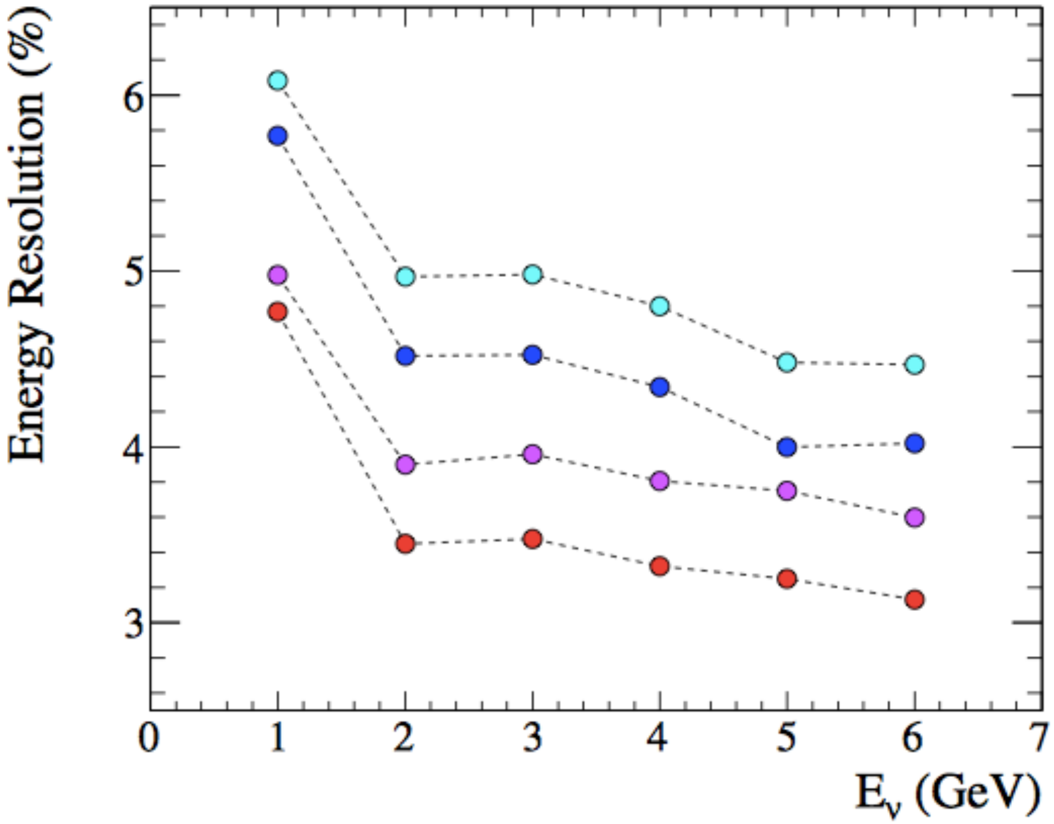
- Missing energy due to secondary ν's from μ decays is a good estimate of total energy carried away by secondary ν's.
- If a detector is capable to tag Michel electrons from μ decay at rest and to measure their energy, the total Emiss can be inferred
- Complication: μ lifetime
  ~ slow scintillation 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)
⇒ 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 <~1% => light collection efficiency $\varepsilon > 6 \times 10^{-4}$

ArXiv:1408.0848

Our extrapolation to WA105 was $\varepsilon \sim 8 \times 10^{-4}$: ok !

(need to check all this....)

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

Summary on “physics” requirements

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

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

These features will be implemented for the next version of the ParisROC (also useful for JEM-EUSO), probably next year

Meanwhile, tests will be performed with the existing version

2) Impact of rate in WA105

Rate in WA105

The event rate in WA105 will be dominated by cosmic μ's (~7 kHz ~ $10^4 s^{-1}$)

- overall readout time of the ParisROC should be <~0.1 ms. It is currently 100μs if all channels are hit. OK

- will it really be possible to use of scintillation light for triggering ? during the drift of 1 particle, 10-20 muons will cross the detector…

- muons give very large signals: impact of ringing PMTs ? to be studied (need to lower PMT gain ?)

3) Latest ideas on RO for WA105

4) Plans for ParisROC tests

➔ see talk by N.N.