High precision neutrino physics with ENUBET

Prof. Andrea Longhin

Per gli studenti di LT e LM in Fisica

Settimana della didattica
DFA UniPD, 28/9/2021

The neutrino

ENUBET
A. Longhin

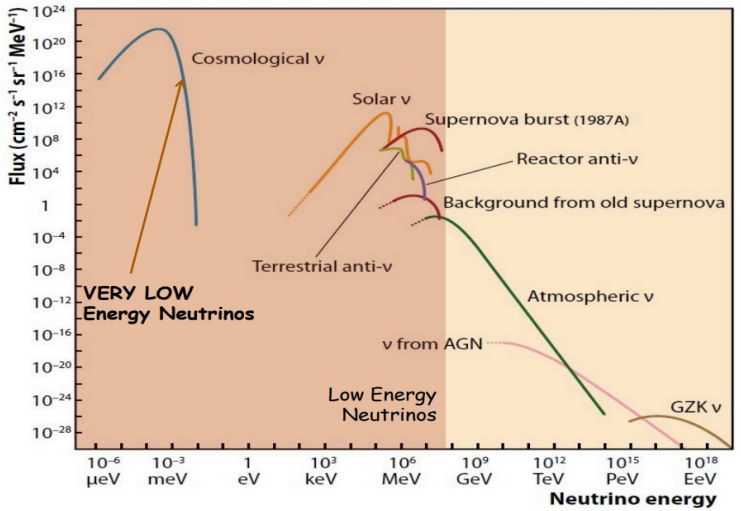
Hypothesis 1932 (Pauli), discovery 1957 (reactors, Reines-Cowan)

Extremely abundant:

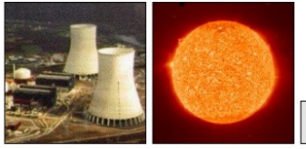
the Sun → $6x10^{10}/s/cm^2$!!!

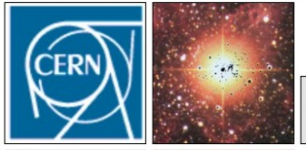
the Early Universe → $336/cm^3$ (indirect!)

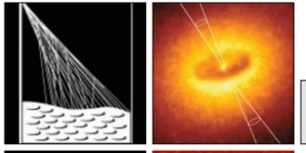
Many sources over ~20 orders of magnitude in energy →

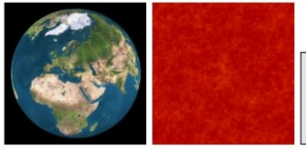


Where do neutrinos come from?









✓ Nuclear reactors

✓ Particle accelerators

✓ Earth Atmosphere (Cosmic rays)

✓ Earth interior (Natural Radioactivity)

Sun ✓

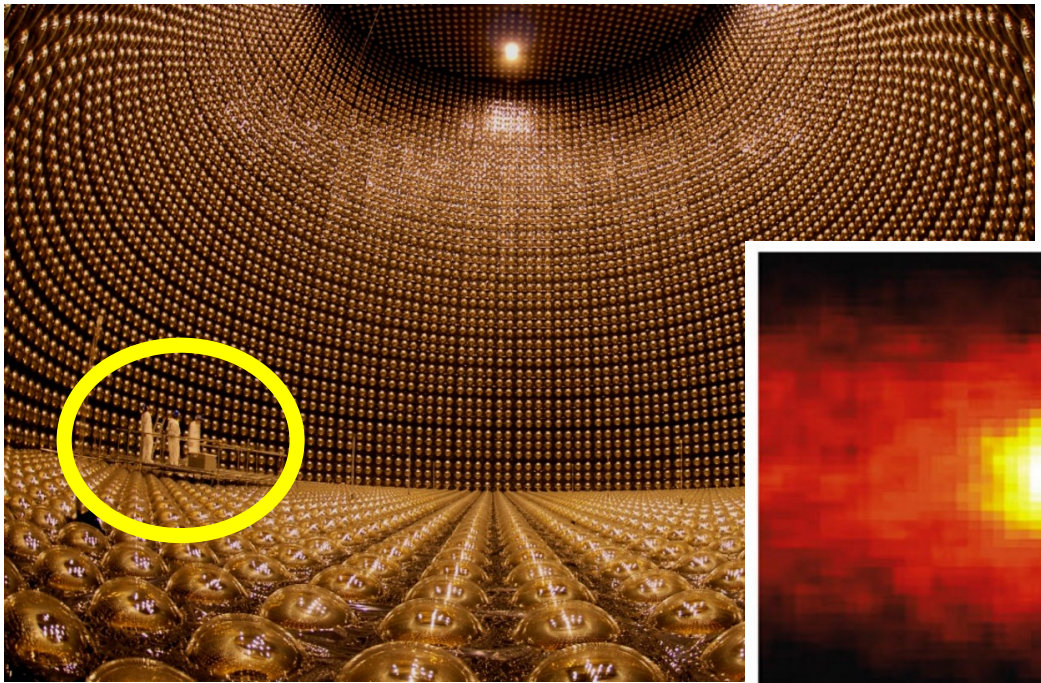
Supernovae SN 1987A ✓

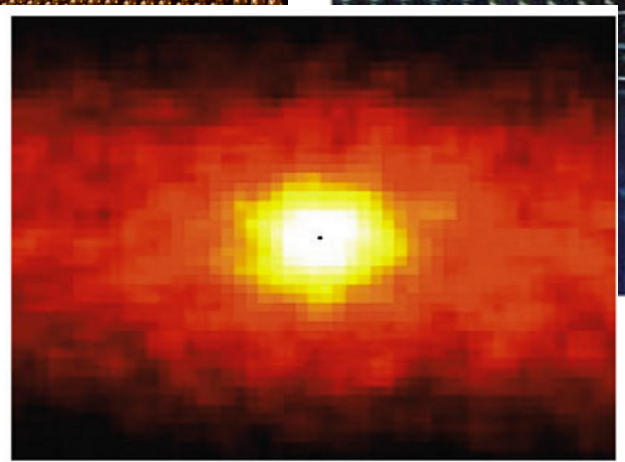
Accelerators in astrophysical sources ?✓

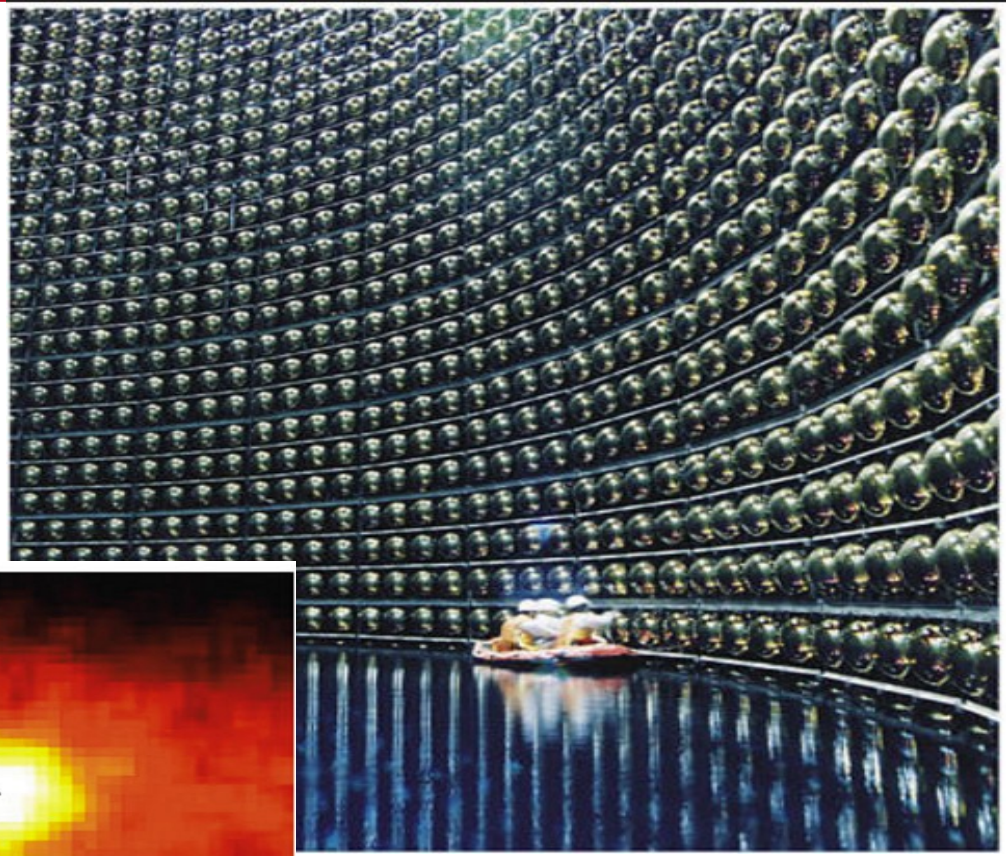
Early Universe (today 336 ν/cm³) Indirect evidence

Weak interaction only

The only elementary particle with weak interaction only → gigantic and refined detectors



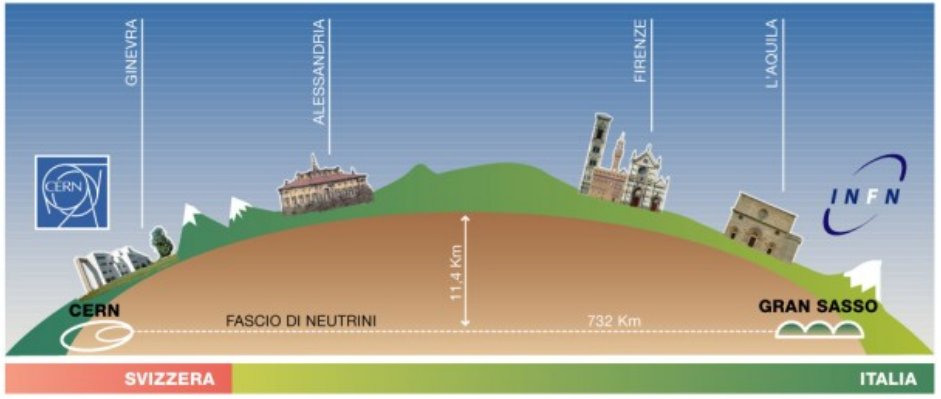


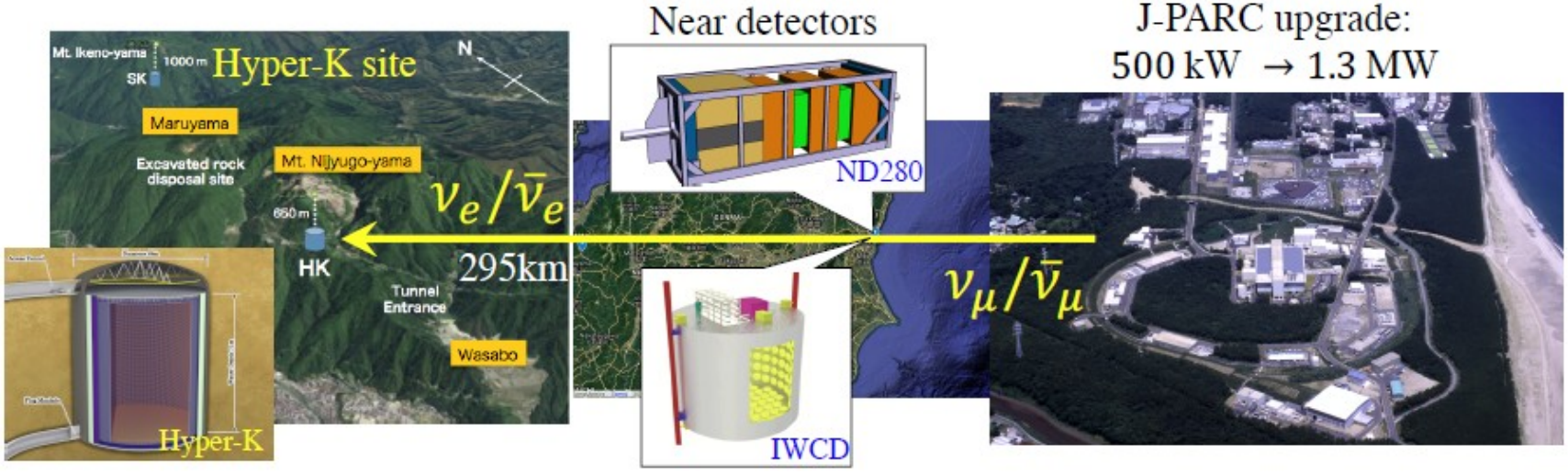


← The Sun neutrino-graphed by Super-Kamiokande

Tunnel ? no thanks

Beams of O(100 km) or more feasible underground
→ oscillation experiments (flavor transitions)





T2K experiment

Light … but not too much

1998: discovery of neutrino oscillations → at least 2 out of the 3 neutrinos have a non-zero mass (< 1 eV) → Nobel 2015 (Kajita, McDonald)

NB: ~O(1 M) times lighter that the electron: what makes the neutrino mass so unnaturally lighter than the leptons (to which they are intimately related)?

High-mass "right-handed" counterparts? → portal towards physics beyond the standard model (high masses)

Masses from the Higgs mechanism? Or intrinsically different particles? (Majorana fermions).

Open questions for new experiments

Do ν violate the CP symmetry as quarks? A handle to understand the matter-over antimatter asymmetry in the universe?

We currently only now the squared masses differences… Which is the mass of the lightest neutrino? which is the actual ordering ?

Several experiments hint to “new” neutrinos beyond those with a standard lepton counterpart (sterile neutrinos). Will exotic physics be confirmed?

What is needed to progress?

Why is the field so open ? νs are difficult to "manipulate" and control:

- **Need to detect them far away + weak interactions → large statistical uncertainties**
- **Even when close to the source interaction mechanisms at the most interesting energies are difficult to measure → large systematic uncertainties**

Systematics are becoming the driving limitation
→ Desperate need for high quality experimental inputs

ENUBET is an idea (supported by the ERC) to study a new concept neutrino source with unprecedented precision

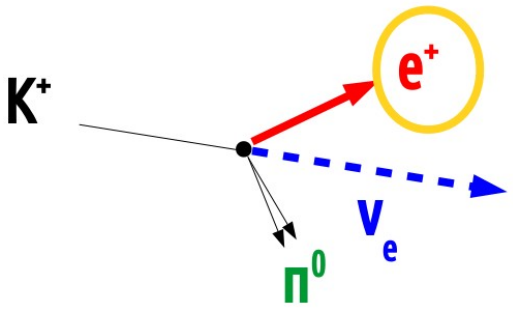
European Research Council
Established by the European Commission

The ENUBET challenge

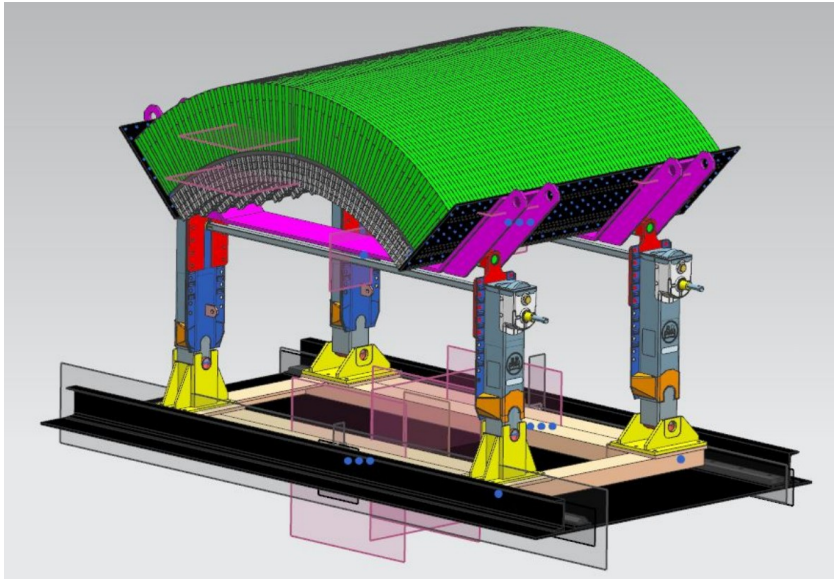
Reach a O(1 %) control on the flux → precise physics

How ? “counting” positrons from kaon decays with a large/scalable detector

ENUBET → Enhanced NeUtrino Beams from kaon Tagging



(1 e^+ = 1 neutrino)

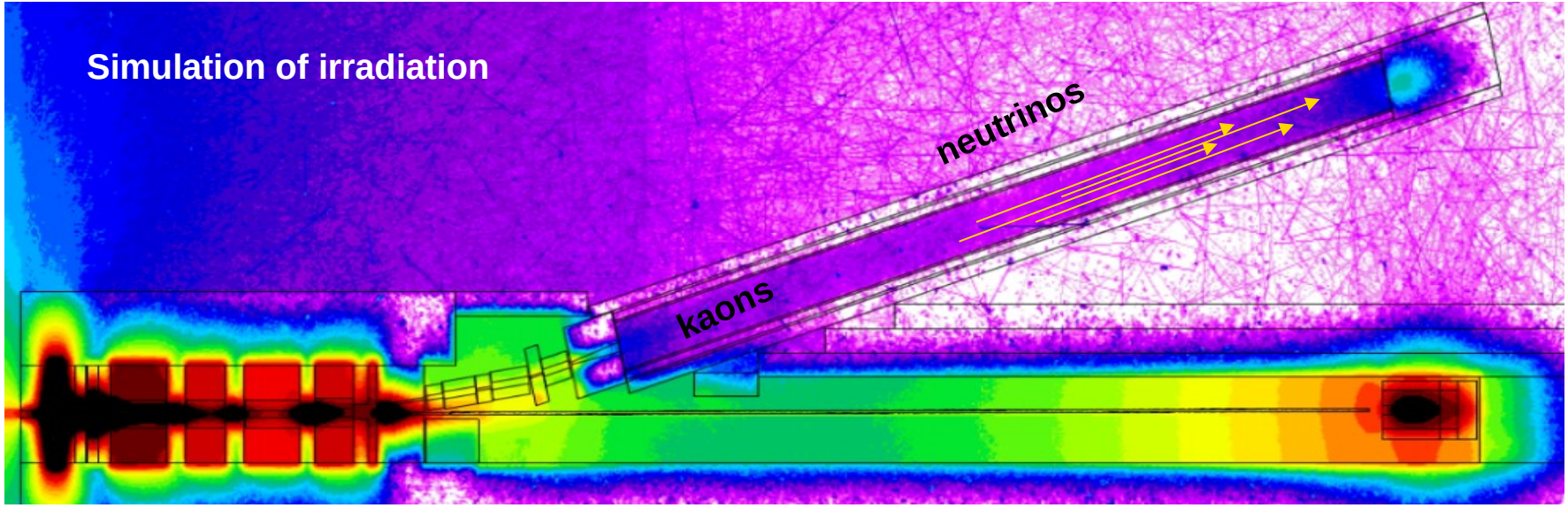


Challenges for the detector:

fast electronics / radiation tolerance / good particle identification with a cost-effective solution

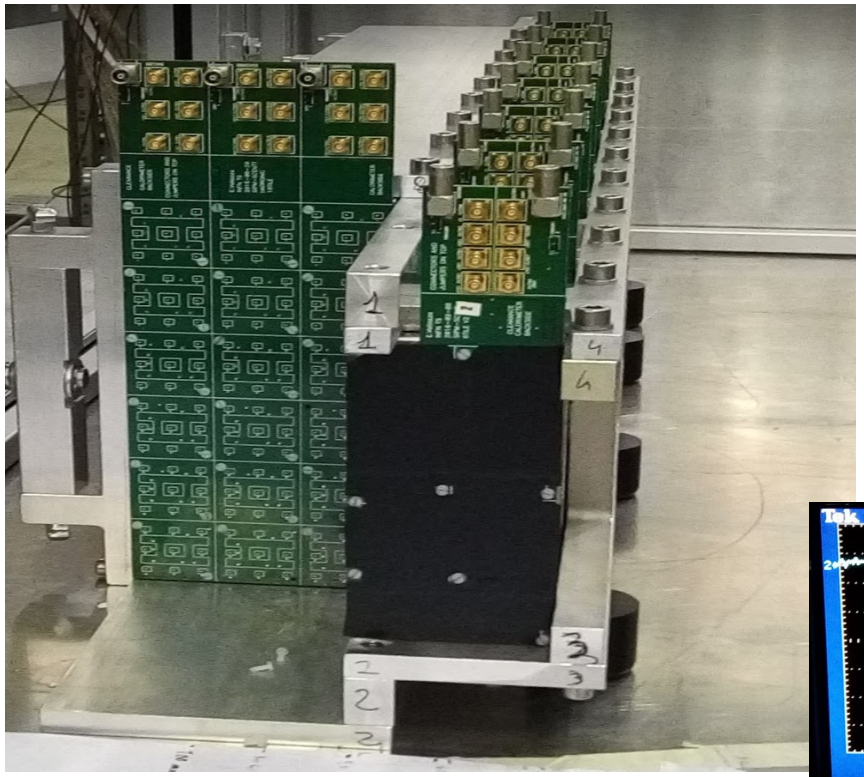
In practice ...

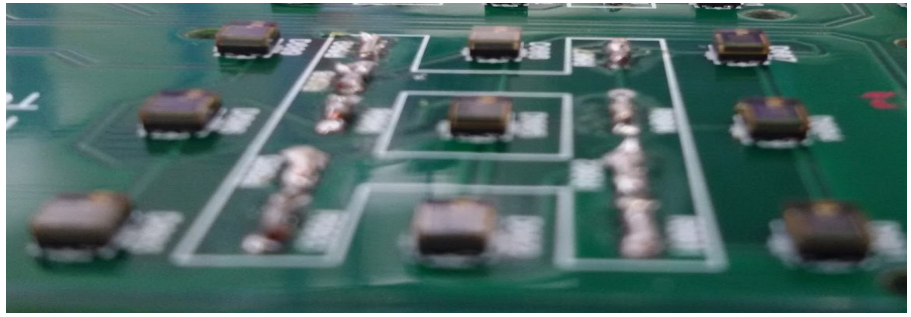
We are designing/simulating a magnetic system to focus the charged particles producing neutrinos (kaons)

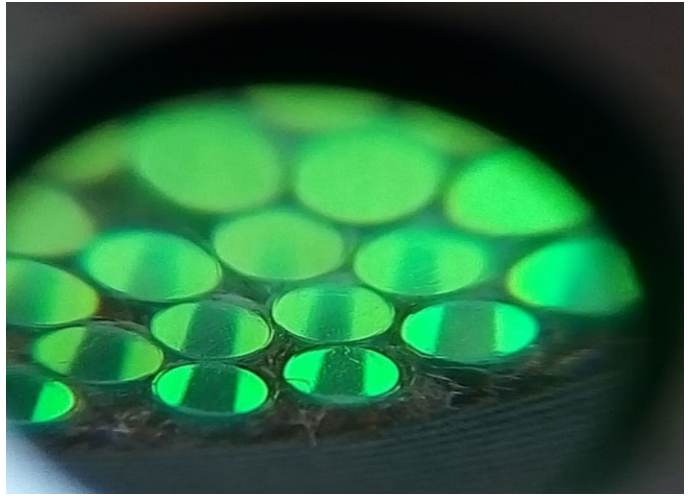


In practice ...

We are developing a new particle detector and the readout electronics to measure the charged particles associated to neutrino

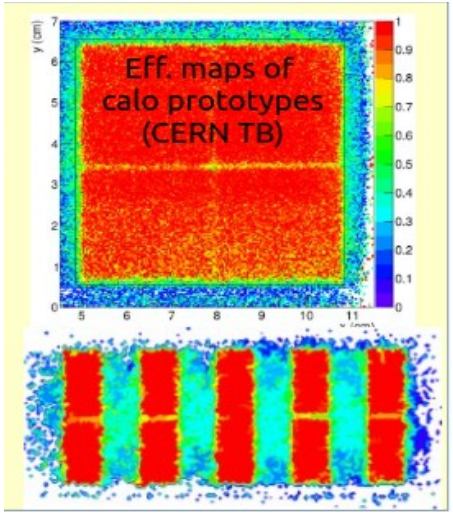


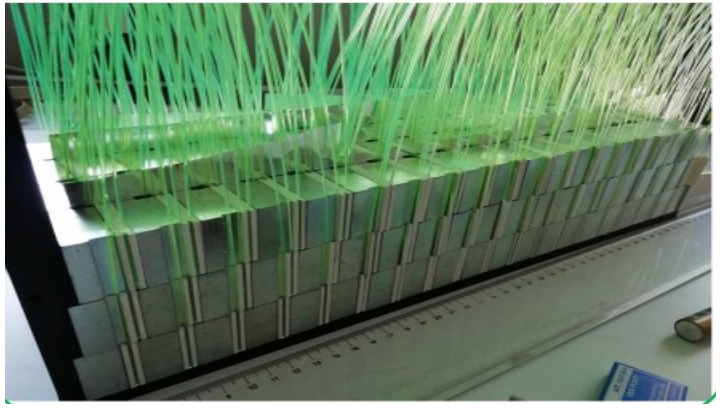




In practice ...

… that we test with particle beams at CERN and at our laboratory at INFN Legnaro

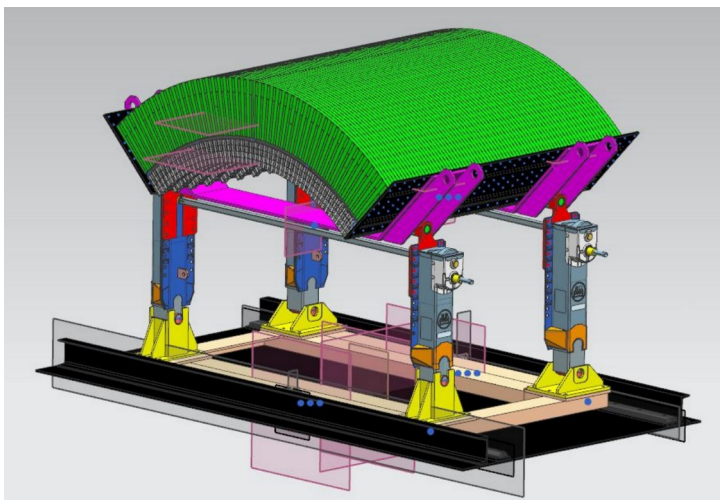




Competences development, opportunities

Accelerator physics: study proton extraction, focusing of particles
Simulation: doses, particle tracking in magnetic fields, detector simulation
Advanced analysis/statistics : data from detector prototypes. Lepton reconstruction with multivariate tools. Assessment of ultimate achievable systematic errors.
Hardware: Development of sampling calorimeters, silicon photo-multipliers.
Network Interaction with an international team and big research institutes (INFN, CERN)

A particularly interesting moment: the "demonstrator" of the lepton tagger is being built at Legnaro and will be tested at CERN in 2022.



Involvement in established neutrino experiments: T2K

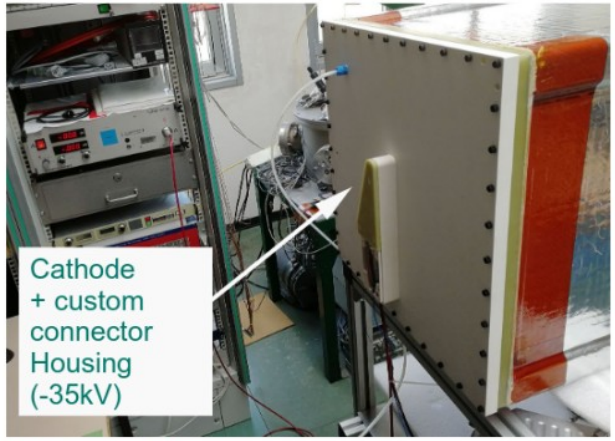
The group is also involved in the T2K neutrino oscillation experiment in Japan

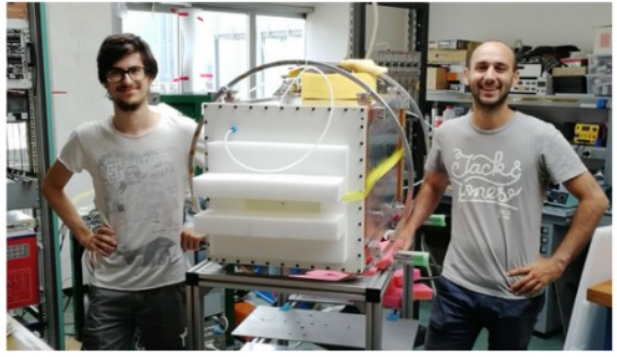
Currently the “hot” activity is the construction of a new detector (TPC) in Legnaro. Padova responsibility (Prof. G. Collazuol).

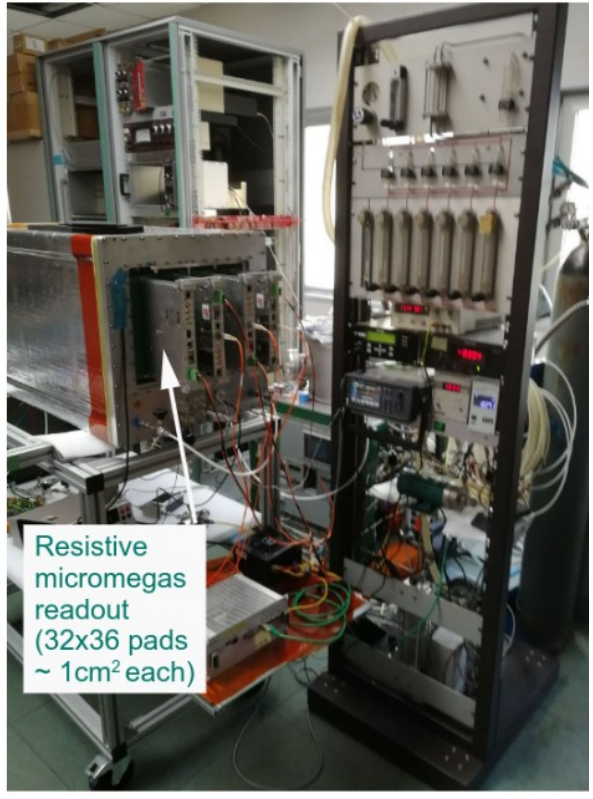
Will be installed in Japan in 2022.

Several students already successfully involved (ask!)

Opportunities for hardware + data analysis of a running world leading neutrino experiment.







For more info ...

http://enubet.pd.infn.it

Bordeaux 2018

Or even better… let's talk about it

Some specific proposals for theses follow

(can be tailored to specific interests)

ENUBET: 60 physicists, 12 institutions

T1: Risposta di fotosensori al silicio per applicazioni di calorimetria per fasci di neutrino monitorati

15

ENUBET
A. Longhin

Contatti

Relatore: *Prof. Andrea Longhin*
DFA, via Marzolo 8, uff. 174
Ricevimento libero: e-mail andrea.longhin@unipd.it
http://www.pd.infn.it/~longhin

Altri relatori

Prof. Gianmaria Collazuol, *gianmaria.collazuol@unipd.it*

Possibili correlatori

- *Dr. Fabio Pupilli, fabio.pupilli@pd.infn.it*
- *Dr. Fabio Iacob, fabio.iacob@unipd.it*
- *Dr. Michelangelo Pari, michelangelo.pari@unipd.it*
- *Dr.ssa Claudia Caterina Delogu, cdelogu@pd.infn.it*

TRIENNALE

T2: Ottimizzazione della linea di fascio del progetto ENUBET con algoritmi genetici

Contatti

Relatore: *Prof. Andrea Longhin*
DFA, via Marzolo 8, uff. 174
Ricevimento libero: e-mail andrea.longhin@unipd.it
http://www.pd.infn.it/~longhin

Altri relatori

Prof. Gianmaria Collazuol, *gianmaria.collazuol@unipd.it*

Possibili correlatori

- *Dr. Fabio Pupilli, fabio.pupilli@pd.infn.it*
- *Dr. Fabio Iacob, fabio.iacob@unipd.it*
- *Dr. Michelangelo Pari, michelangelo.pari@unipd.it*
- *Dr.ssa Claudia Caterina Delogu, cdelogu@pd.infn.it*

TRIENNALE

M1: Caratterizzazione del dimostratore del progetto ENUBET con fasci di particelle al CERN-PS

17

ENUBET
A. Longhin

Contatti

Relatore: *Prof. Andrea Longhin*
DFA, via Marzolo 8, uff. 174
Ricevimento libero: e-mail andrea.longhin@unipd.it
http://www.pd.infn.it/~longhin

Altri relatori

Prof. Gianmaria Collazuol, *gianmaria.collazuol@unipd.it*

Possibili correlatori

- *Dr. Fabio Pupilli, fabio.pupilli@pd.infn.it*
- *Dr. Fabio Iacob, fabio.iacob@unipd.it*
- *Dr. Michelangelo Pari, michelangelo.pari@unipd.it*
- *Dr.ssa Claudia Caterina Delogu, cdelogu@pd.infn.it*

MAGISTRALE

M2: Riduzione dell'incertezza sistematica sul flusso di neutrini da constraints sui leptoni associati

Contatti

Relatore: *Prof. Andrea Longhin*
DFA, via Marzolo 8, uff. 174
Ricevimento libero: e-mail andrea.longhin@unipd.it
http://www.pd.infn.it/~longhin

Altri relatori

Prof. Gianmaria Collazuol, *gianmaria.collazuol@unipd.it*

Possibili correlatori

- *Dr. Fabio Pupilli, fabio.pupilli@pd.infn.it*
- *Dr. Fabio Iacob, fabio.iacob@unipd.it*
- *Dr. Michelangelo Pari, michelangelo.pari@unipd.it*
- *Dr.ssa Claudia Caterina Delogu, cdelogu@pd.infn.it*

MAGISTRALE

Zooming out a bit

Suggested links to have a glimpse at the panorama of physics research being done within INFN Commissione 2 (astroparticle)

Research lines: https://agenda.infn.it/event/26309/
In Padova: https://agenda.infn.it/event/27483/contributions/139444/attachments/83272/109685/gr2_preventivi_2022_Longhin_v1.pdf
https://www.pd.infn.it/la-ricerca-in-sezione/fisica-astroparticellare

A dedicated meeting will follow