WA105

A Large Scale Prototype for Future Long Baseline Neutrino Detectors

Thorsten Lux

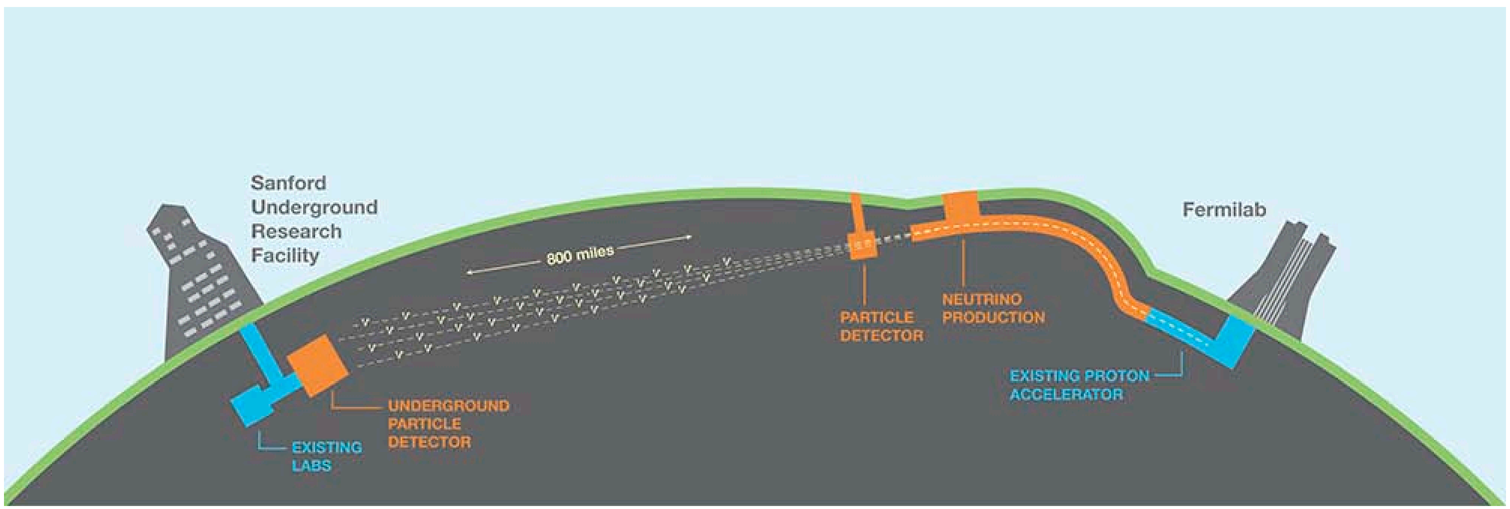
Why a Next Generation?

- Is there any CP violation in the neutrino sector?
- Normal or inverted neutrino mass hierarchy?
- Precise measurement of oscillation parameters.

- What happens in the core of supernovae?
- Is the proton stable?

Like T2K but **BIGGER**

- Longer baseline: 1300 km
- higher intensity neutrino beam
- Far detector: huge LAr TPC instead of water Cherenkov detector

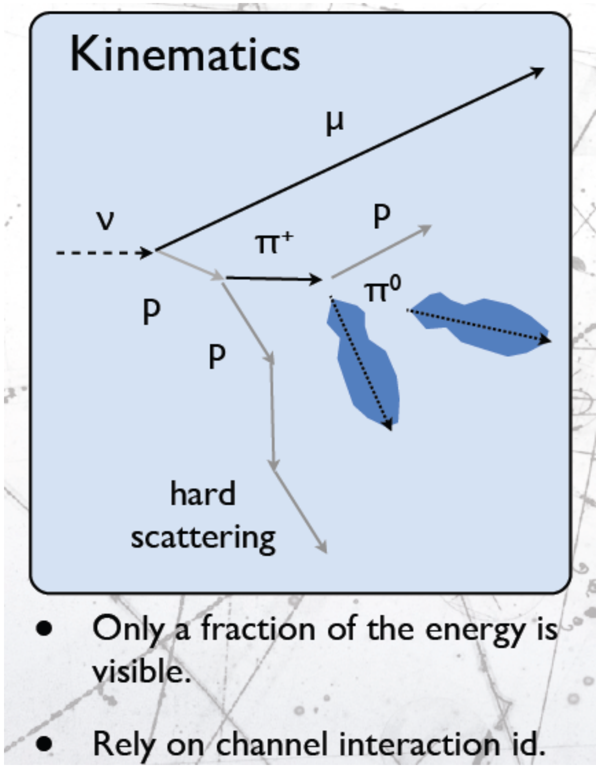


T2K talks: S. Bordoni's Pizza talk, 11.06.2014, and J. Caravaca's Pizza talk, 26.02.2014

Why LAr (TPC)?

- Cheap detector material
- Fully active homogeneous detector
- 3D event topology reconstruction
- dE/dx -> particle identification
- Calorimeter for contained shower
- Low detection threshold (<100 keV in a double phase LAr TPC)
- scalable to large volumes

Water Cherenkov

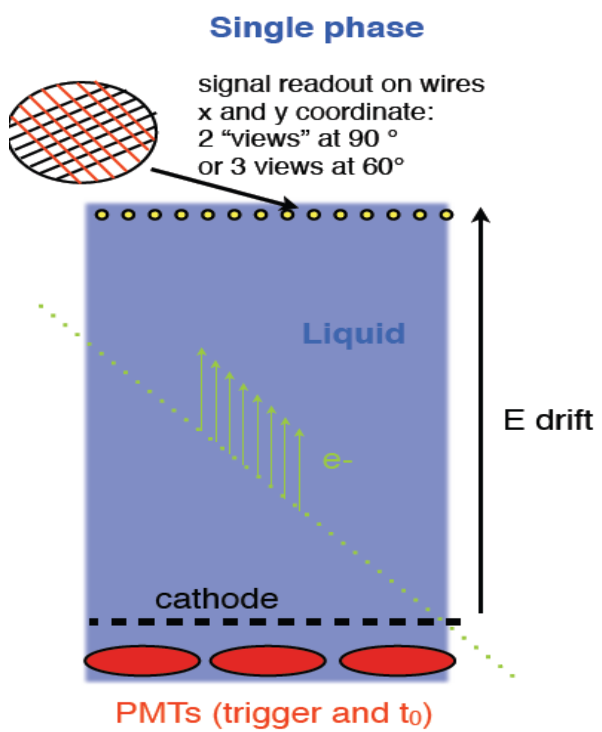


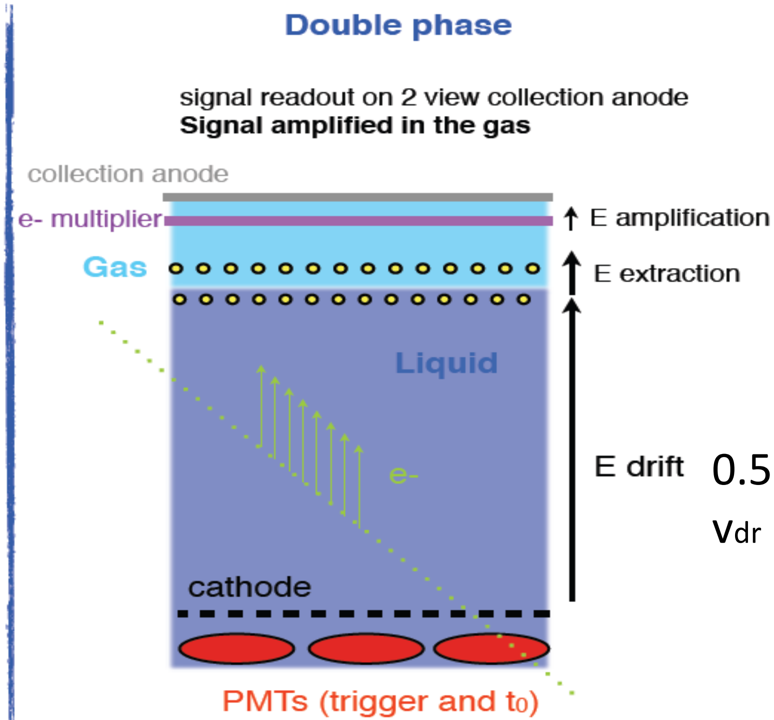
F. Sanchez's Pizza talk, 22.04.2015

2 Options for LAr TPC

- completely filled with LAr -> simple
- no charge amplification -> direct electron signal + induction signal
- ICARUS TPC (600 ton, 1.5 m drift)
- C. Rubbia

- LAr + region with GAr
- Ionization in LAr, e- extracted to GAr + amplified -> larger signal
- suitable for ν + DM experiments (ArDM)
- A. Rubbia

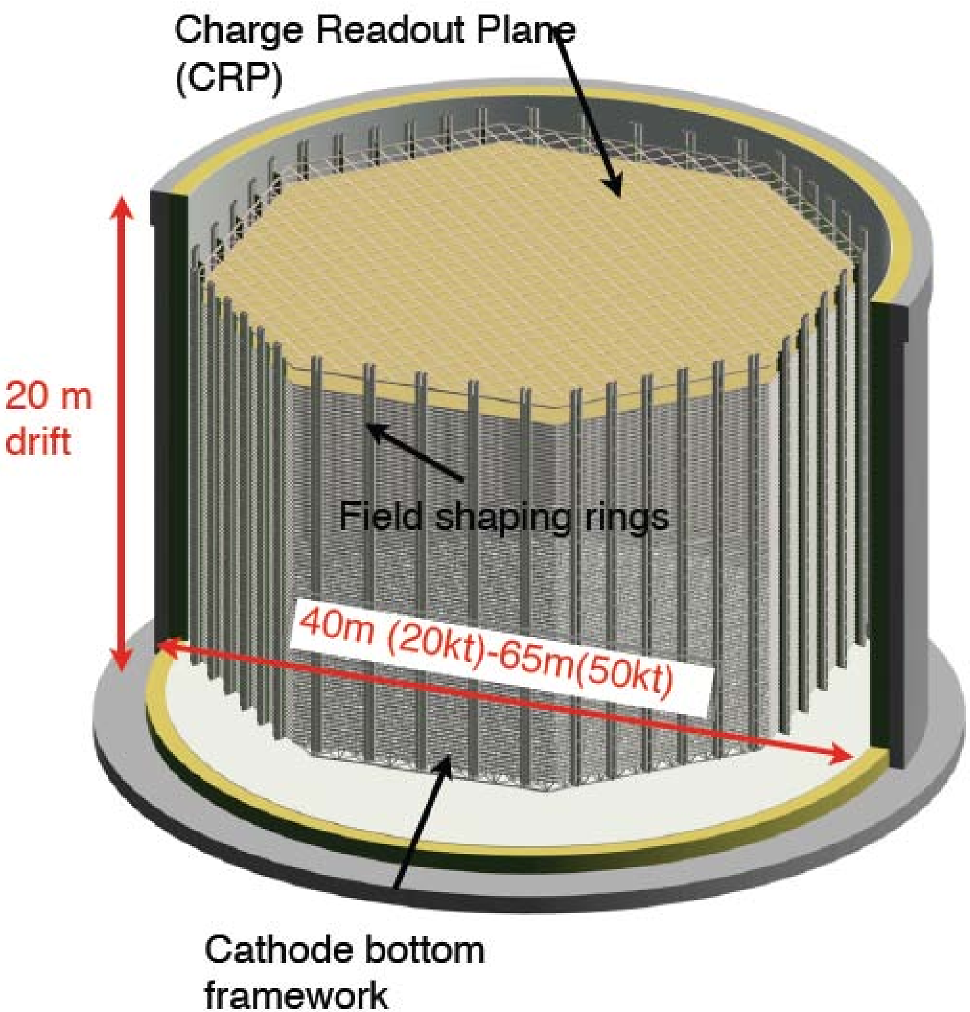




0.5 – 1 kV/cm

v_{dr} = ~2 mm/μs

Size of Far Detector

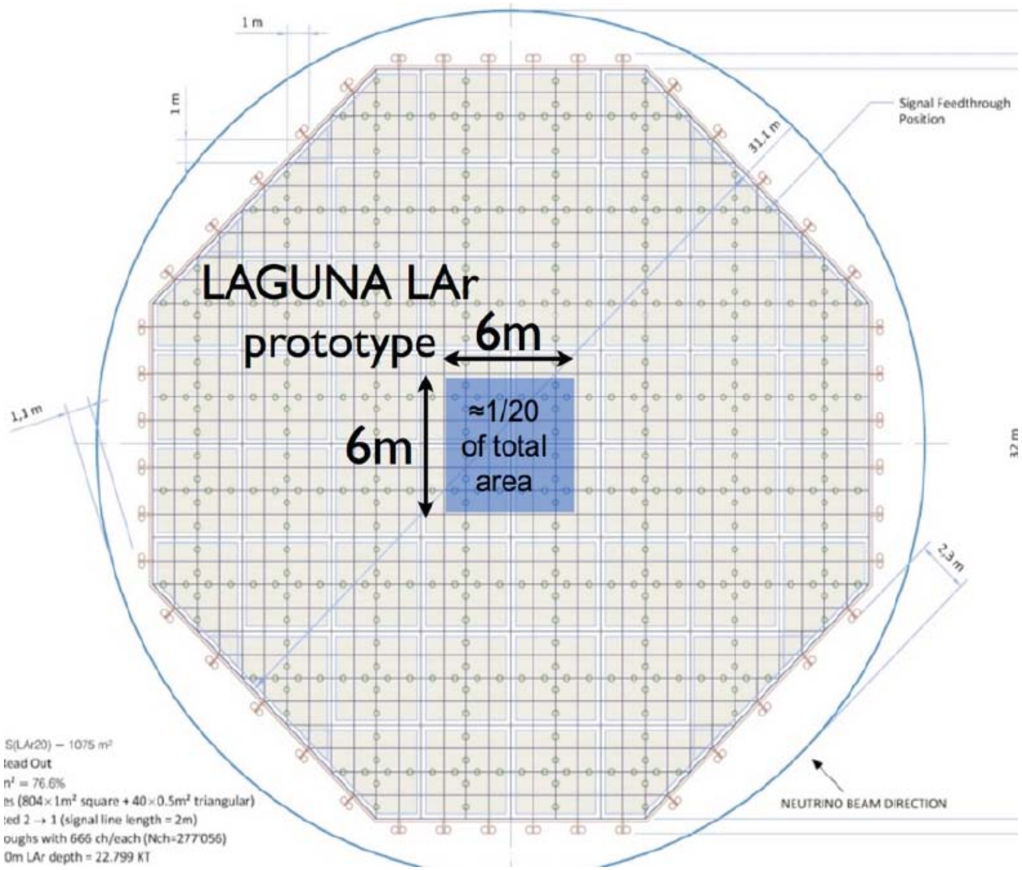


- Far detectors are HUGE
- 20 kt option could contain IFAE workshop bldg
- Construction not trivial

$\Downarrow$

We need a prototype and this prototype has to be big, too!

Size of Far Detector



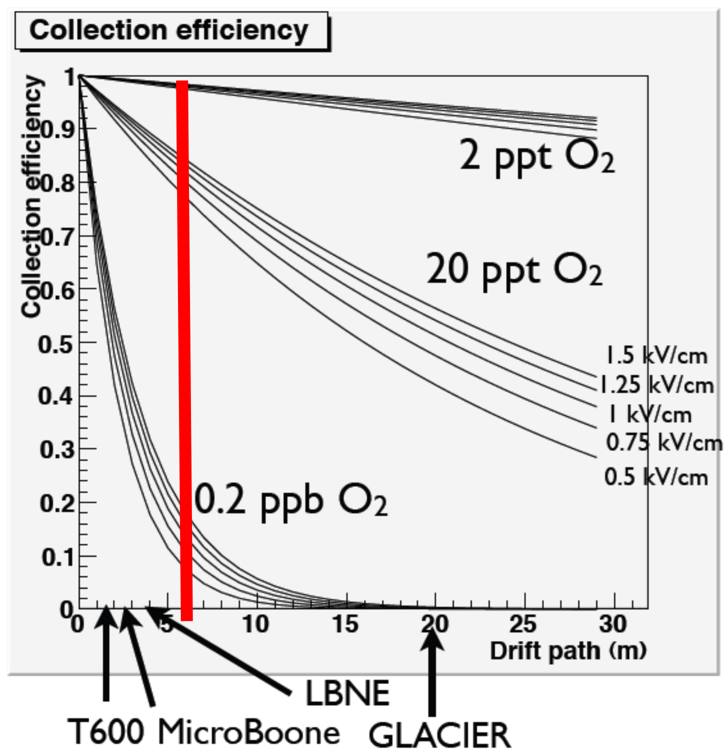
- Far detectors are HUGE
- 20 kt option could contain IFAE workshop bldg
- Construction not trivial

$\Downarrow$

We need a prototype and this prototype has to be big, too!

The Challenges

- Large cryogenic system: 84 K < T_{op} < 87 K
- O_2 level in **ppt** range (1 O_2 : 1000.000.000.000 Ar)
- up-to 600 kV@cathode for 6 m drift
- 36 m^2 of MPGD readout (T2K TPC: 12 m^2)
- high reliability for everything inside detector (filling takes long, LAr cost 300 kEuro)
- Long readout time: ~4 ms
- Cosmics (only for WA105)



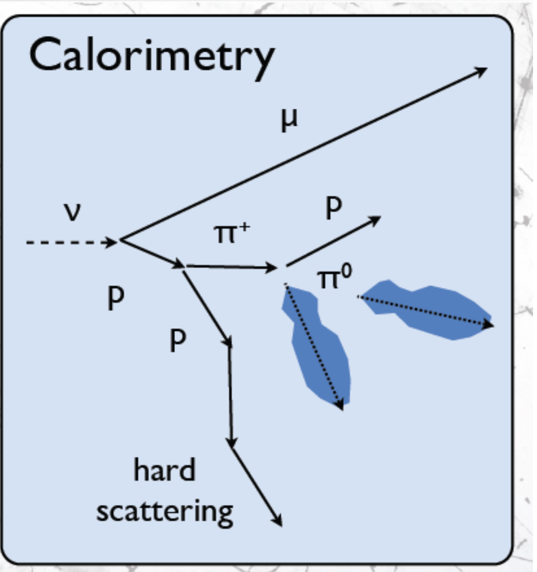
The "Physics Goals"

WA105 is a tracking calorimeter which will allow to study:

• Algorithms to reconstruct the tracks and to identify the particle

• Calorimetric performance using low energetic beam particles => How well can we reconstruct the neutrino energy?

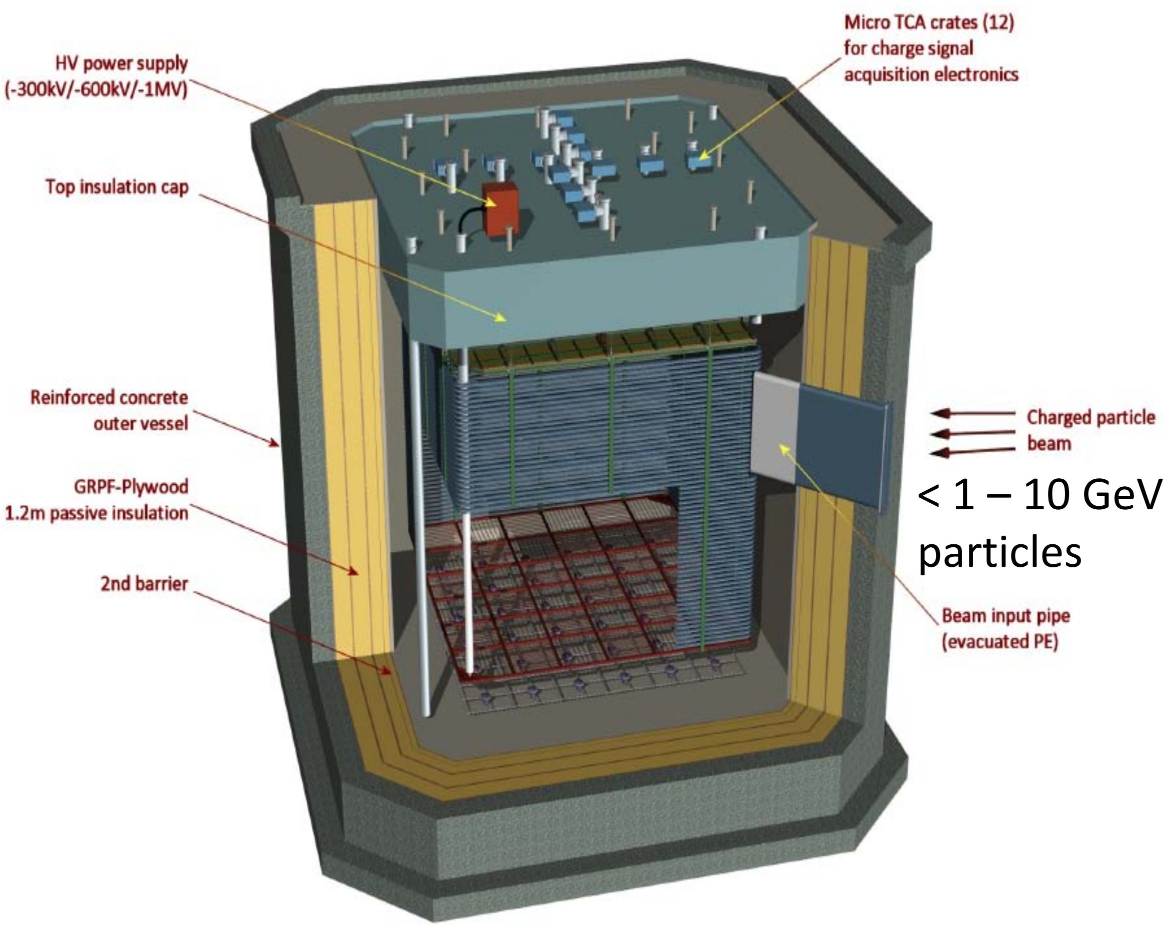
• Hadronic secondary interactions allowing to tune MC models



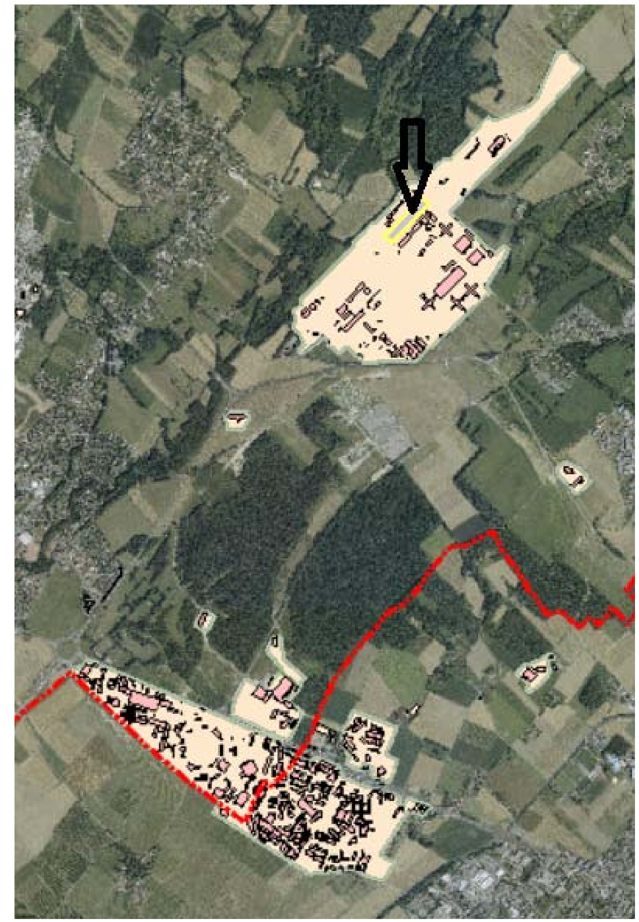
• The visible energy is altered by the hadronic interactions and it depends on hadron nature.

F. Sanchez's Pizza talk, 22.04.2015

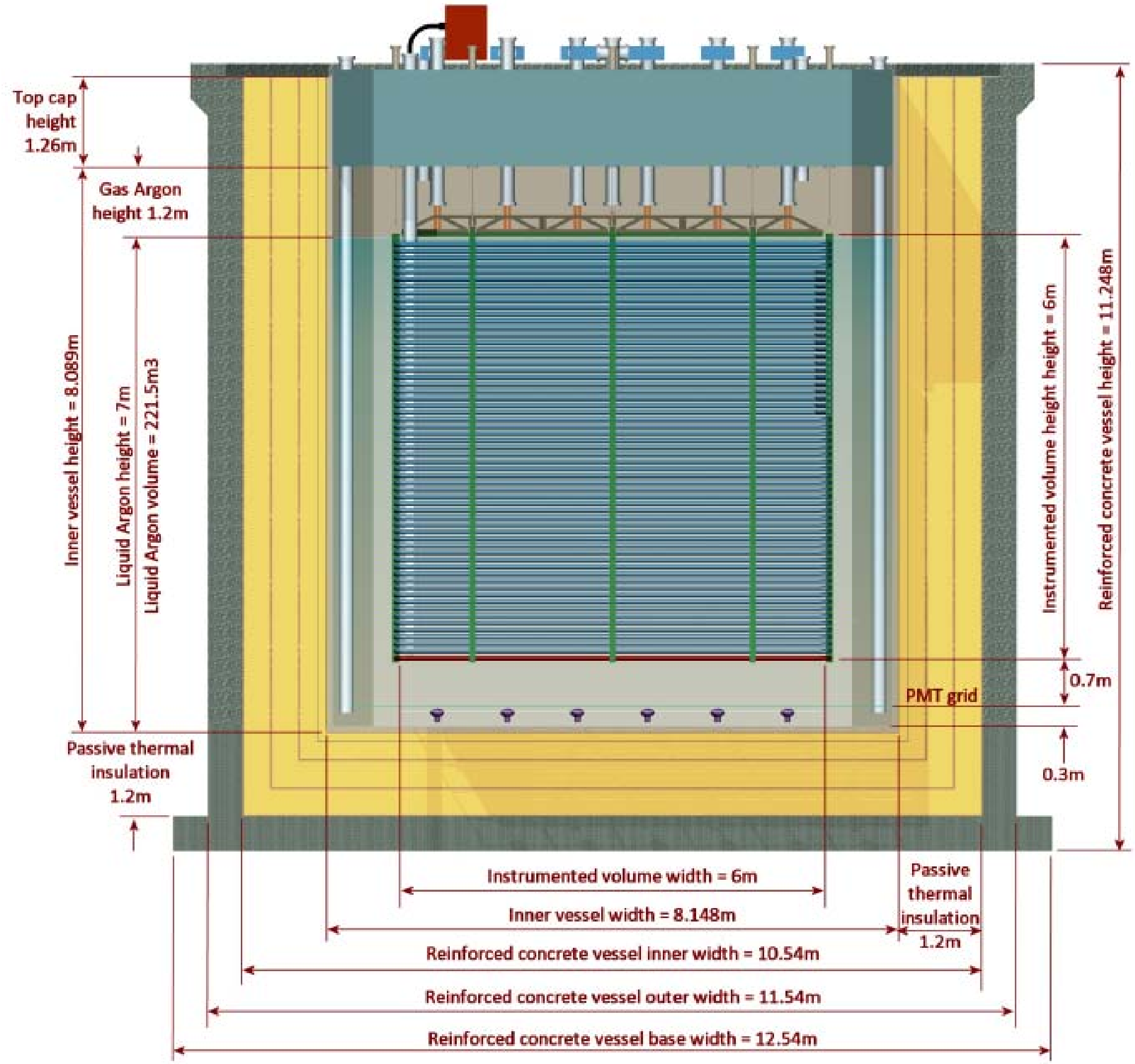
WA105: A 6x6x6 m^3 Prototype



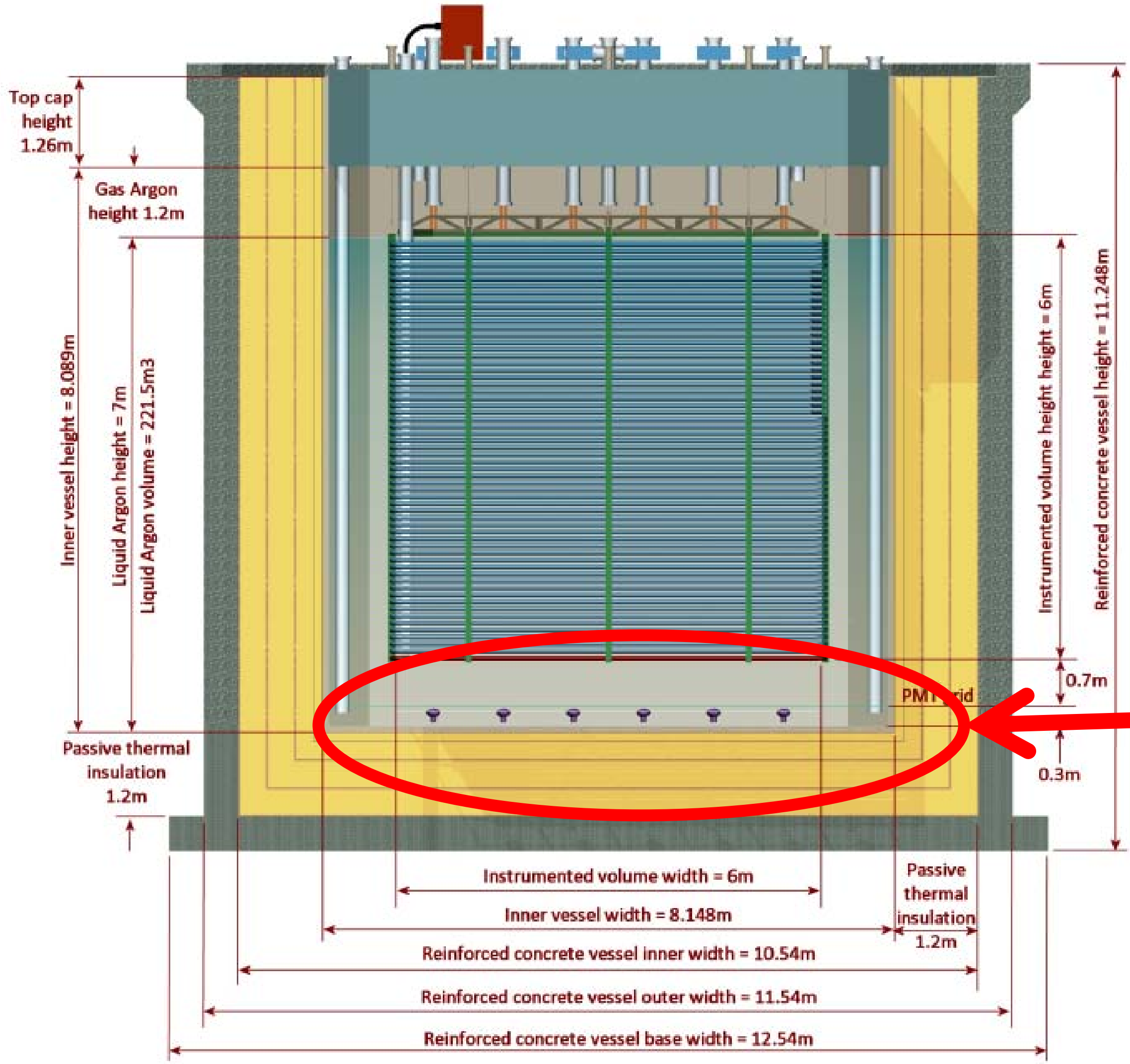
Bldg 887 (EHN1), Prevessin Site



WA105: A 6x6x6 m^3 Prototype

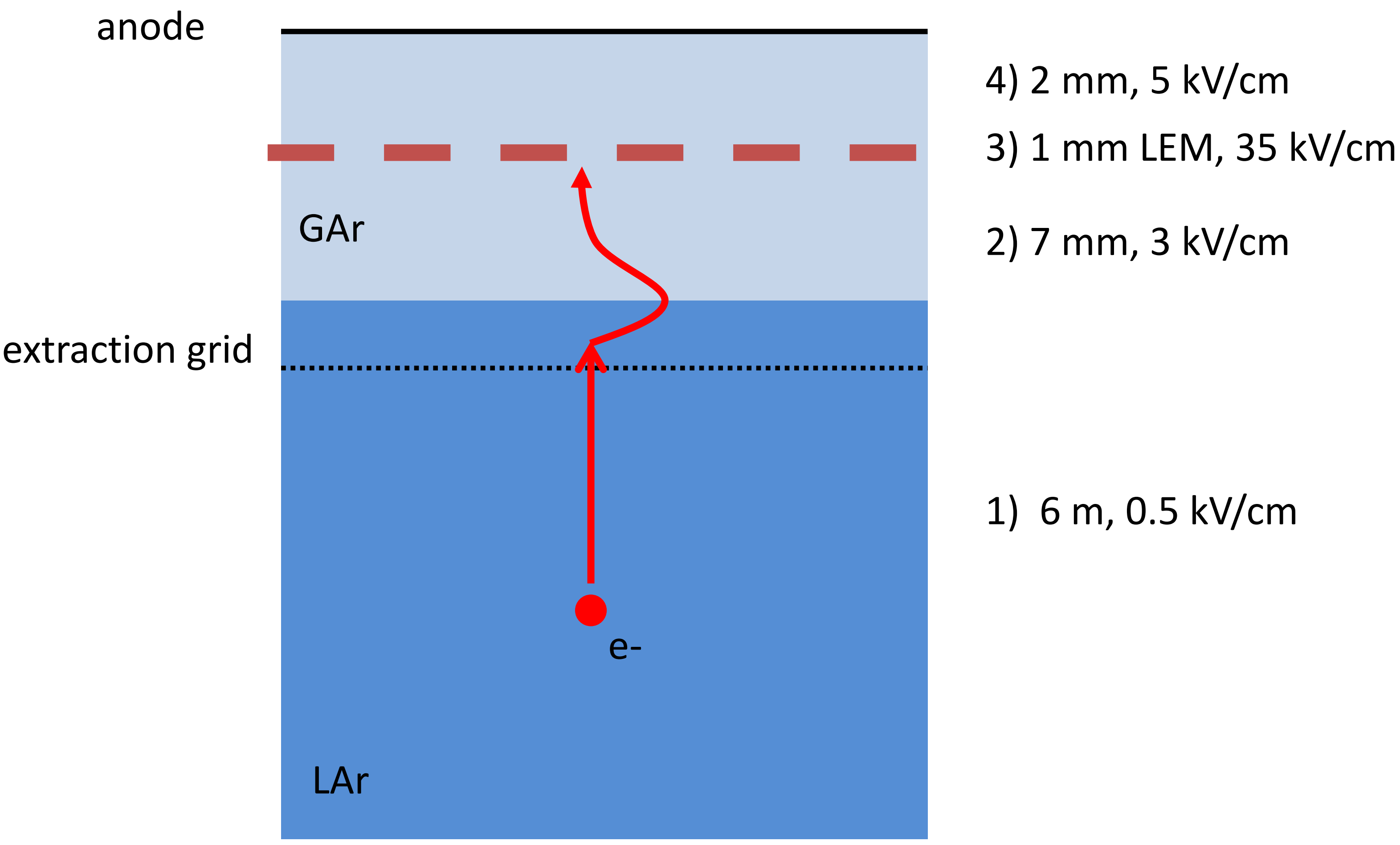


WA105: A 6x6x6 m^3 Prototype



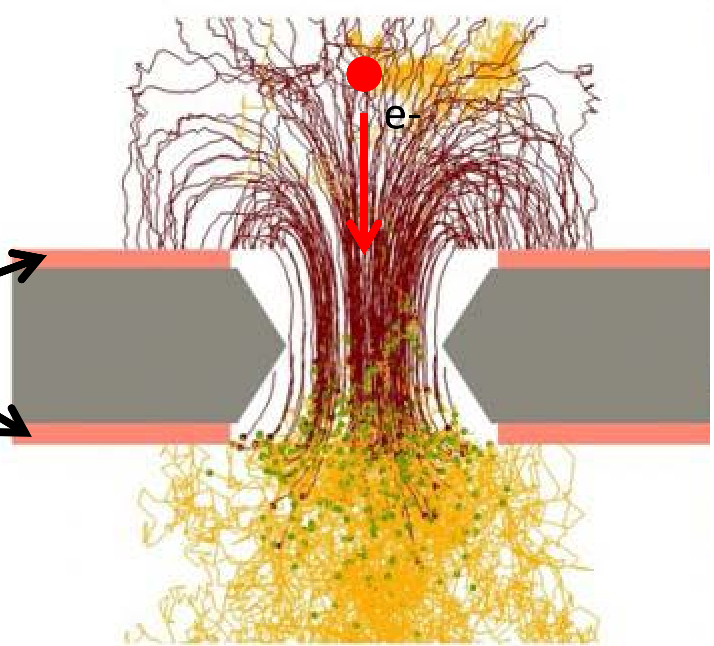
IFAE/CIEMAT:
36 PMTs

Charge Readout



Remember Pizza Seminar
28.1.2015 from Shikma Bressler

LEM/THGEM

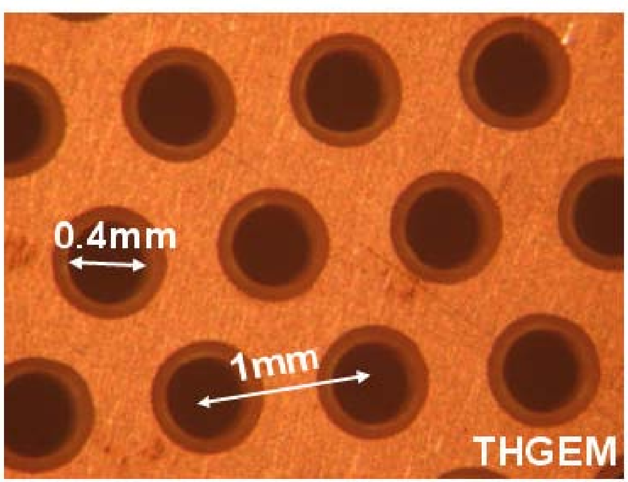


ΔV = several hundred V

Copper layer

G10

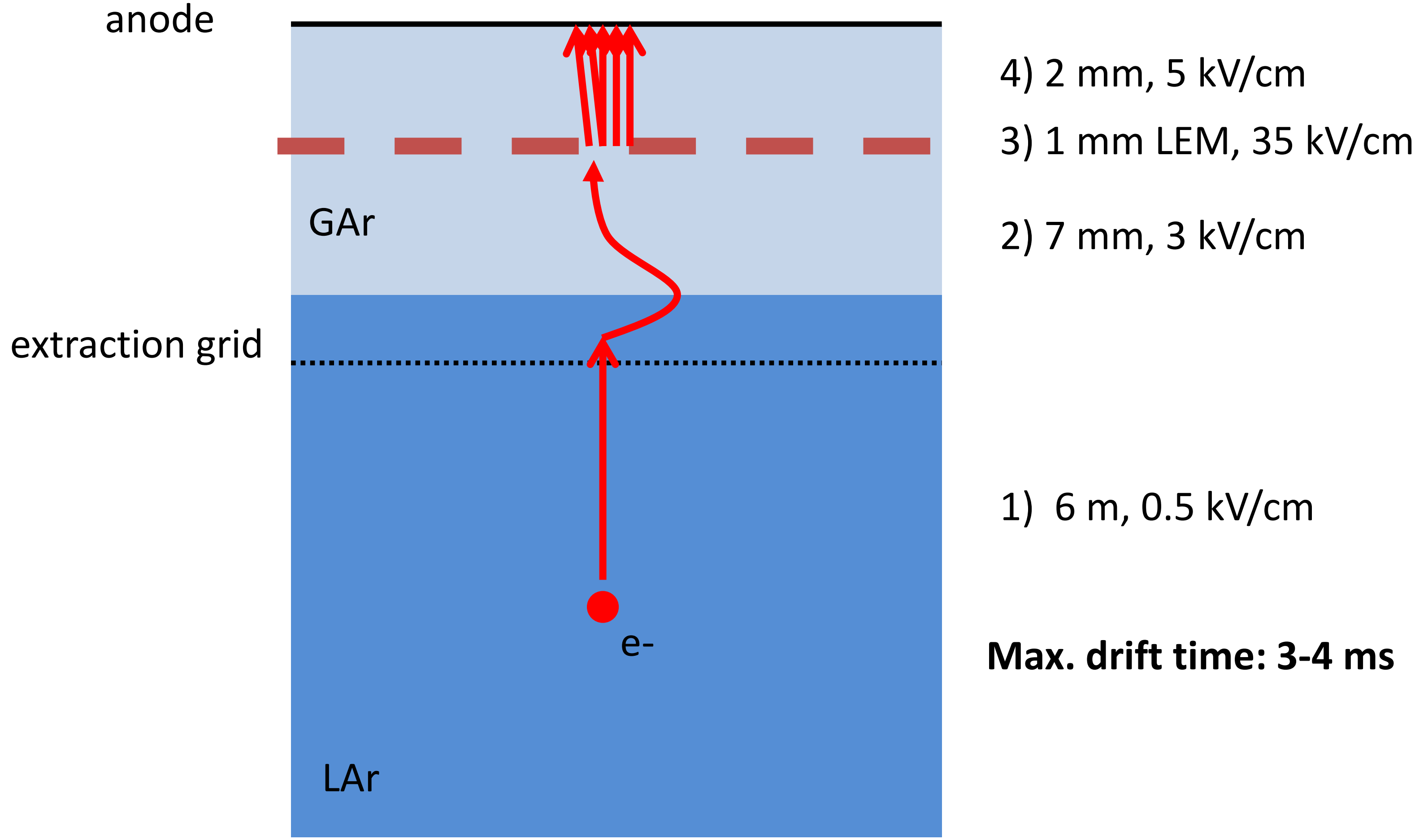
Copper layer



- cheap technology => industrial PCB standard
- large areas of 50x50 cm^2 possible
- robust
- gains of about 20 in pure Ar

=> might not sound much but might make the difference for long drift distances!

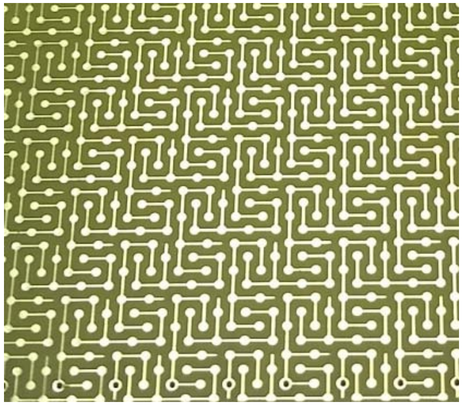
Charge Readout

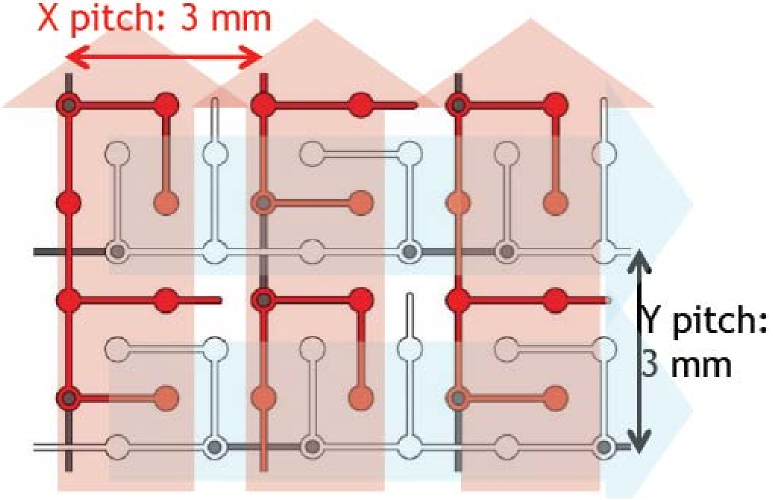


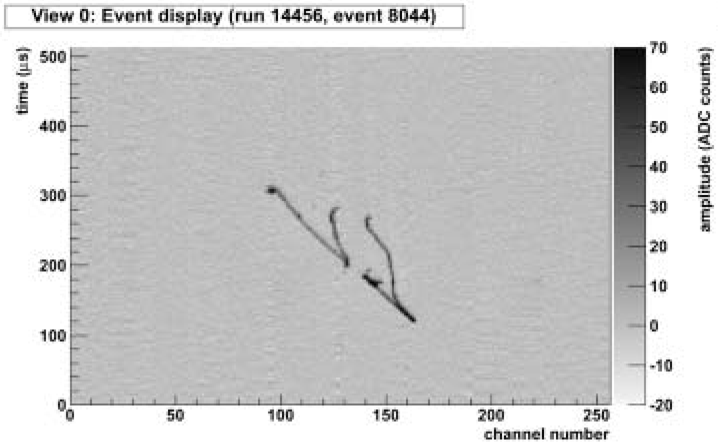
Max. drift time: 3-4 ms

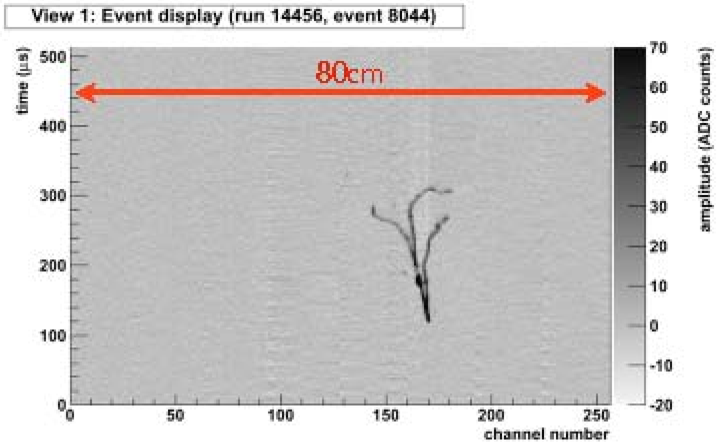
Charge Readout

- 2D anode consists of strips with 3 mm pitch
- complicated pattern to optimize charge sharing
- 2 independent views (xt and yt)
- 7680 readout channels

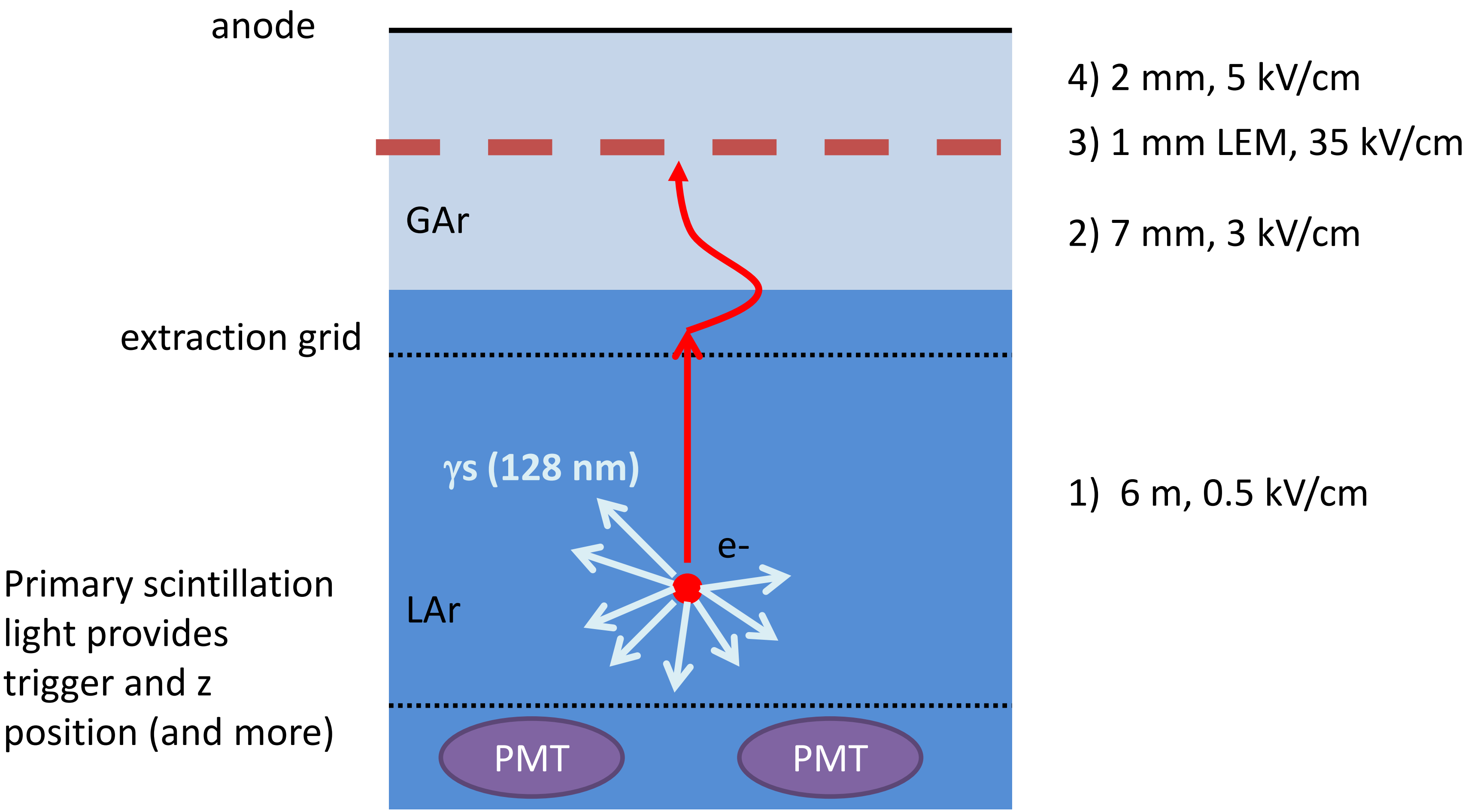






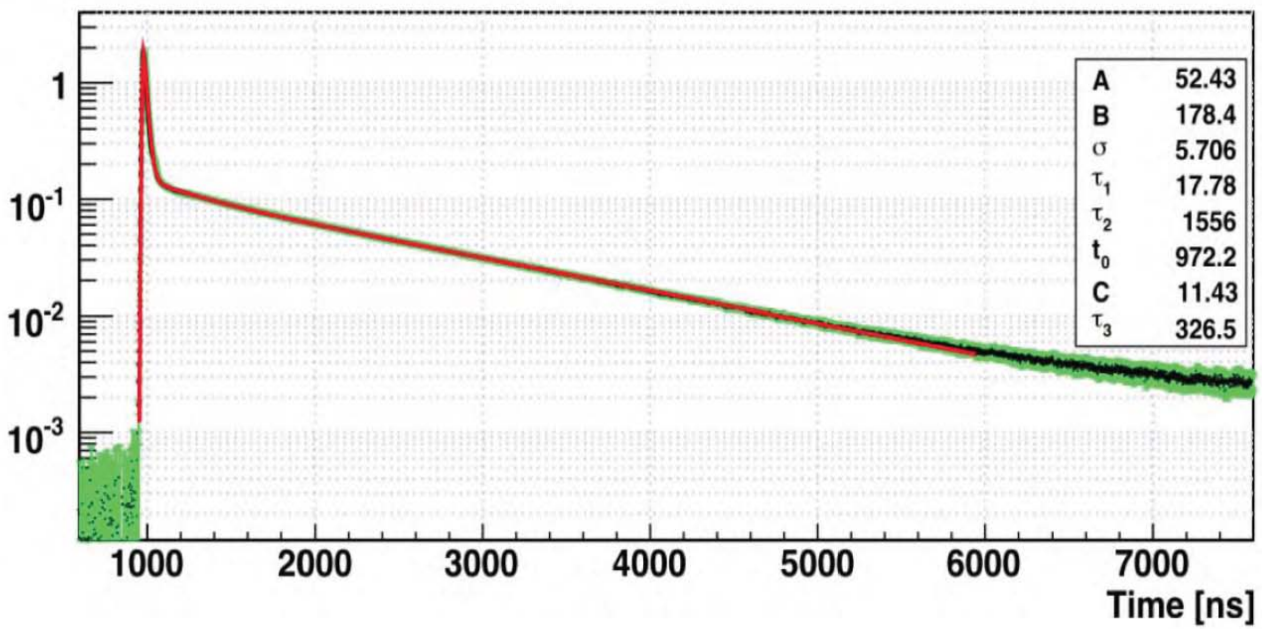


Light Readout



Light Readout

- primary light has 2 components:
  - fast componente, singlet: ~ 7 ns
  - slow componente, triplet: ~ 1.6 μs
- ratio depends on ionizing process (alpha higher fraction of singlet, betas/gammas more triplet; pulse shape analysis possible)
- for WA105 the fast component is interesting => delta peaks with tail for trigger logic



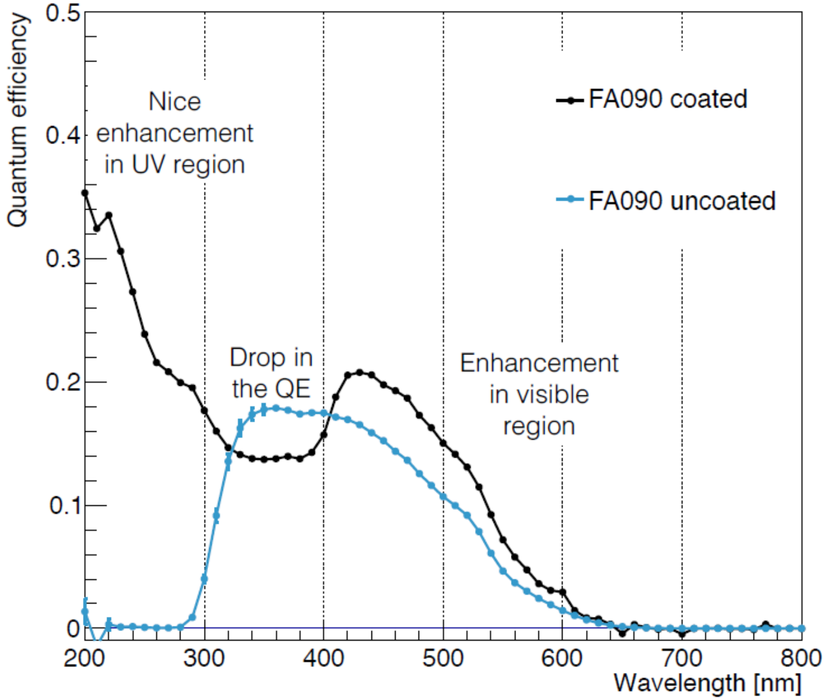
Light Readout

128 nm (VUV range) is a nasty wavelength!

- Quartz windows not transparent for this λ
- Other windows e.g MgF_2 too expensive

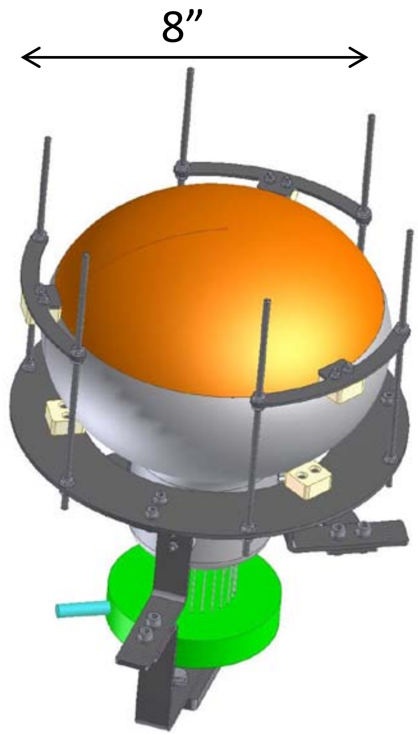
Solution:
Tetraphenyl butadiene (*TPB*) shifts the light from 128 nm to 450 nm!

=> We can use “standard” PMTs!



Stefania participated in these measurements

Light Readout



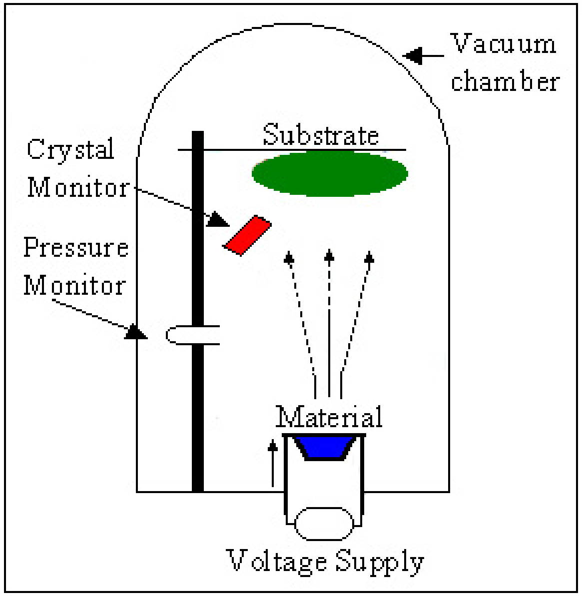
2 options for the TPB coating:

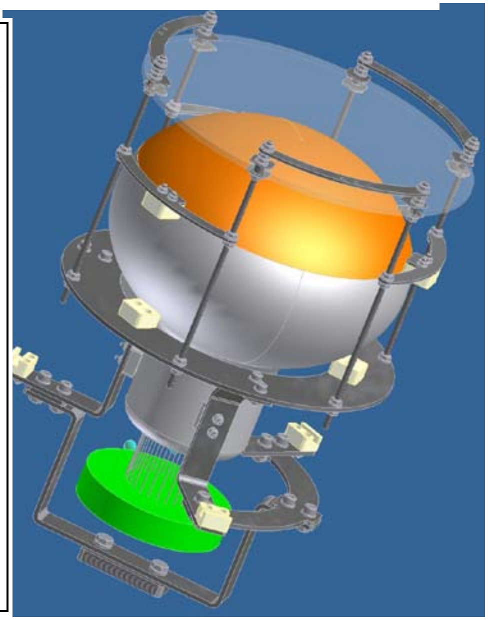
1. Coating directly the entrance window of the PMTs => difficult to handle, whole PMT has to be shipped
2. Placing a acrylic plate coated with TPB in front of PMT => simpler, possibly cheaper but some light losses (no problem for us)

TPB coating is best done with thermal evaporation => we need a big evaporation chamber!

CERN one option but expensive ...

I am in contact with CNM and UB for alternatives in Barcelona





Cosmics: Some numbers

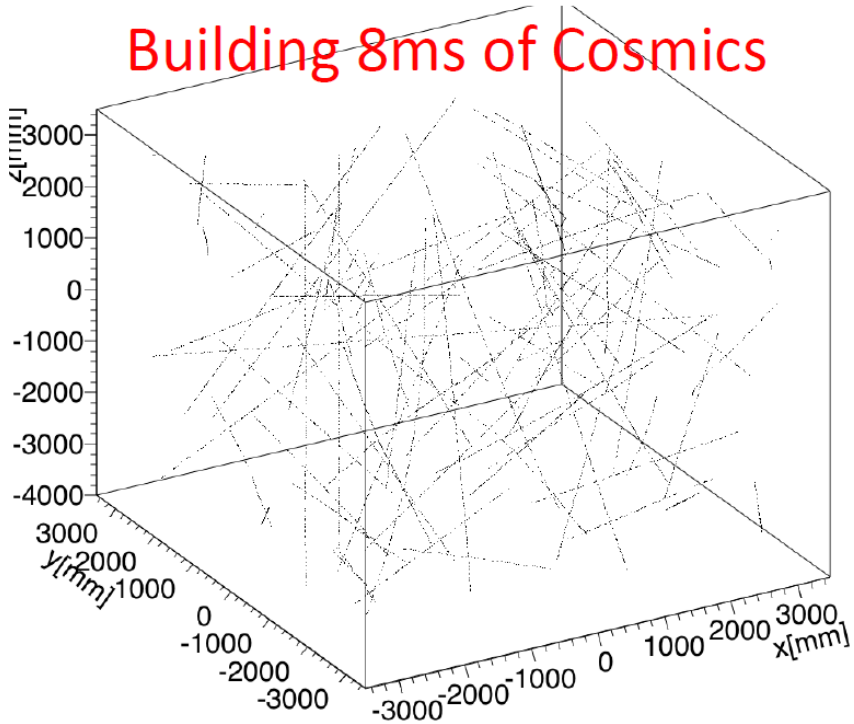
Cosmics are good for prototypes but in our case also a complication …

In 10x10 cm^2 we get about 1 cosmic per second …
$\Rightarrow$We have 360.000 cm^2 + 600 cm of depths ...
$\Rightarrow$ We expect ~12 kHz of cosmics!
$\Rightarrow$ In 4 ms of readout time, 48 cosmics overlapping **+ beam event**

But it is worse ...

Each cosmic deposits about 2 MeV/cm
$\Rightarrow$ 50.000 e/ions, 50.000 γ per cm
$\Rightarrow$ 30 million e/ions and γ per MIP in 600 cm

Building 8ms of Cosmics

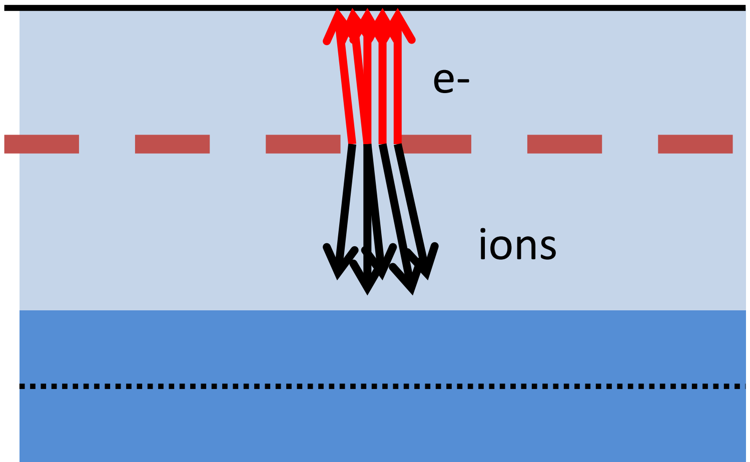


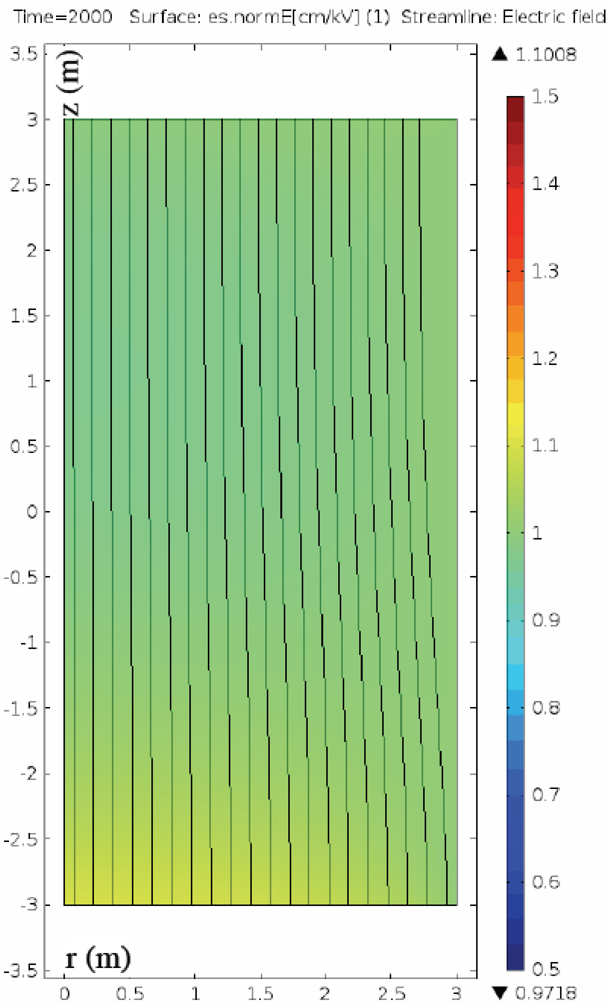
Space Charge Effects

- 30 million e- per MIP are reaching the LEM
- ... each creates 20 e-/ion pairs ....
- ... ions drift back towards cathode ...
- **.... 600 million ions + 30 million primary ions**

Good news: Important fraction ends on LEM surface but still many will reach drift volume

Space charge effects will cause field distortions
⇒ Event reconstruction will be a challenge!
⇒ CVC (Center for Visual Computing) might help





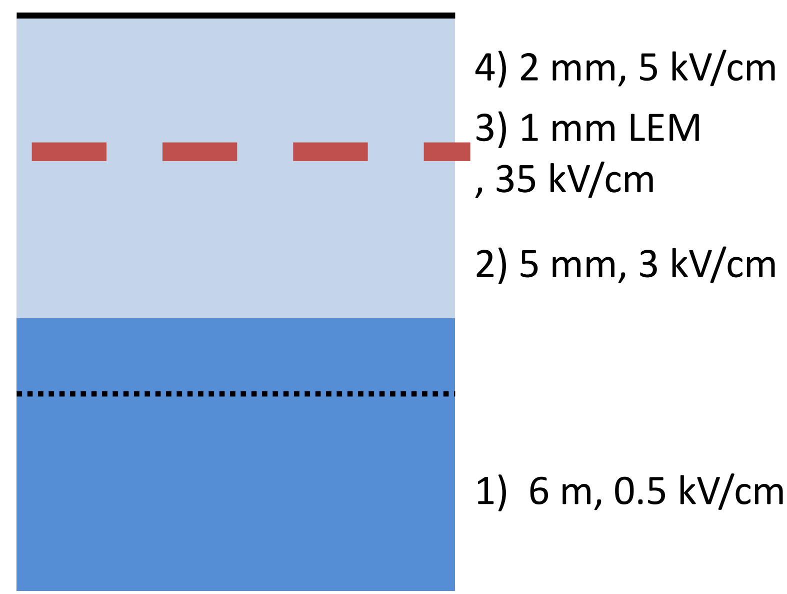
Electroluminescence Light

Also the light is not so trivial as it seems on the first look ...

Naive expectation: 10 million photons in 20-30 ns + 20 million in 4-5 μs
=> should be easy to detect and use as trigger but ...

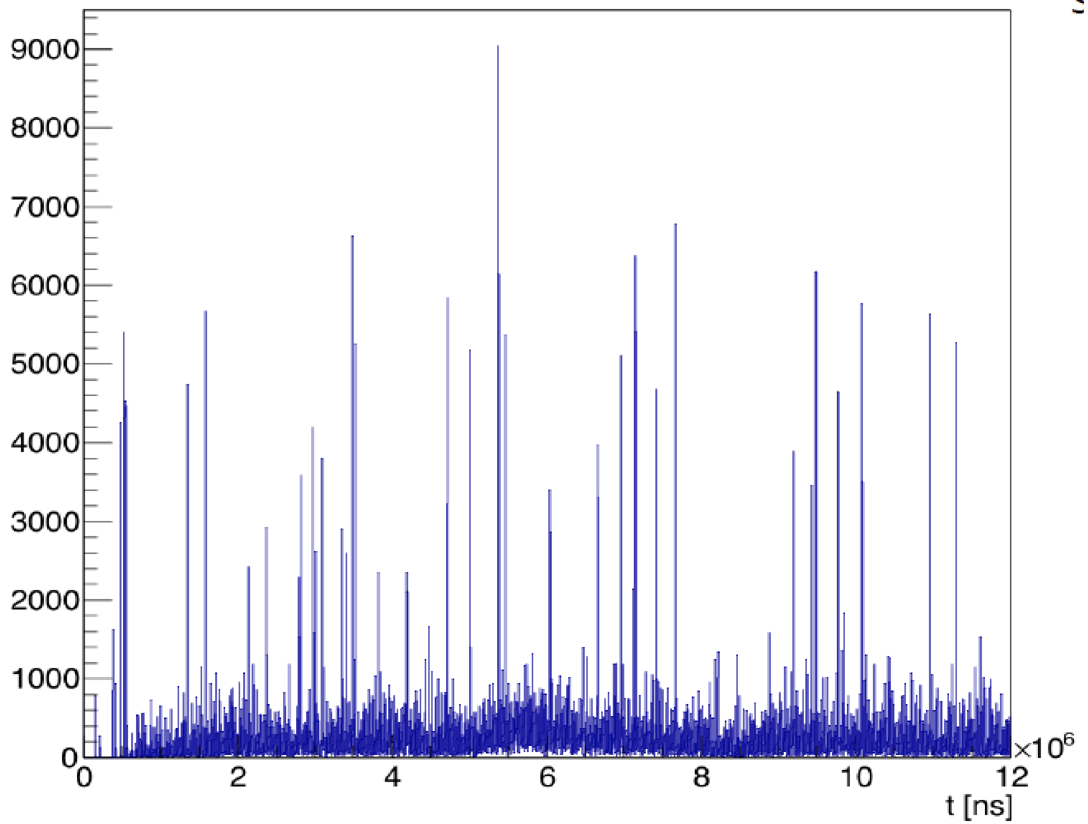
In GAr we produce electroluminescence light (see A. Garcia's Pizza talk, 14.01.2015)

- in 2) about 20 γ/e towards cathode
- in 4) about 500 γ/e_{pr} towards PMTs (mainly shielded by LEM)
- in the LEM also 100s γ/e (mainly/partly shielded by LEM)



=> There will be a "constant" background with spikes from the fast component!

Light Waveform



Bruno Bourguille going to join the light simulation efforts

Cosmics only an issue for WA105, in an underground lab flux reduced by 10^4 to 10^5!

Conclusions

- WA105 a double phase TPC filled with 300 tons of LAr located at CERN
- Challenging step before next generation of neutrino experiments can start
- Spanish groups are responsible for the light readout of WA105
- Collaborative work share foreseen: common cryogenic test bench for PMT characterization at CIEMAT, TPB coating and first quality tests possibly done in Barcelona
- R&D studies on alternative light detection systems in parallel
- Data taking should start 07/2018 to have testbeam before LHC shutdown

CERN WA105 6x6x6 TPC DEMO	2014				2015				2016				2017				2018				2019			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
CRYOGENICS AND COMMISSIONING																								
-management set-up				X																				
-contract preparations for design					X																			
-design								X	X															
-liquid infrastructure installation											X	X	X											
-detector installation													x	x	x	x								
-final test and cleaning																	X							
-Lar commissioning (filling and cooling)																		X						
START OF EXPERIMENT																								