LAGUNA-LBNO and the WA105/LBNO-DEMO

Luca Agostino
On behalf of WA105 collaboration

7th international symposium on
"Large TPCs for low-energy rare event detection"

17-12-2014

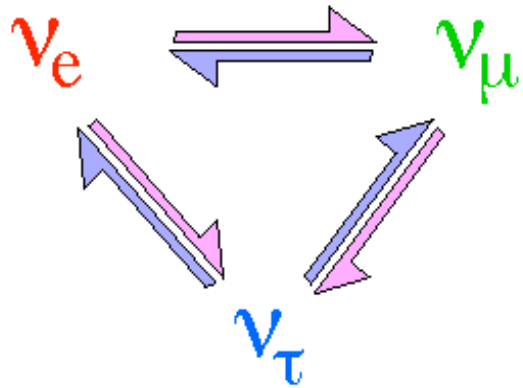
OUTLOOK

- SCIENTIFIC MOTIVATION OF NEW GENERATION NEUTRINO EXPERIMENTS
- THE LAGUNA-LBNO DESIGN STUDY RESULTS
- LBNO-DEMO MOTIVATION AND OVERVIEW
- MAIN COMPONENTS
- CONCLUSIONS

NEUTRINO PHYSICS BEYOND THE STANDARD MODEL

Flavour eigenstate ≠ Mass eigenstate

Mixing parameters:



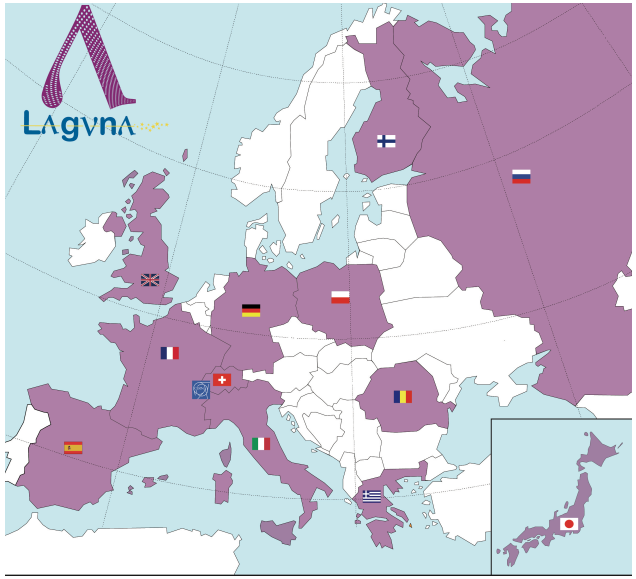
- Three angles: $\theta_{12}\theta_{23}\theta_{13}$
- One complex phase δ_{CP}
- Two squared mass differences Δm^2_{13} Δm^2_{12} HIERARCHY UNKNOWN

UNKNOWN

Pontecorvo – **M**aki – **N**akagawa – **S**akata matrix

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \times \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \times \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Atmospheric neutrinos | Reactor neutrinos | Solar neutrinos

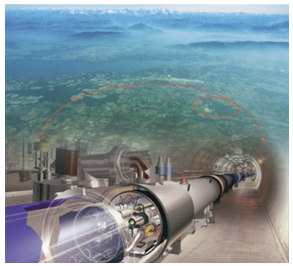


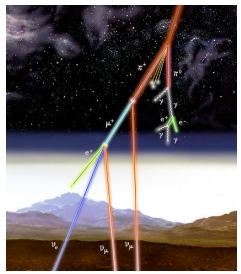
LAGUNA-LBNO: Large Apparatus for Grand Unification and Neutrino Astrophysics and Long Baseline Neutrino Oscillations

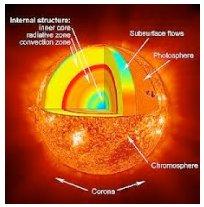
LAGUNA-LBNO consortium = 13 countries, 45 institutions, ~300 members

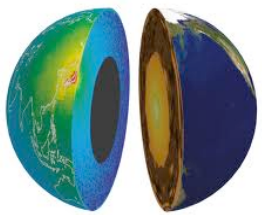
FP7 DS: 2011 - 2014

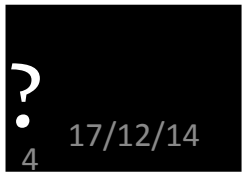
LAGUNA-LBNO Physics:











1. Accelerator based:

- **Mass Hierarchy**
- **δ_{CP}**
- PMNS precision
- 3 ν or 3+n ?

2. Non-Accelerator based:

- Proton decay

3. Neutrino Astronomy:

- Supernova neutrinos
- Diffuse Supernova Neutrinos
- Solar Neutrinos
- Atmospheric Neutrinos

4. Geo-neutrinos

5. Dark Matter

THE LAGUNA-LBNO EXPERIMENT

GLACIER (Giant Liquid Argon Charge Imaging ExpeRiment, **2003**)

- New concept of Double Phase Liquid Argon TPC for CP-violation and future deep underground detector, up to 100 kton mass (hep-ph/0402110)

LAGUNA DS (FP7 Design Study **2008-2011**)

- ~100 members; 10 countries
- 3 detector technologies ⊗ 7 sites, different baselines (130 → 2300km)

LAGUNA-LBNO DS (FP7 DS Long Baseline Neutrino Oscillations, **2011-2014**)

- ~300 members; 14 countries + CERN
- Fully engineered detector designs for 20/50 kt DLAr, 50 kt LSc, 540 kt WCD
- Infrastructure design, construction scheme and full costing

LBNO (CERN SPSC EoI for a very long baseline neutrino oscillation experiment, **June 2012**)

- An incremental approach with high level physics starting from phase 1 (MH + LCPV + Astro)
- ~230 authors; 51 institutions

CERN-SPSC-2012-021, SPSC-EOI-007

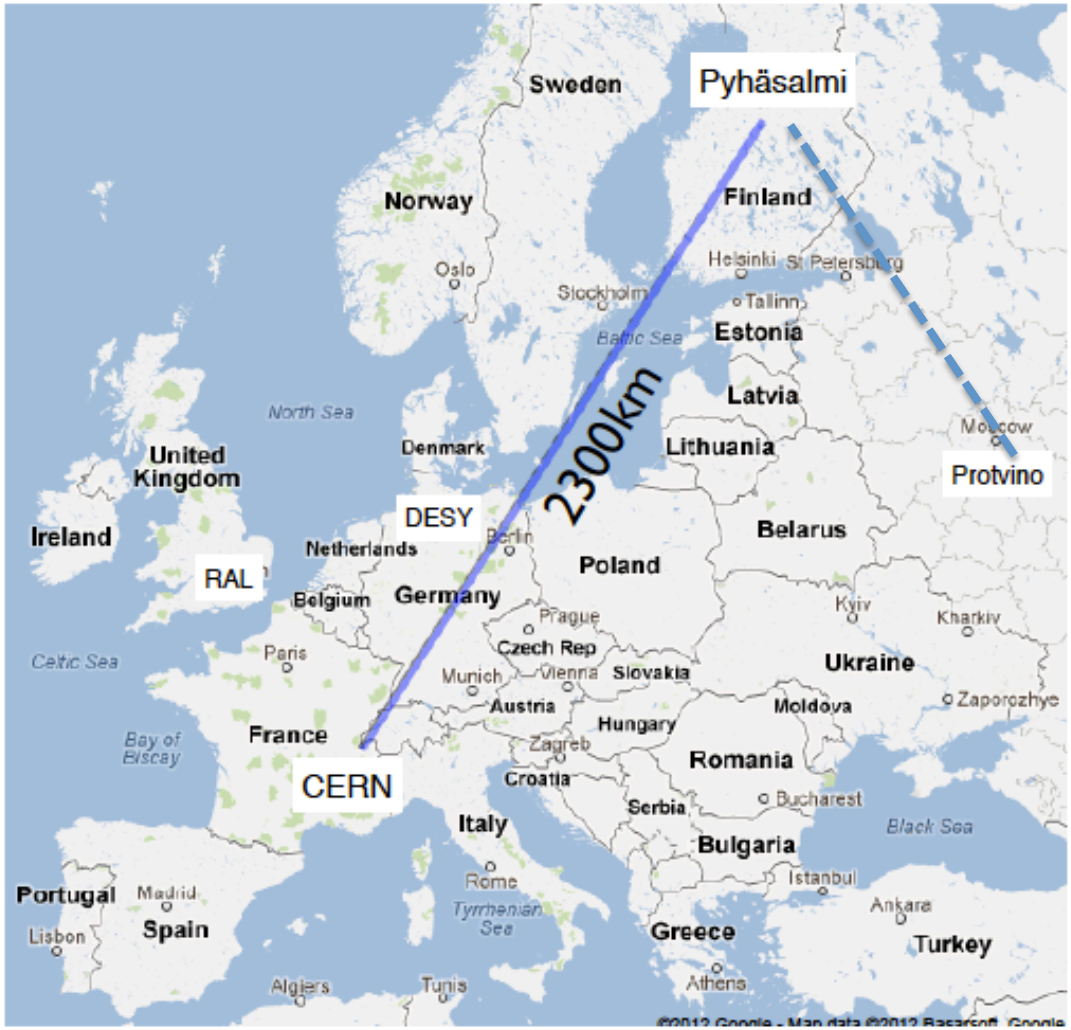
- Design study is **concluded** and the deliverables soon on the Archive

LBNO-DEMO WA105 (@CERN first Collaboration meeting 16-17 **October 2014**)

- kt-scale demonstrator for LBNO @ CERN: engineering and charged particle calibration

CERN-SPSC-2014-013, SPSC-TDR-004

LAGUNA/LBNO CERN TO PHYÄSALMI CN2PY:



- 2300 km baseline from CERN (CN2PY) + 1160 km baseline from PROTVINO(P2P)

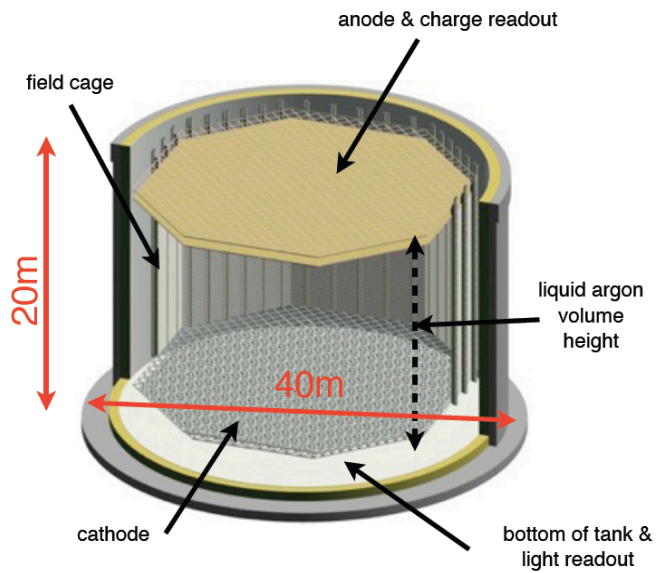
- SPS 400 GeV protons – 750 kW beam
- HPPS 50 GeV protons – 2 MW beam
- IHEP 70 GeV potons – 450 kW beam

- Liquid Argon double phase TPC detector

GLACIER : Incremental approach

- Phase 1 : LBNO20 (20kton)
- Phase 2: LBNO20+50 (70kton)

LBNO20 20 kton full cost = 226 M€



AN INCREMENTAL APPROACH

- **5 kton PILOT**:

  5kt DLAr detector

  ❑ First kton scale installation of Double Phase Liquid Argon underground

  ❑ Astrophysics and underground neutrino detection without beam

  ❑ Proton decay

LBNF ?

- **Phase I (LBNO20)**:

  24kt DLAr detector + beam from CERN SPS (750kW,Ep=400GeV)

  ❑ Guaranteed 5 σ MH determination + 46 % δ_{CP} coverage at 3 σ

  ❑ *p-decay sensitivity from p->Kv improved by 1 order of magnitude w.r.t. current limit*

- **Phase II (LBNO70)**:

  70 kt DLAr detector + HPPS beam (2 MW, Ep = 50 GeV) or Protvino beam

  ❑ δ_{CP} coverage at 5 σ

  ❑ *sensitivity to MH effect on SuperNovae neutronization burst*

+

- **LBNO-DEMO**:

  6X6X6 m^3 DLArgon at CERN ➔ Exposure to charged hadron beam (0.5-20 GeV/c)

  ❑ Demonstrate the operation of double phase LAr detectors at the multi-100-ton scale

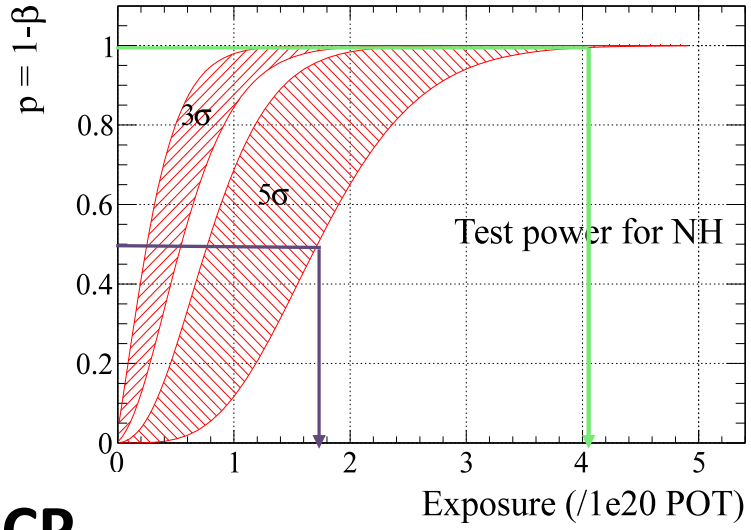
  ❑ Test and extrapolate technical solutions to large scale in an "affordable" way

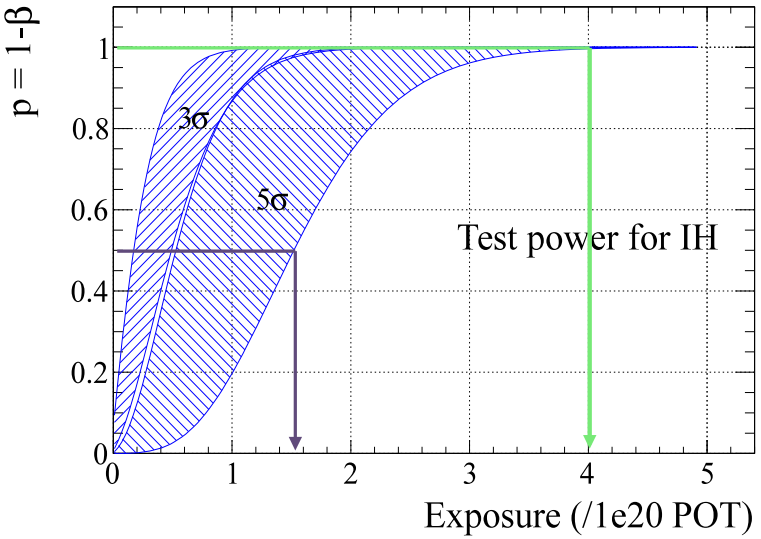
  ❑ LBNO-DEMO provides precise calibration of energy response as a function of E —> very important for neutrino oscillation systematics

MASS HIERARCHY AND CP COVERAGE

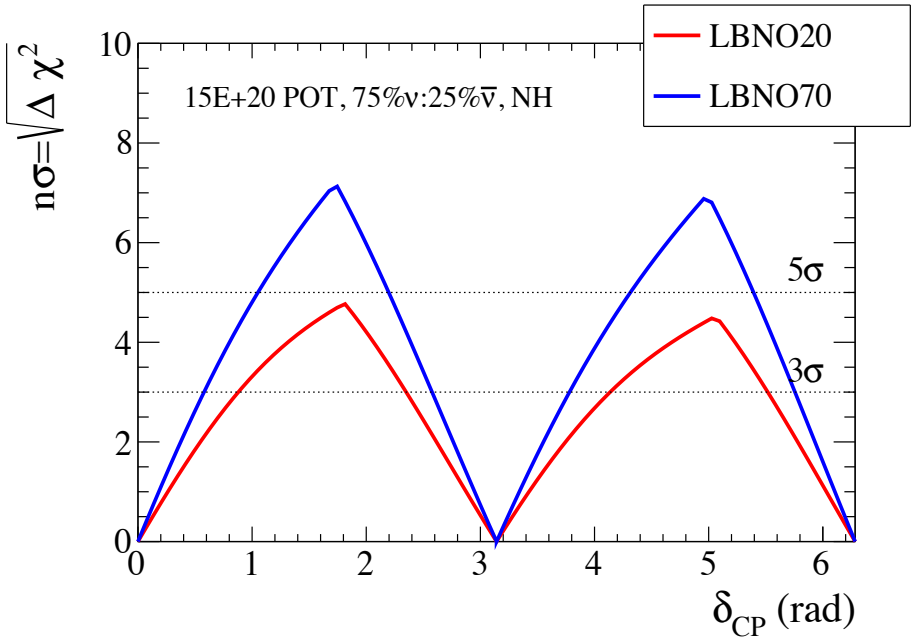
MH Power vs exposure for all values of δ_{CP} (shaded bands) LBNO20 + SPS

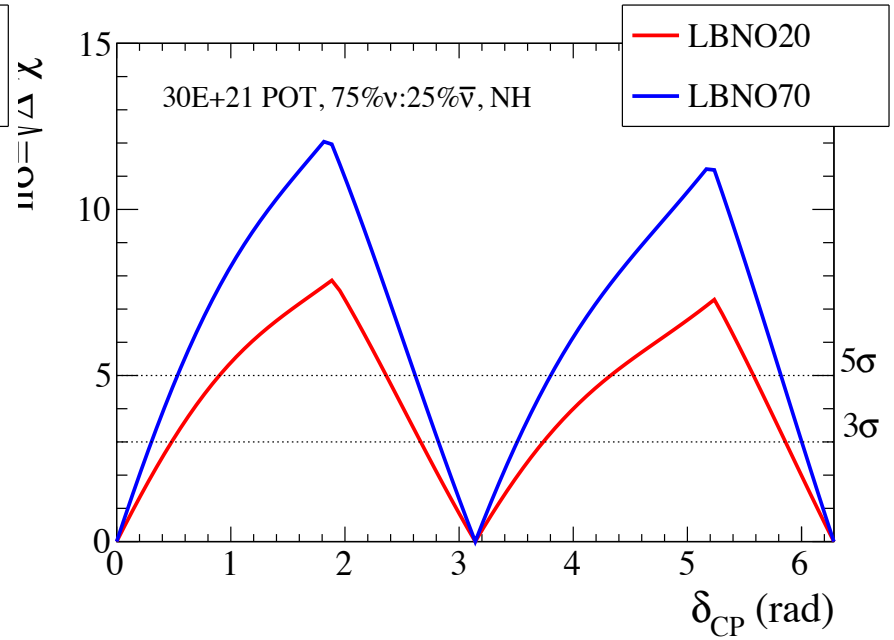
JHEP05(2014)094





CP





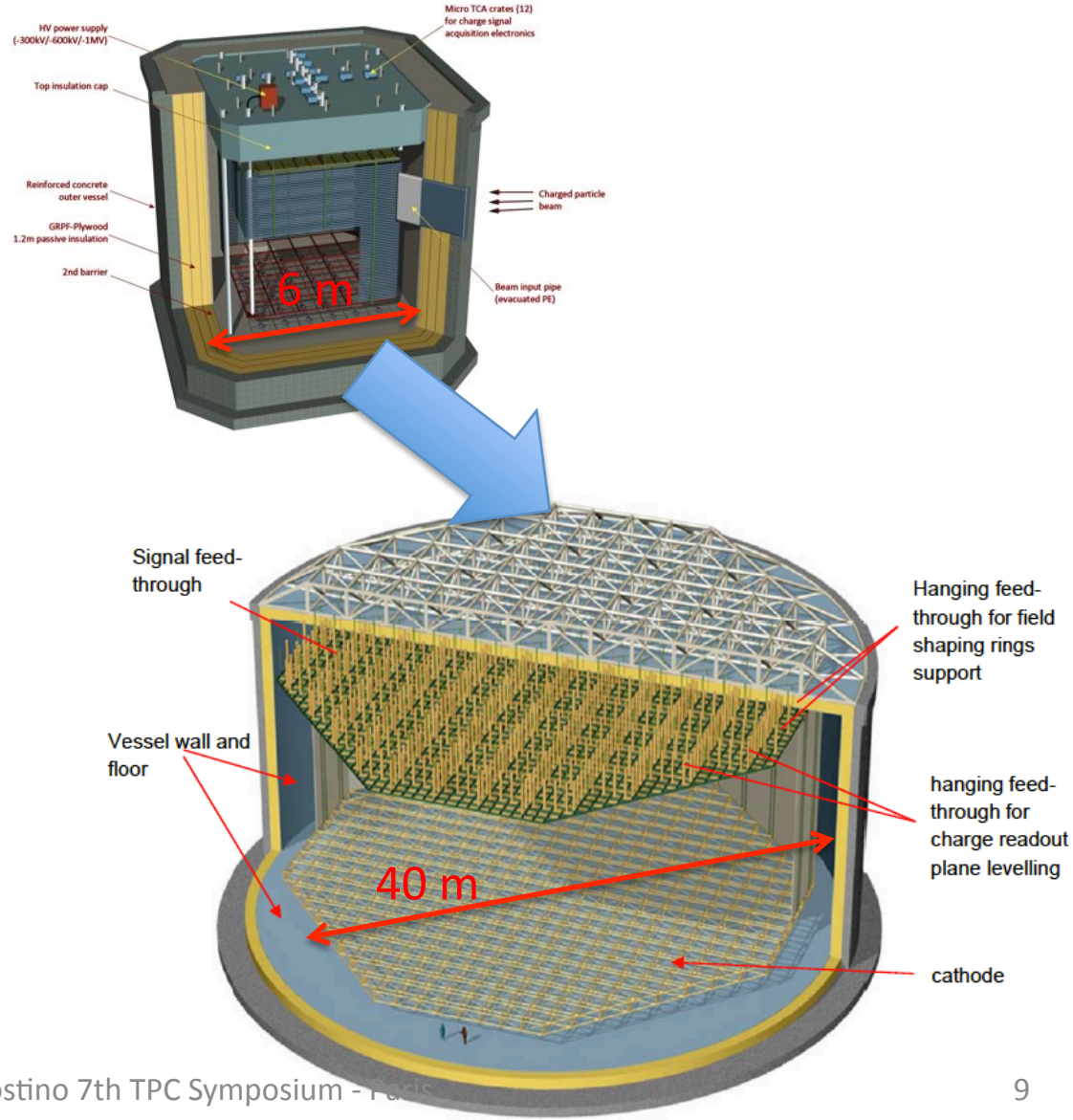
arXiv:1412.0593v1

WHY A PROTOTYPE FOR LBNO?

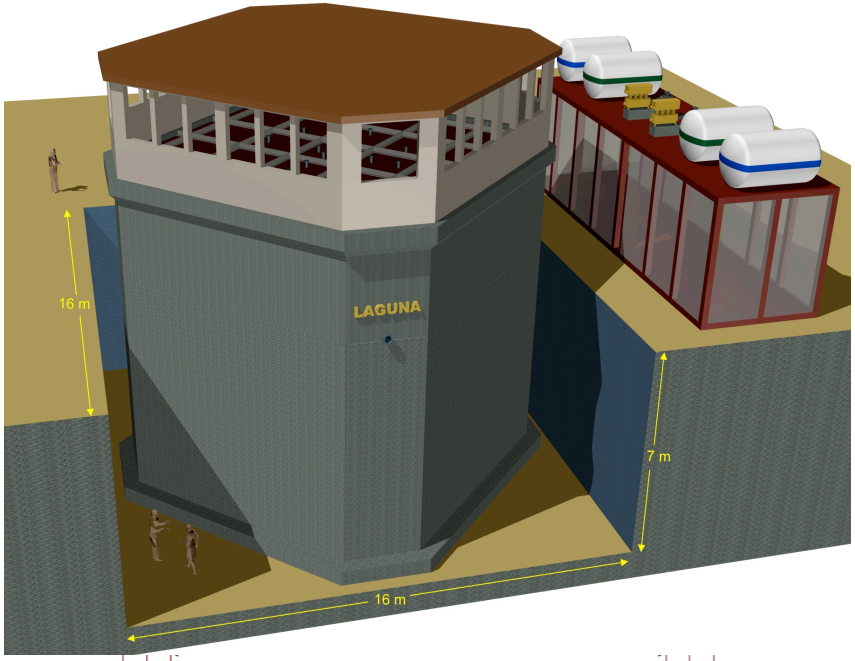
LBNO-DEMO IS THE LAST STEP BEFORE THE LARGE-SCALE EXTRAPOLATION TO MULTI-KTON UNDERGROUND DETECTORS

- Liquid **Argon purity** under control
- Large **hanging structure**
- Long term **stability** of light readou
- Large area **read-out**
- Very **high voltage** generation
- **cold** end **warm electronics**

A LARGE SCALE PROPTOTYPE TO DEMONSTRATE THE FEASIBILITY OF THE LBNO GLACIER DETECTOR

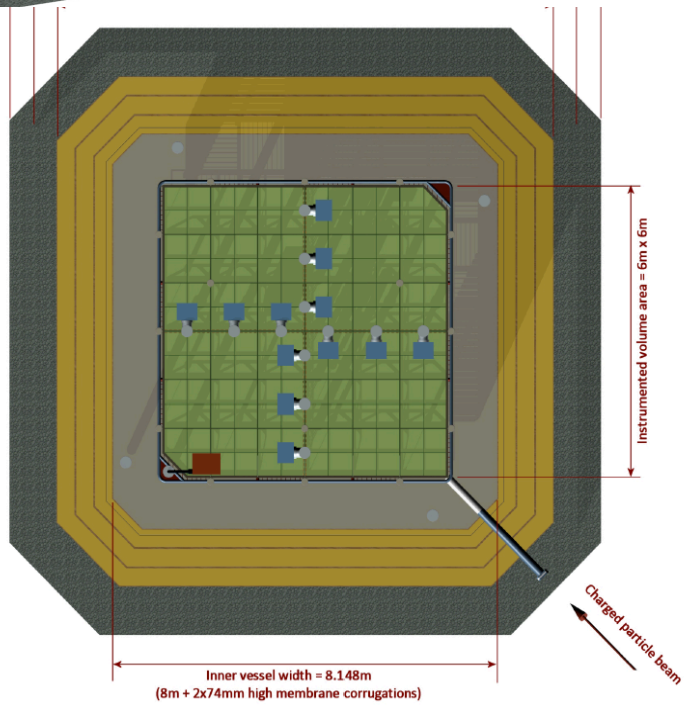


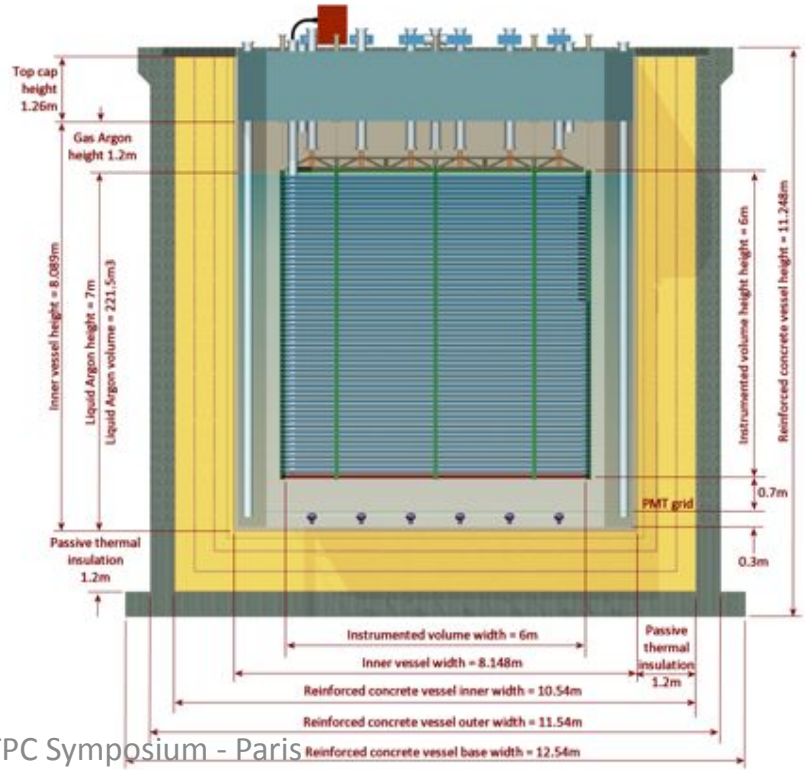
WA105/LBNO-DEMO



MAIN TPC PARAMETERS

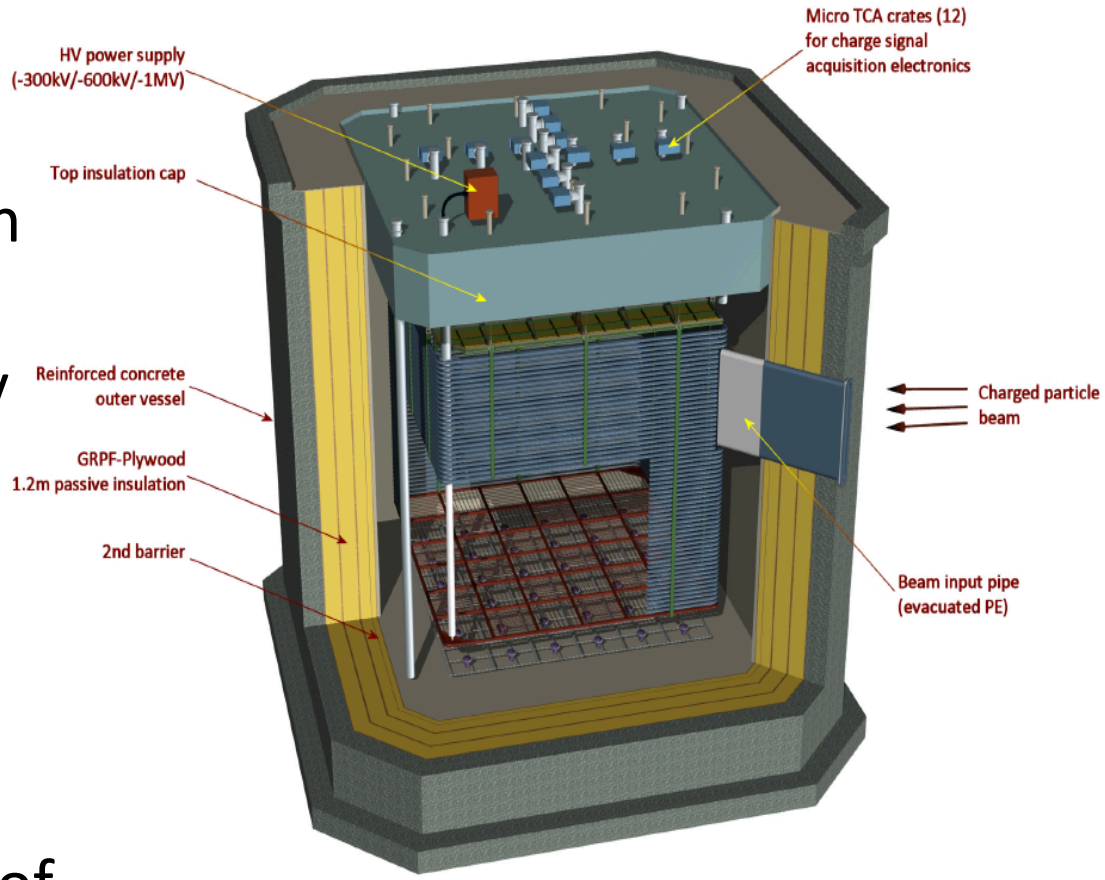
- Inner vessel size: 8.3×8.3×8.1 m^3
- Active LAr area: 36 m^2
- Total LAr mass: 705 t
- Drift field: 0.5 – 1.0 kV/cm
- # of charge readout modules: 36
- # signal feedthrough: 12





WA105 GOALS

- Calorimeter in charge particle beams, energy reconstruction
- Automatic event reconstruction
- Particle identification efficiency from track signature
- Measure of charged pion cross sections on Argon nuclei
- Development and proof-check of industrial solutions



Data-taking performed by using a well known charged particles beam

WA105 COLLABORATION

- LAPP, Université de Savoie, CNRS/IN2P3, Annecy-le-Vieux
- OMEGA Ecole Polytechnique/CNRS-IN2P3
- UPMC, Université Paris Diderot, CNRS/IN2P3, Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE)
- APC, AstroParticule et Cosmologie, Université Paris Diderot, CNRS/IN2P3, CEA/Irfu, Observatoire de Paris, Sorbonne Paris Cité
- IRFU, CEA Saclay, Gif-sur-Yvette
- Université Claude Bernard Lyon 1, IPN Lyon

- Institut de Fisica d'Altes Energies (IFAE), Bellaterra (Barcelona)
- CIEMAT

- University of Glasgow
- University College London

- University of Jyväskylä
- University of Oulu
- Rockplan Ltd

- Faculty of Physics, St.Kliment Ohridski University of Sofia

- Institute for Nuclear Research of the Russian Academy of Sciences, Moscow

- Horia Hulubei National Institute (IFIN-HH)
- University of Bucharest

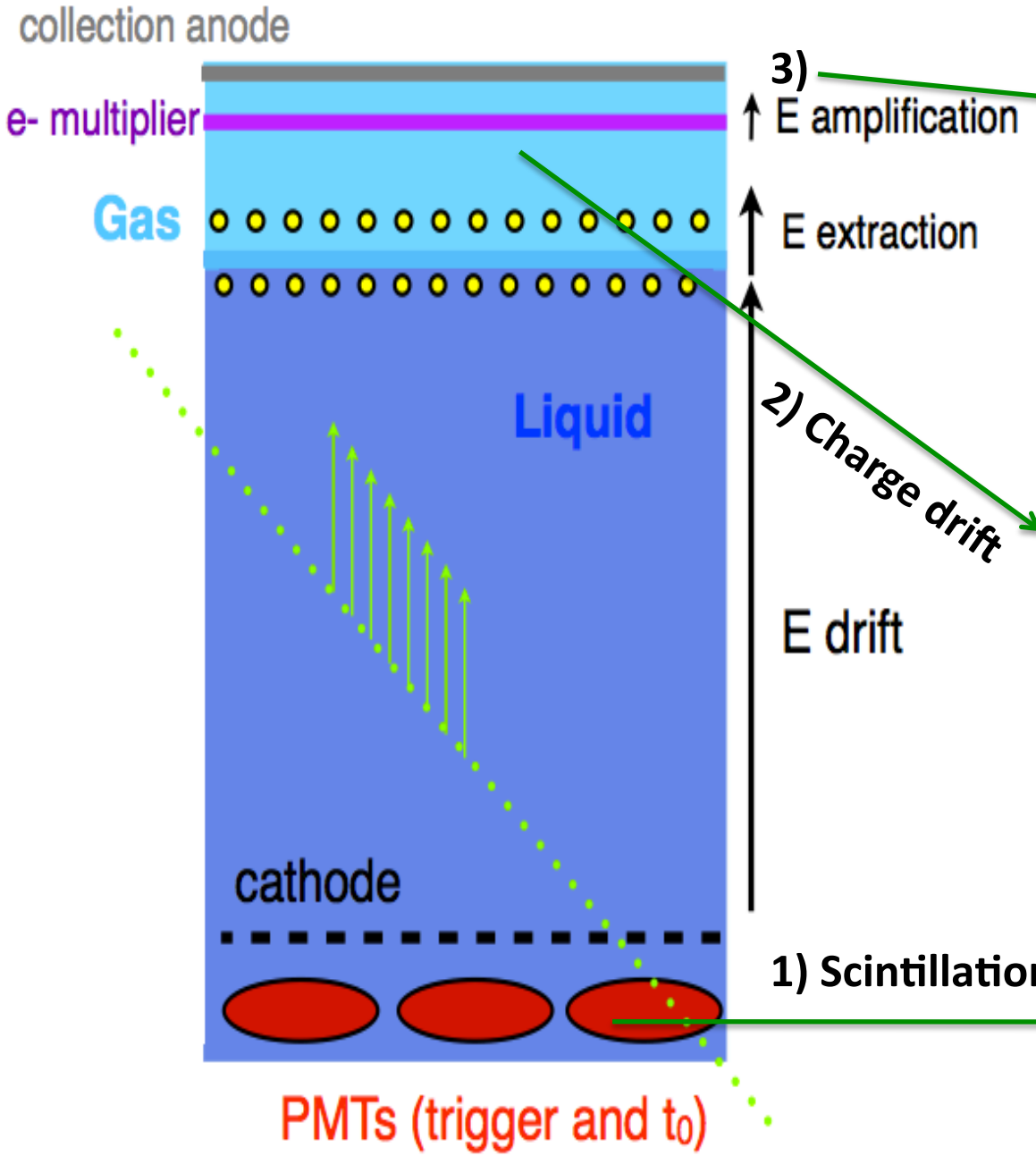
- University of Geneva, Section de Physique,
- ETH Zürich

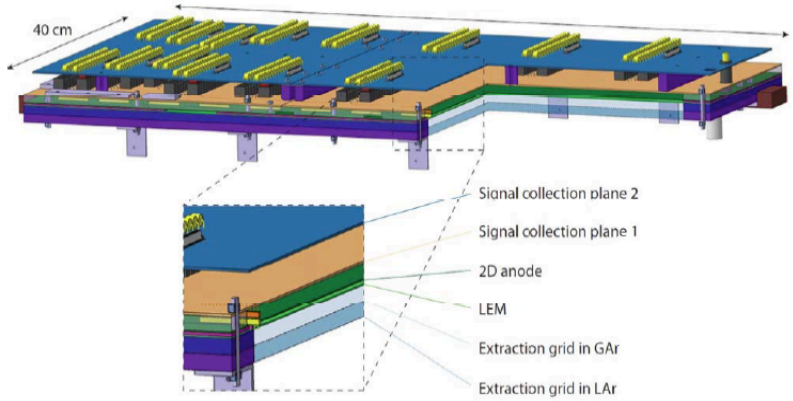
- INFN-Sezione di Pisa

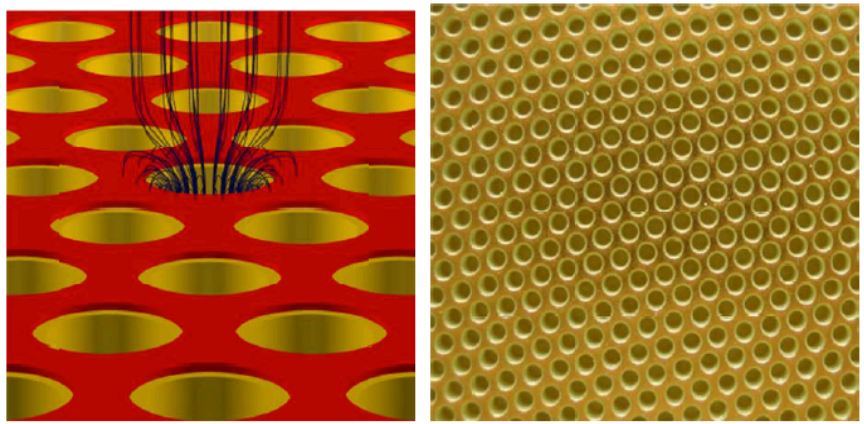
- CERN

- High Energy Accelerator Research Organization (KEK)

DOUBLE PHASE LAR TPC PRINCIPLE





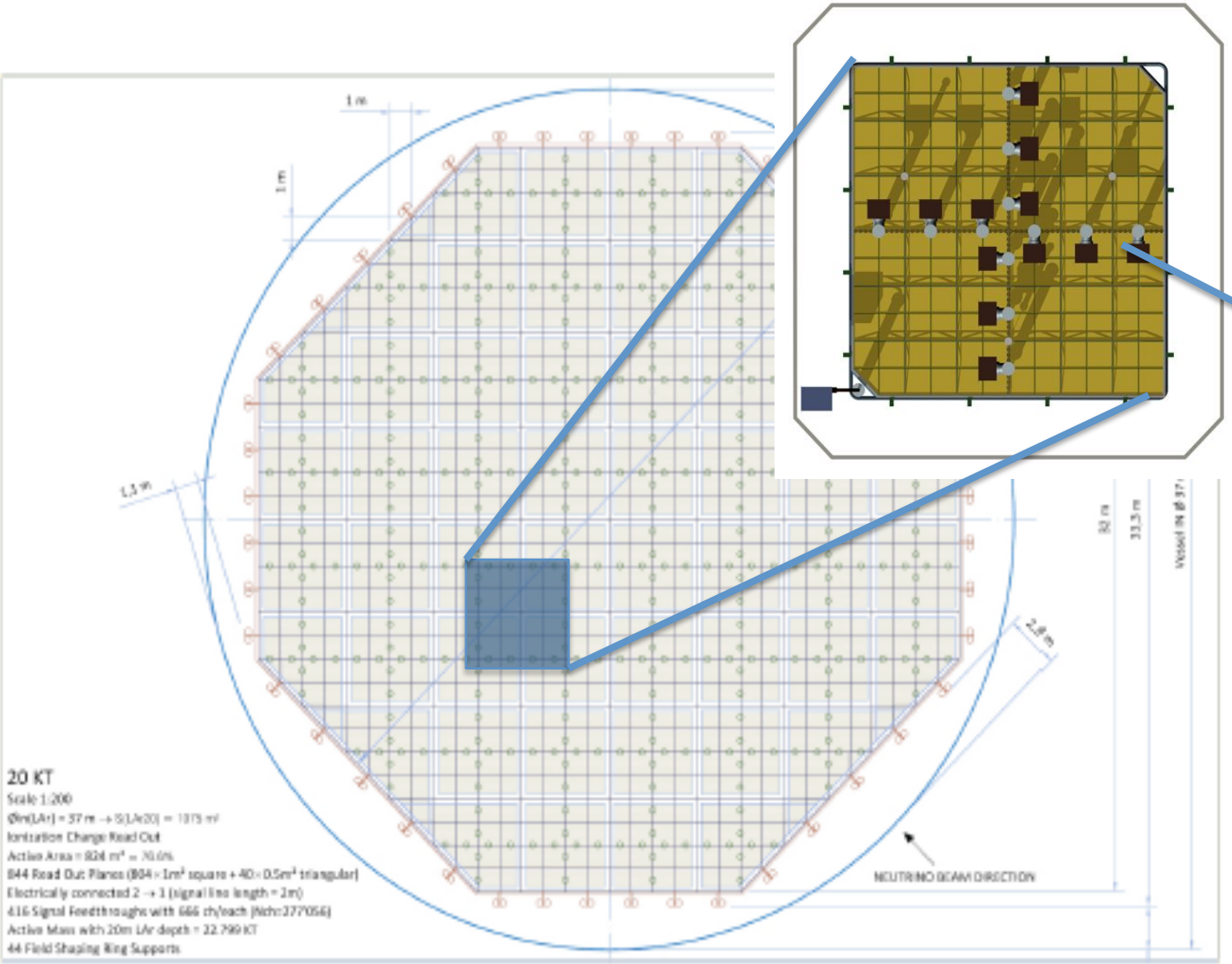


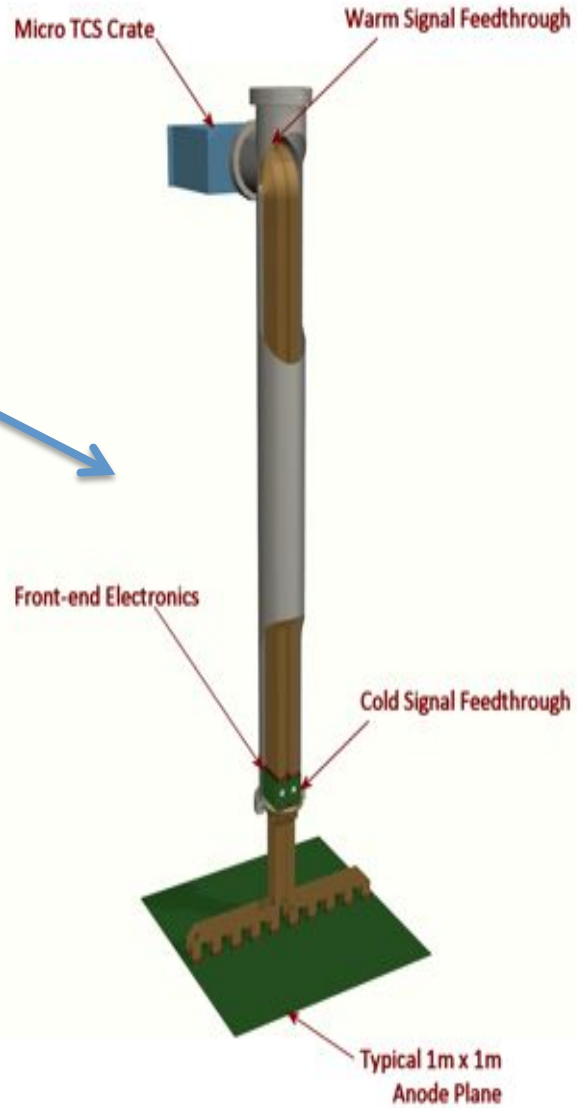
CHARGE READOUT (1)

36 m² active surface equivalent to 1:20 of 20 kton GLACIER.

12 signal feed-through **chimneys**

F/E + Cold/warm signal feed-through + Micro TCS Crate

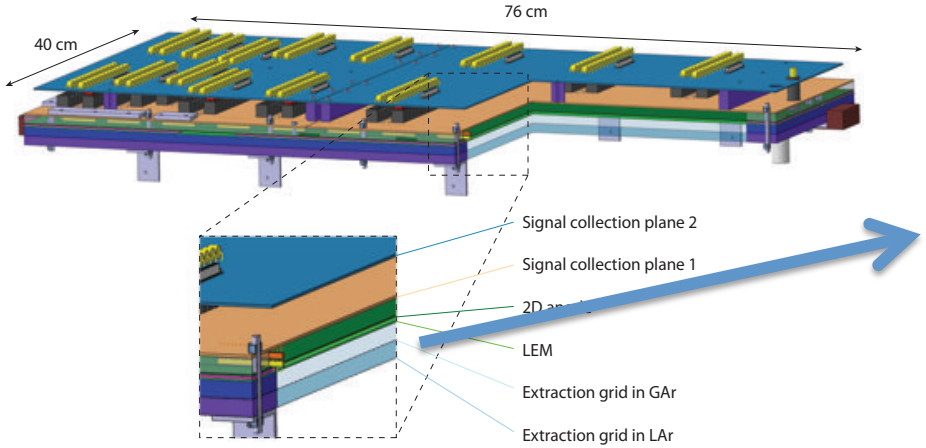


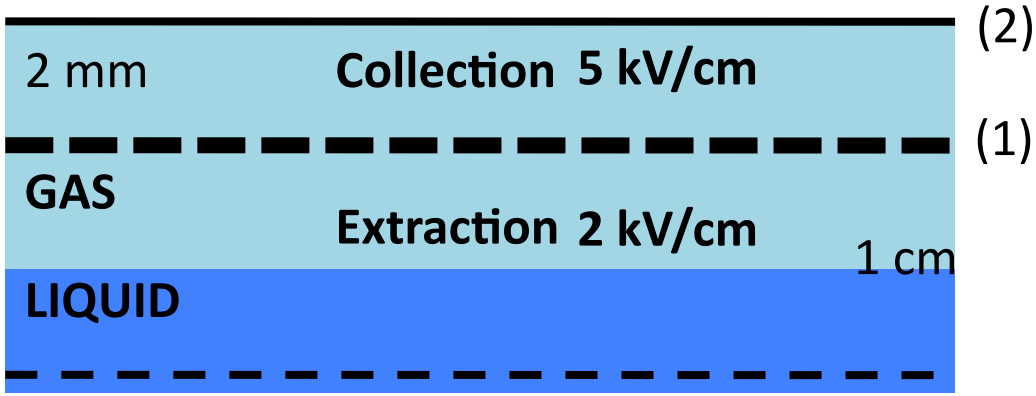


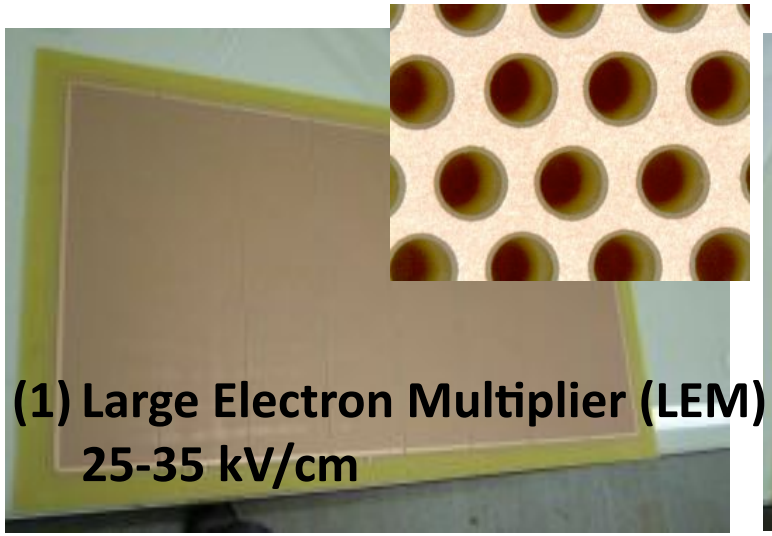
CHARGE READOUT (2)

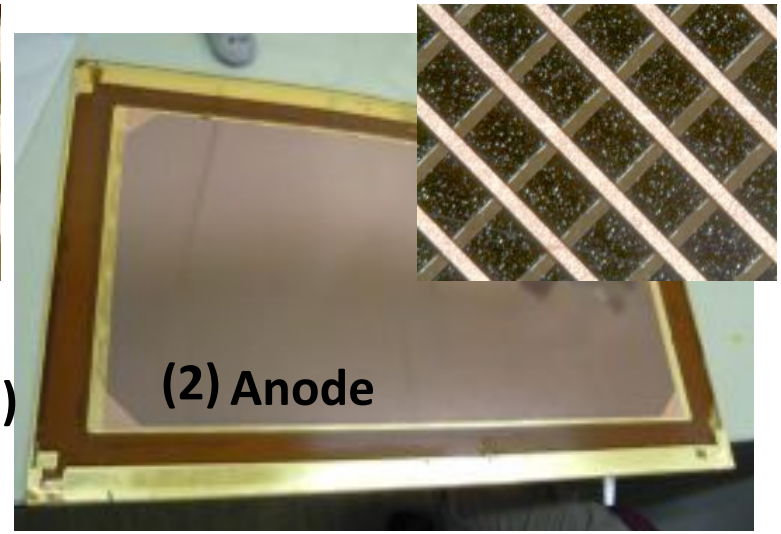
AMPLIFICATION SECTION:
EXTRACTION GRID - > LEM -> ANODE

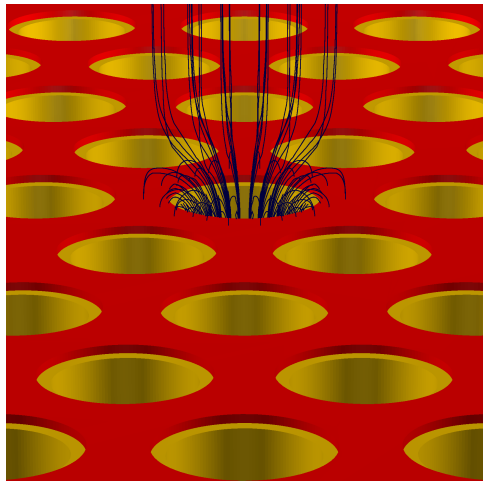
See talk by Wu Shouxing



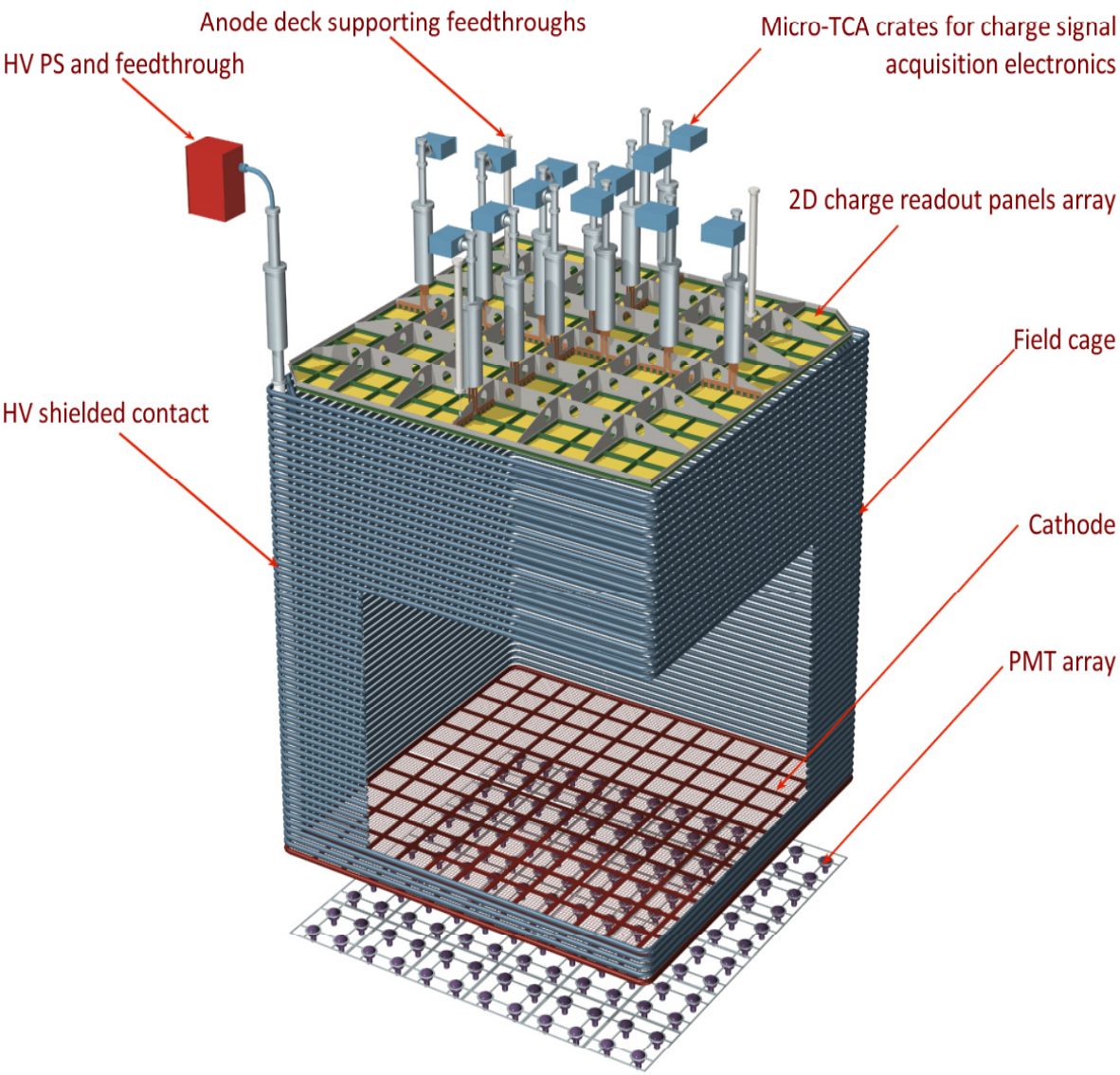








DRIFT CAGE AND HV



Drift cage of scaled design developed in LAGUNA-LBNO for 20/50 kton.

Drift field: **0.5-1kV/cm**

Potential difference: **300-600 kV**

60 equally spaced electrodes

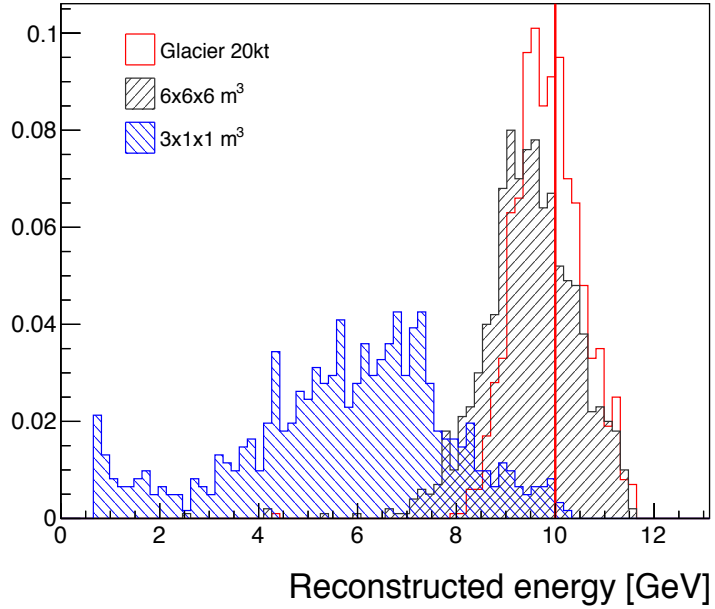
Drift velocity of electrons: **1.6-2.0 mm/s**

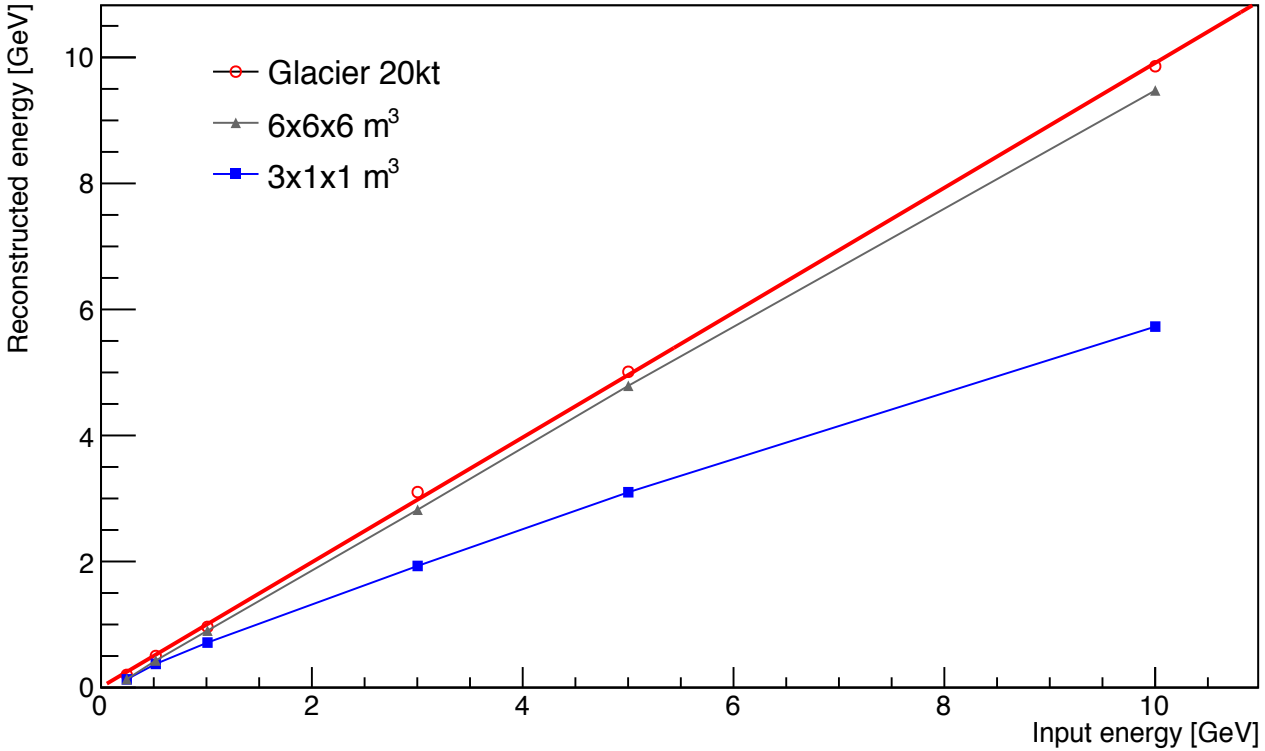
Heinzinger power supply

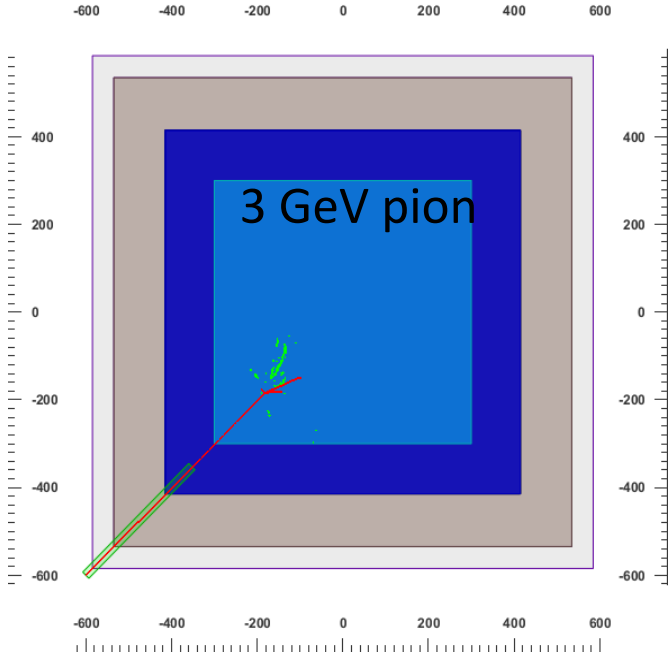
SHOWERS CONTAINMENT AND RECONSTRUCTION (1)

- SHOWERS ENTIERELY CONTAINED IN THE DEMONSTRATOR

- ENERGY DISTRIBUTION CENTERED ON THE INITIAL ENERGY OF THE PARTICLE



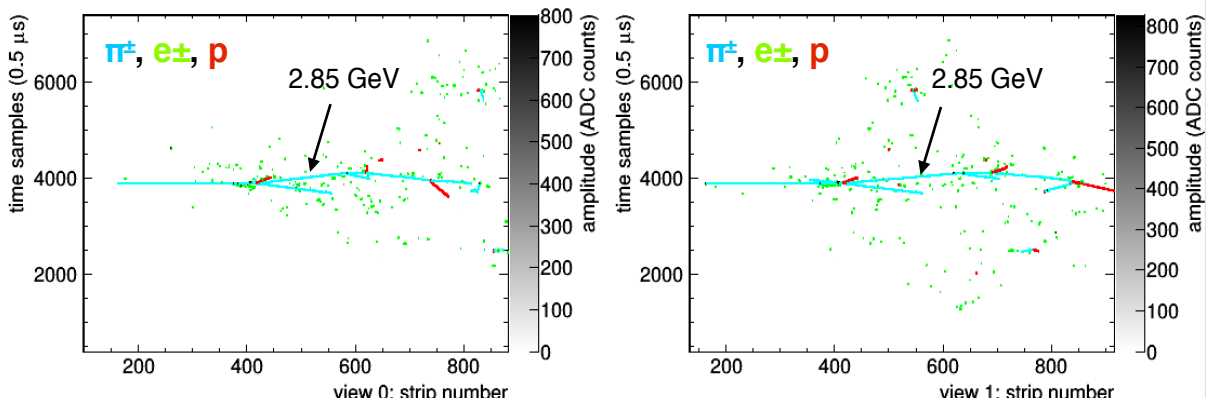




SHOWERS CONTAINEMENT AND RECONSTRUCTION (2)

THE DEMONSTRATOR IS A COMPLETELY HOMOGENEOUS CALORIMETER WITH GRANULARITY OF **3×3 mm²** WITH FULL CONTAINMENT

- HIGH ACCURACY IN HADRONIC SHOWER RECONSTRUCTION FOR THE VALIDATION OF SIMULATIONS

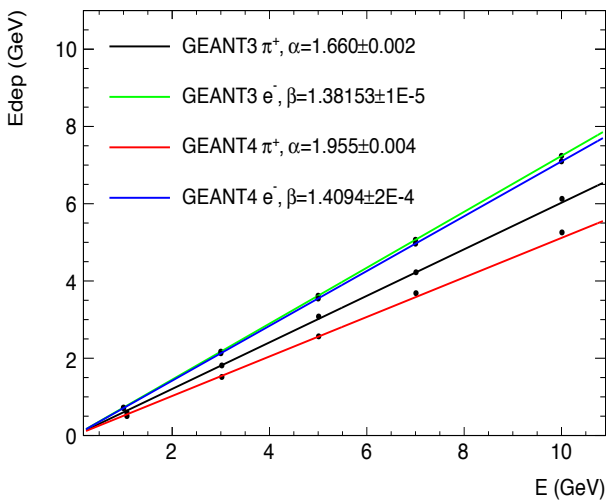


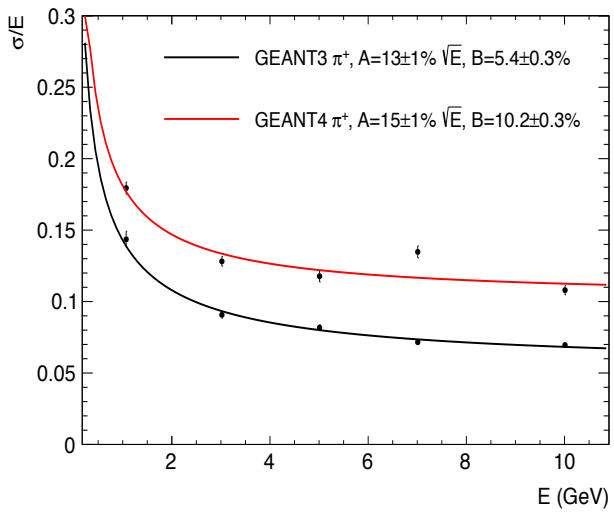
- ENERGY RECONSTRUCTION

$$E_{reco} = \alpha E_{had} + \beta E_{em}$$

$$\sigma / E = A / E + B$$

- ENERGY RESOLUTION

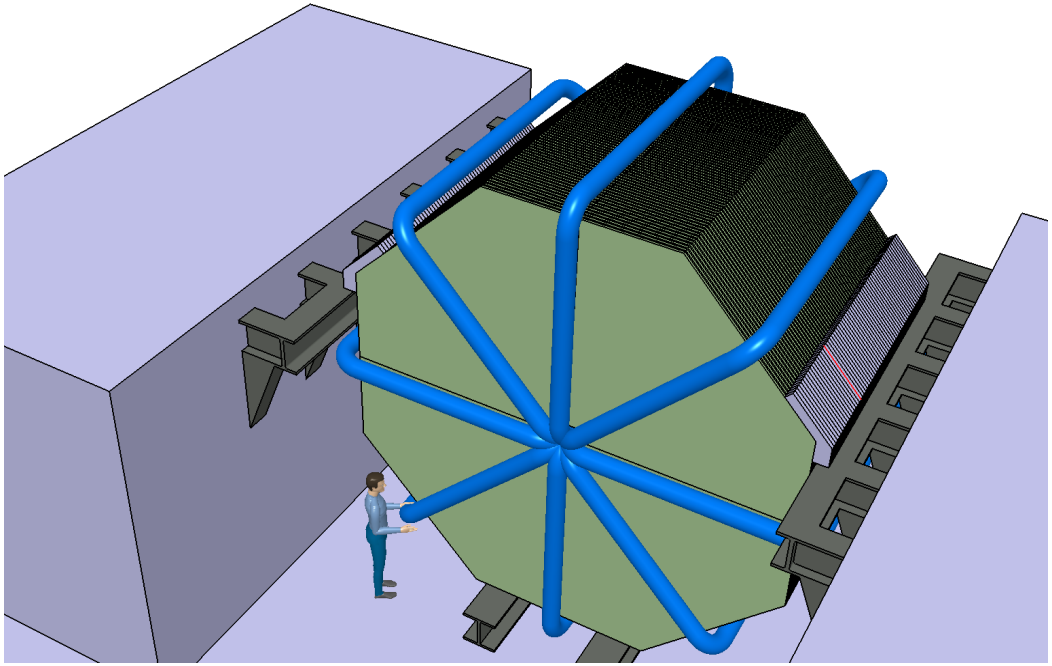


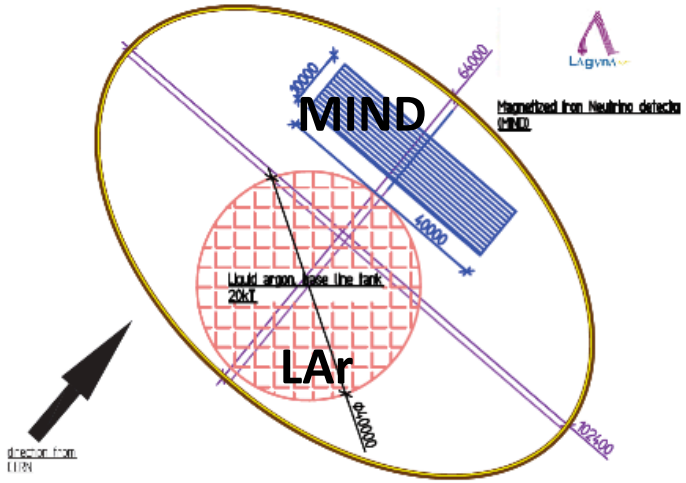


- AUTOMATIC RECONSTRUCTION SOFTWARE NEEDED

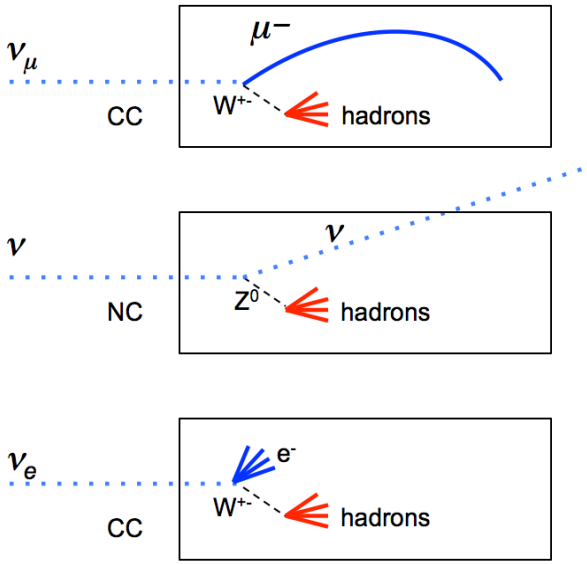
MIND for WA105

Magnetized **I**ron **N**eutrino **D**etector 500 tons of magnetize iron downstream to LBNO-DEMO



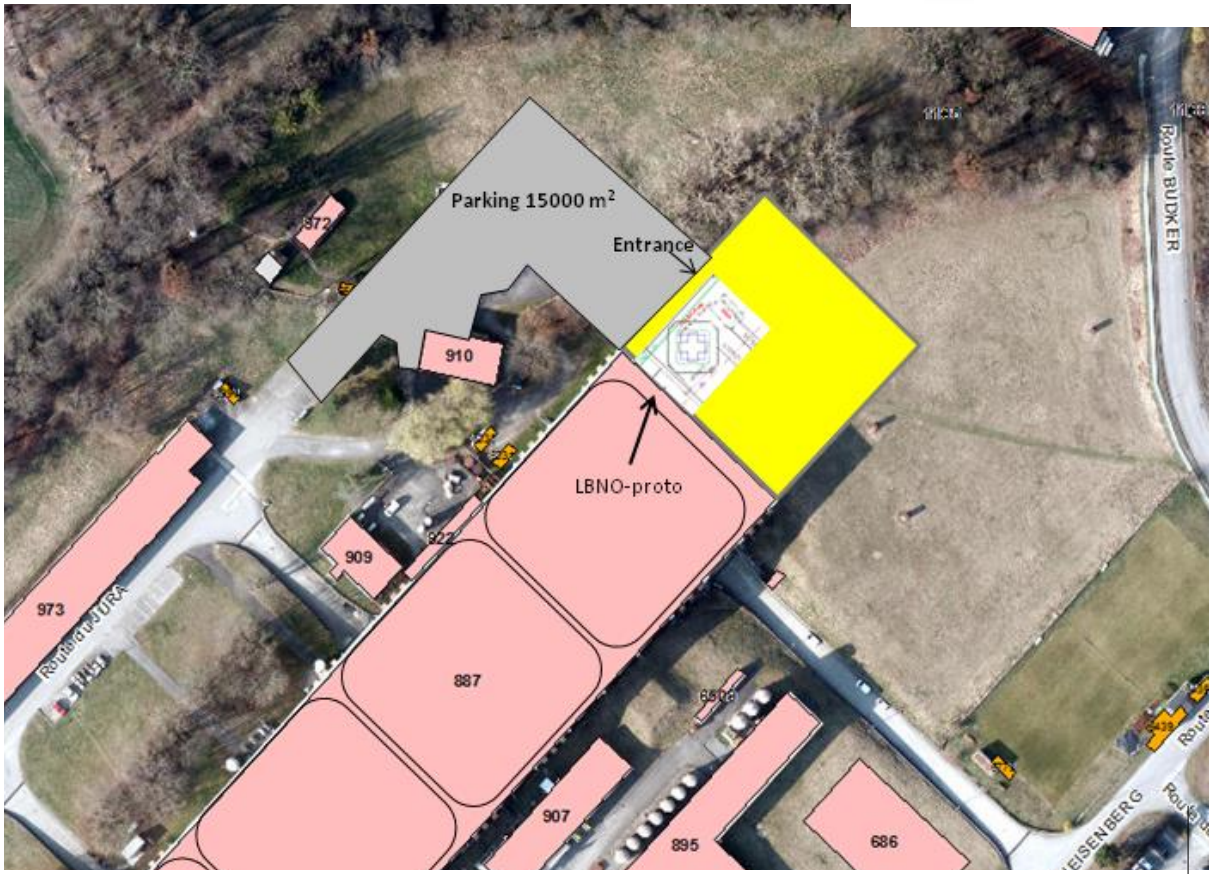


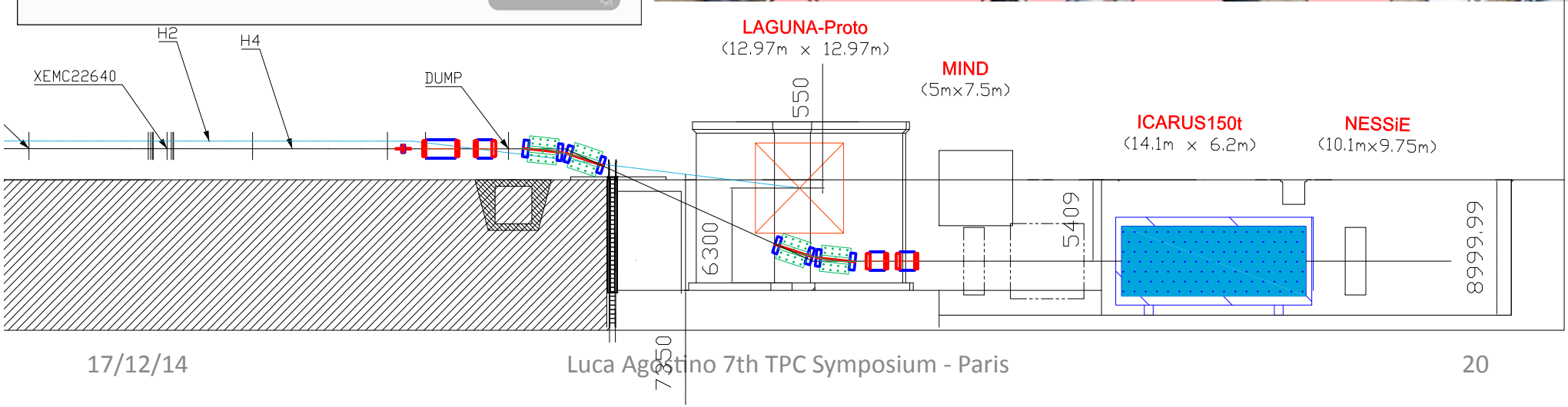
- **CHARGE ID EFFICIENCIES** FOR LOW ENERGY
- INTERACTIONS
- **BACKGROUND** ANALYSES
- **PARTICLE MOMENTUM** RECONSTRUCTION



CERN LOCATION

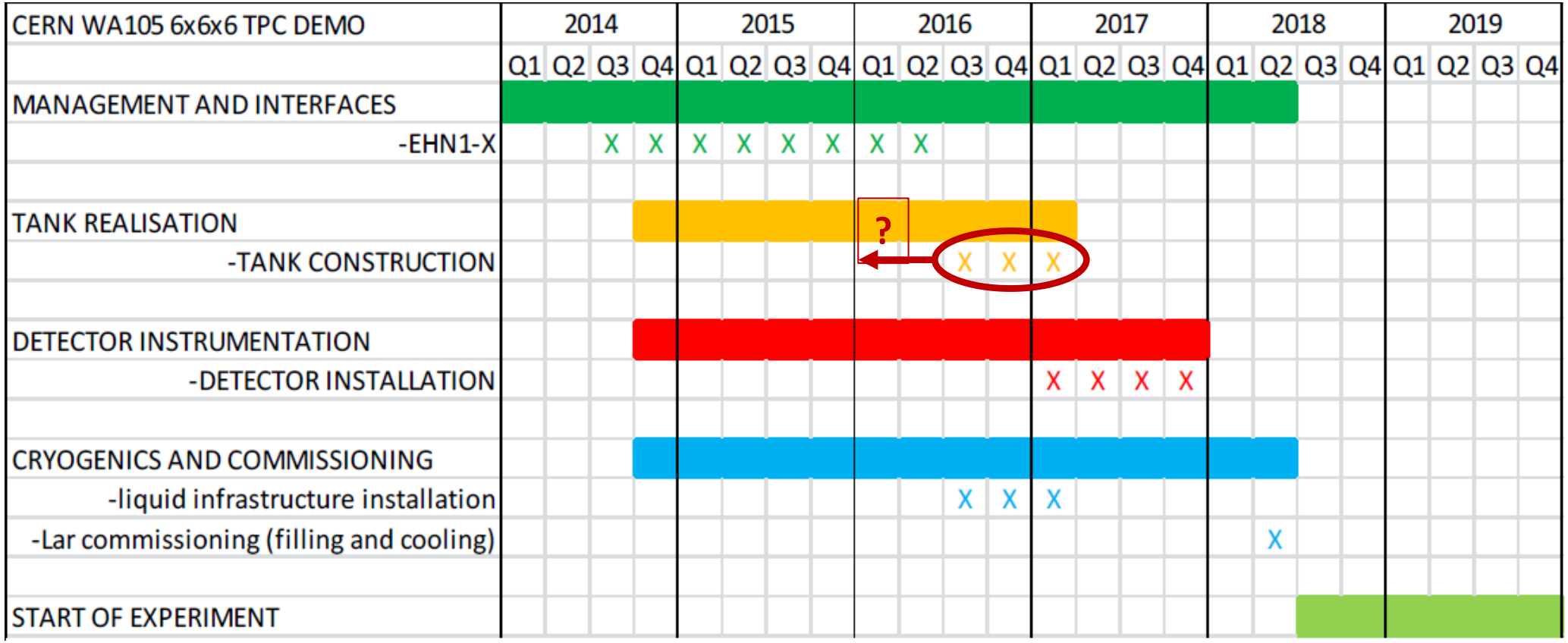
Dedicated extension of the **EHN1** in the **Prevessin** site






The EHN1 extension - 28 October 2014
LBNO-Demo

TIME-SCALE



DATA TAKING EXPECTED BY MID 2018

CONCLUSIONS

THE WA105 COLLABORATION WILL BUILD AND EXPLOIT A 700 ton DOUBLE PHASE LIQUID ARGON LBNO DEMONSTRATOR AT CERN

DEMONSTRATING THE LARGE DOUBLE PHASE DETECTOR FEASIBILITY

STUDYING THE RESPONSE OF THE DETECTOR TO A CHARGED PARTICLES BEAM

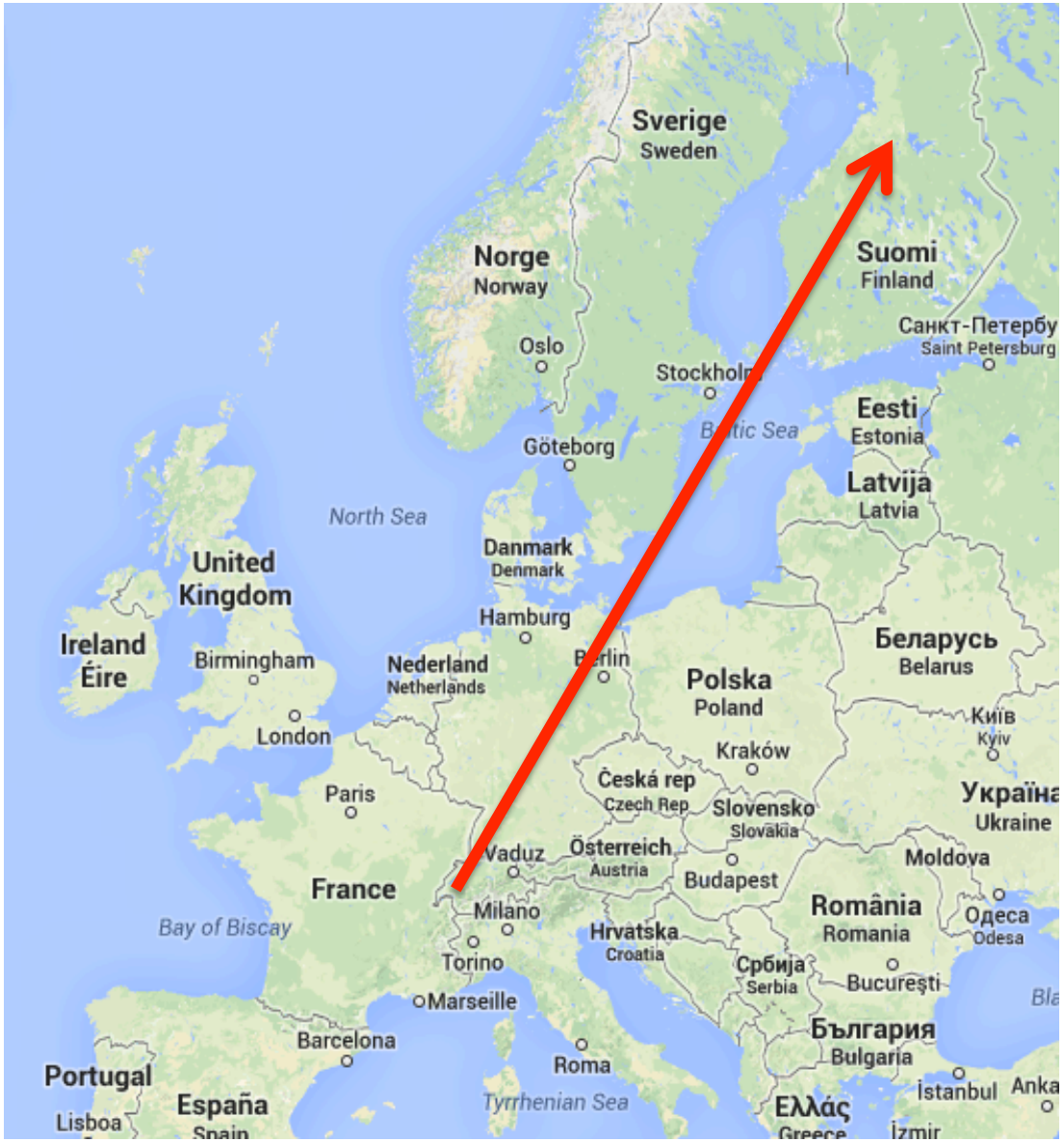
AFFORDING NEW ENGEENIRING AND TECHNICAL CHALLENGES

ALLOWING THE FUTURE CONSTRUCTION OF NEW GENERATION LIQUID ARGON DETECTORS

arXiv:1409.4405

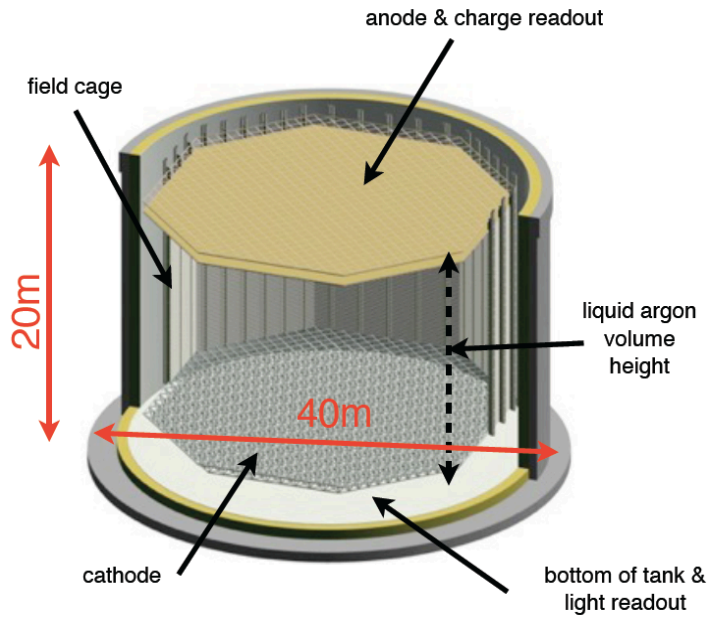
BACKUP

LAGUNA/LBNO CERN TO PHYÄSALMI CN2PY:



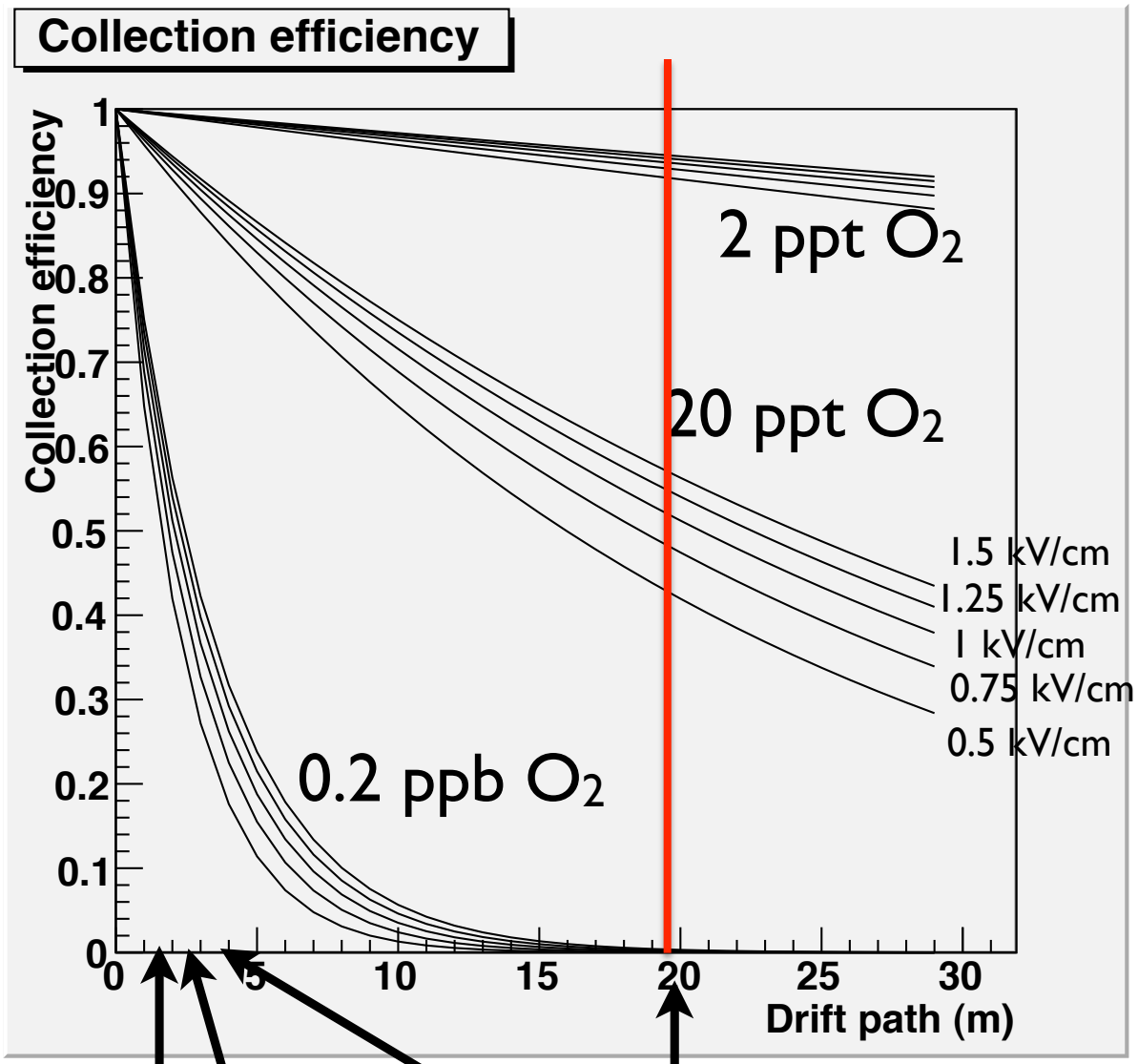
LBNO20 20 kton full cost = 226 M€

- 2300 km baseline from CERN (CN2PY)
- SPS 400 GeV protons – 750 kW beam
- HPPS 50 GeV protons – 2 MW beam
- Liquid Argon double phase TPC detector GLACIER : Incremental approach Phase 1 : LBNO20 (20kton) Phase 2: LBNO20+50 (70kton)



ARGON PURITY

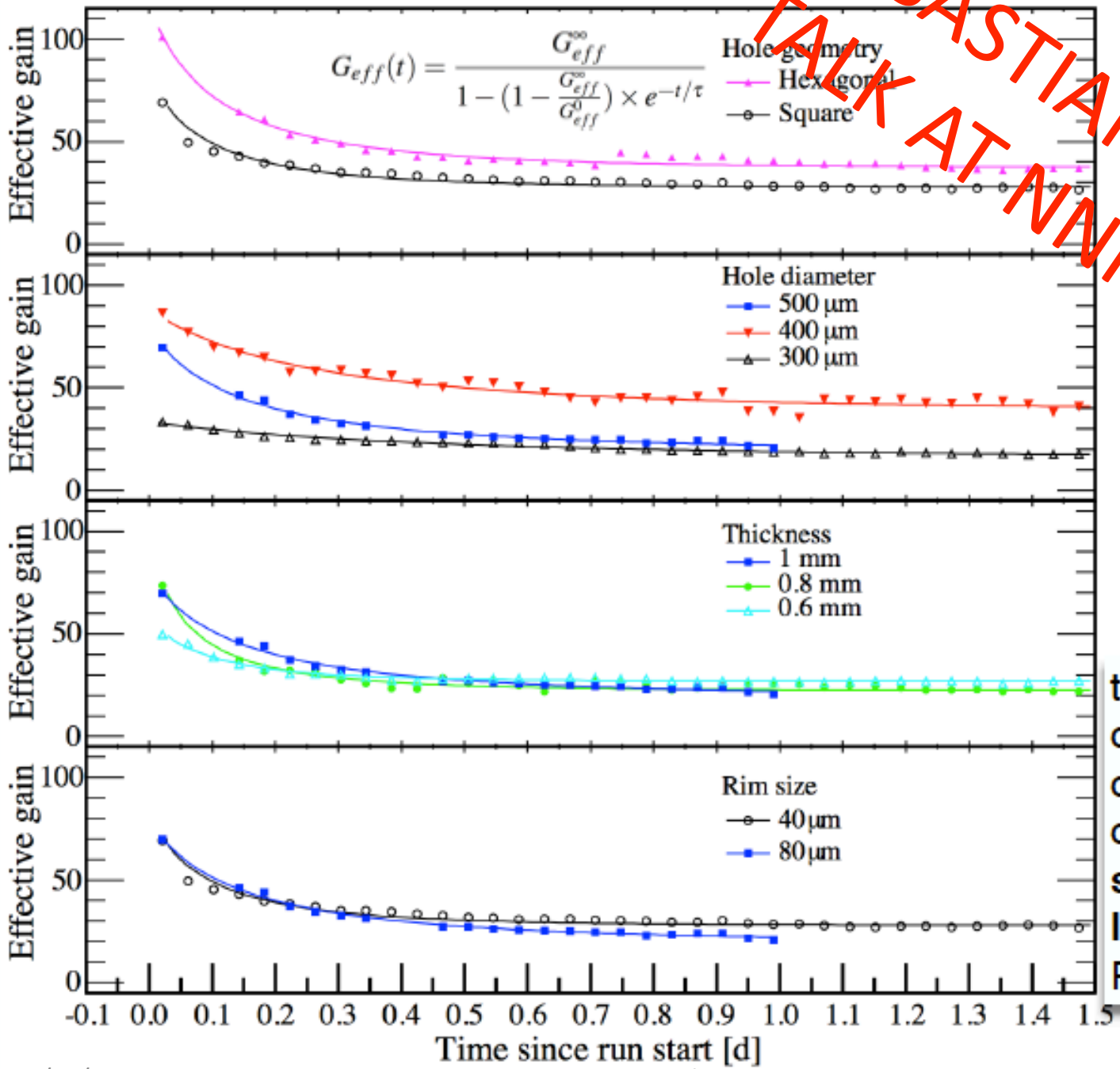
Charge attenuation because of attachment to impurities



T600 MicroBoone LBNE GLACIER

LEM gain stability

SEBASTIAN MURPHY'S TALK AT NNN14



the LEMs have different charging up characteristics but all could be **operated stably at gains of at least 20.**

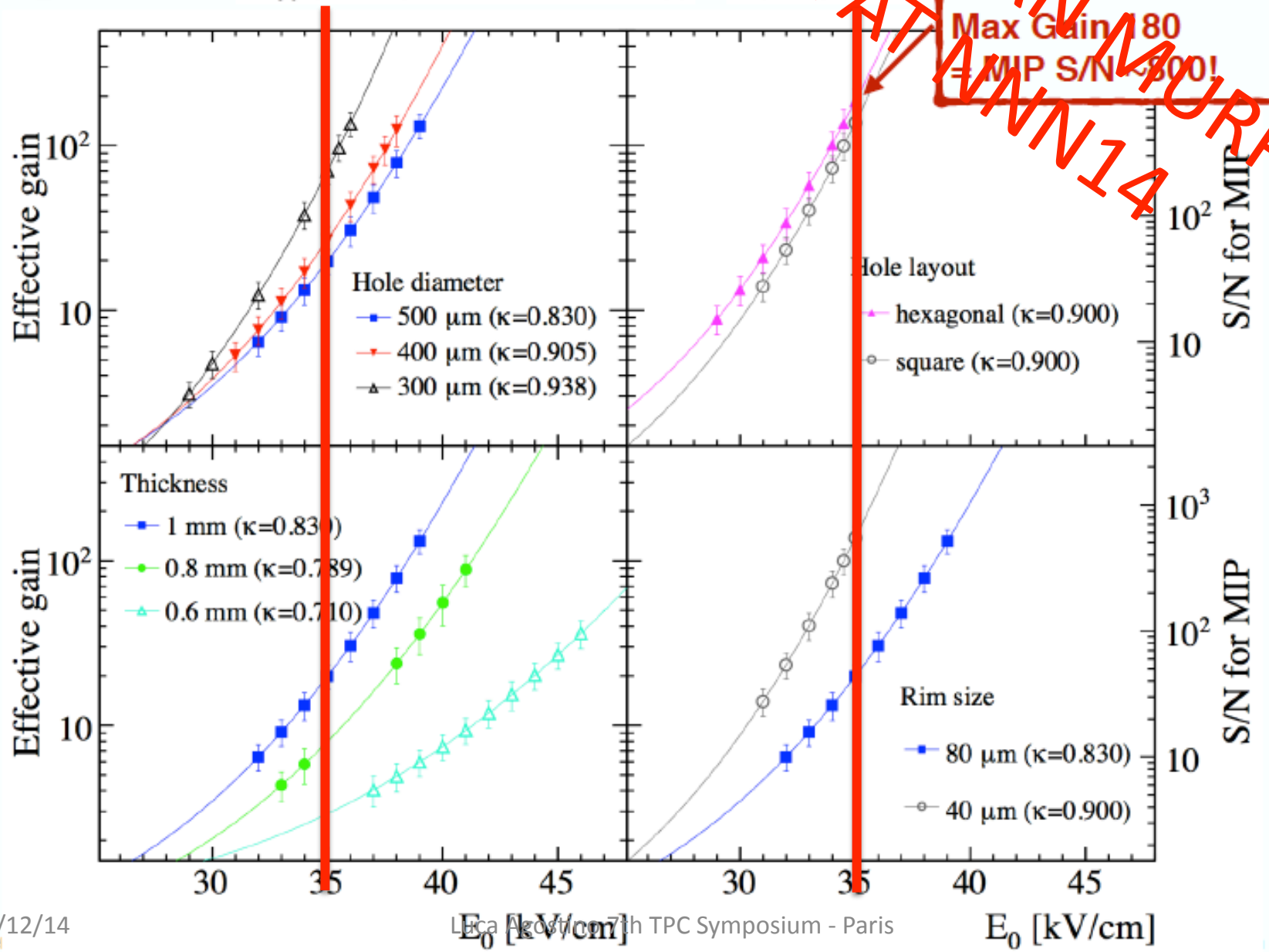
Paper in preparation

LEM gain curves

Fitting function: $G_{eff}(E,\rho,t) \equiv \mathscr{T} e^{\alpha(\rho,E)x} \times \mathscr{C}(t)$ $\alpha(\rho,E) = A\rho e^{-B\rho/E}$

SEBASTIAN MURPHY'S TALK AT WNN14

Max Gain 180
= MIP S/N~800!



DIFFUSION IN LAR

Drift fields E=0.5,0.75,1,1.25,1.5 kV/cm