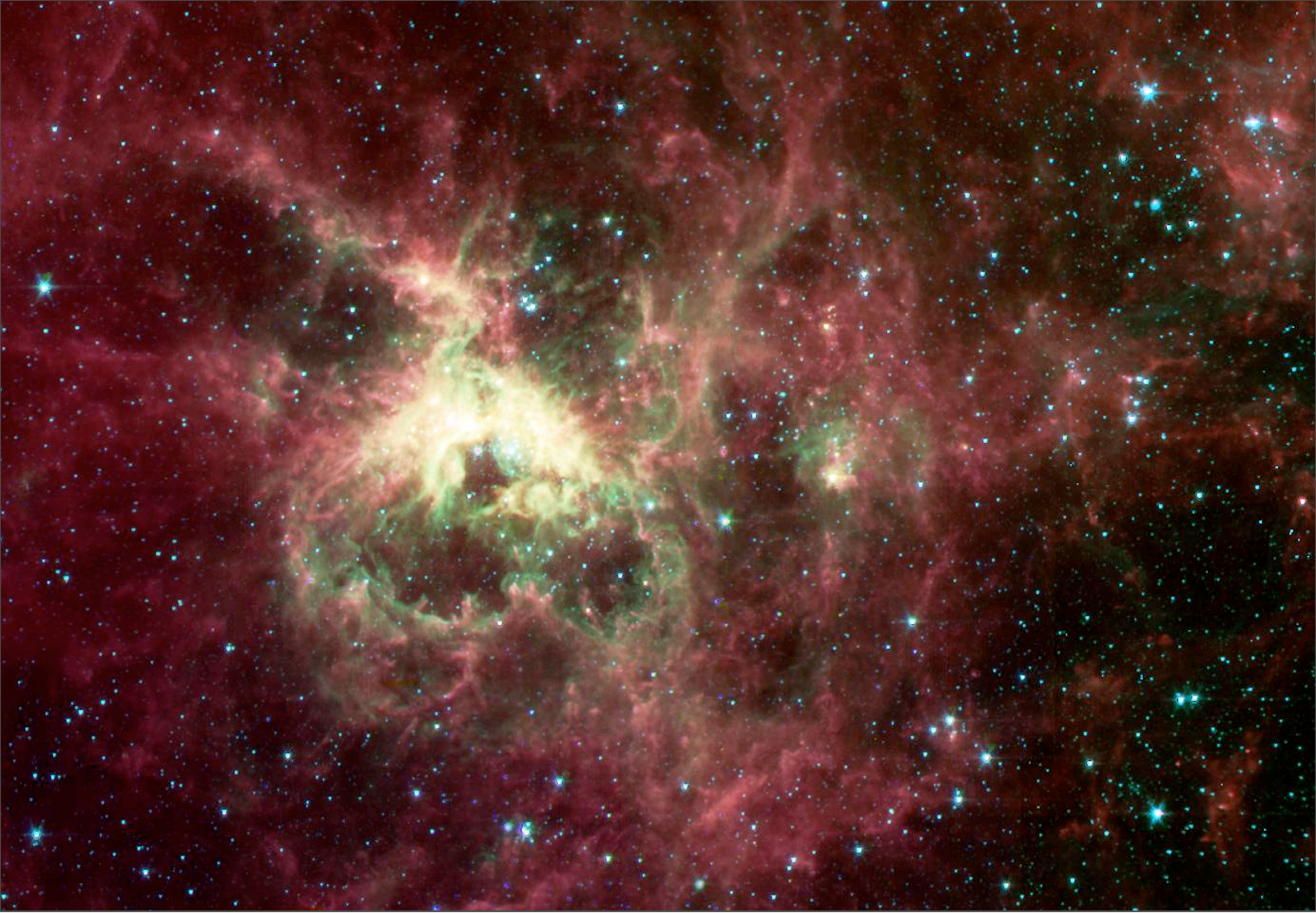

Design of a pan-European infrastructure for Large Apparatus for Grand Unification and Neutrino Astrophysics (LAGUNA)

André Rubbia (ETHZ)

ApPEC/ASPERA thematic group low on energy neutrino and proton decay, Chambery, March 2nd

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- This field of research is at the forefront of particle and astro-particle physics and is the subject of intense investigation also in North America and Asia. Such an infrastructure in Europe would attract scientists from all over the world and ensure that Europe will continue to play a leading and innovative role in the field.

Grand Unification and Neutrino Astrophysics

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- **Rare event detection in very massive detectors will allow the search for proton decays with an unprecedented sensitivity. Proton decay is the most generic and directly verifiable consequence of Grand Unification (GU)**
  - Detecting proton decay implies de facto discovering GU
    - GU implies a new fundamental symmetry between quarks & leptons (hence explains their identical number)
    - GU explains electric charges of elementary fermions
    - GU guides models of fermion masses and mixing
    - GU is one of the motivation for SUSY and SUSY predicts LSP as dark matter
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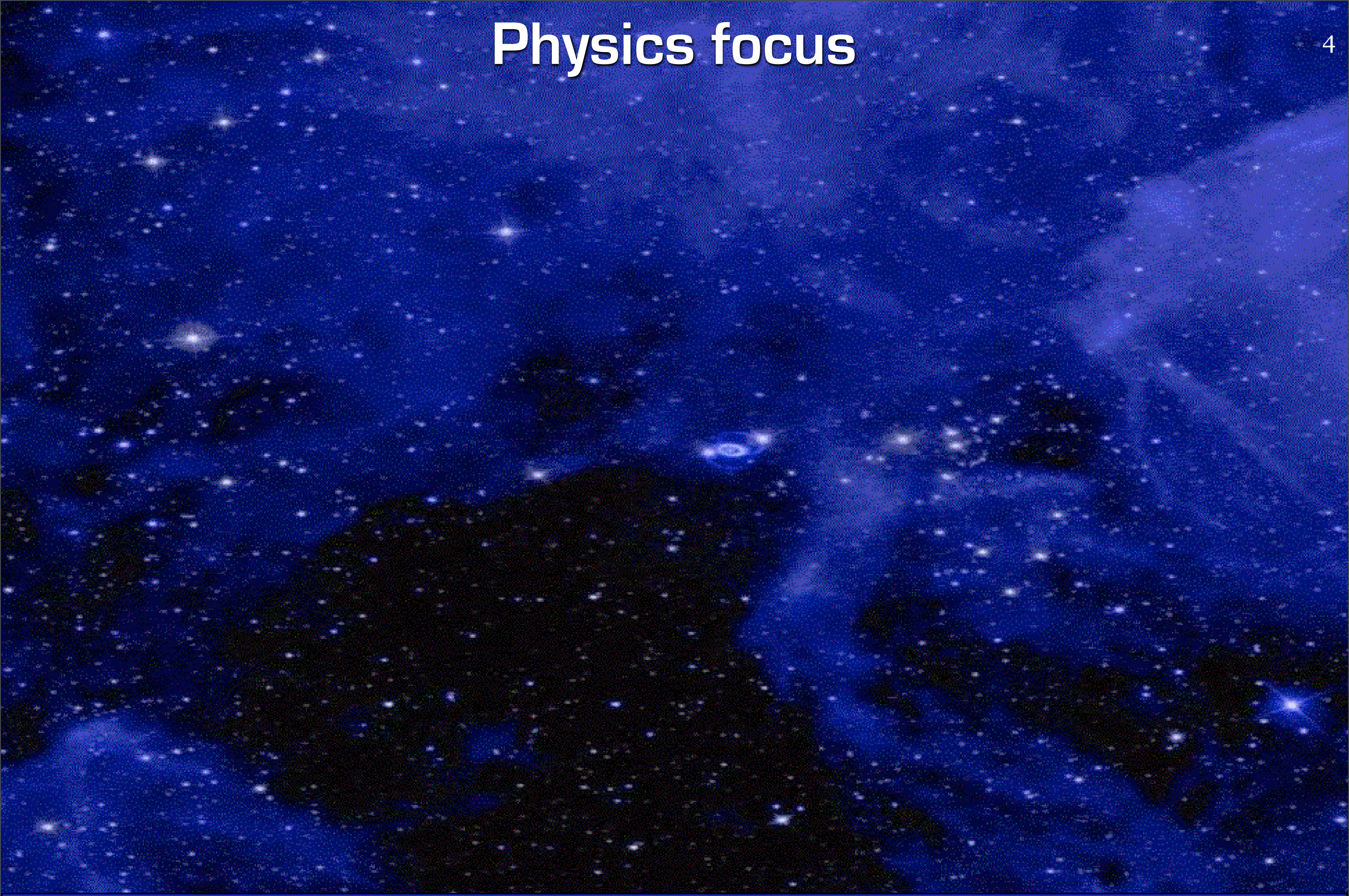
- **Very massive underground detectors will provide an extensive next generation neutrino physics programme**
  - They will detect neutrinos from a galactic Supernova, greatly advancing our understanding of stellar explosions and neutrino properties.
  - They could also further study the Sun's interior with real-time solar neutrino detection and detect geo-neutrinos, as well study of neutrinos produced in the Earth's upper atmosphere with high statistics.
  - Coupled to artificial neutrino beams, they will measure neutrino flavour oscillations with an unprecedented precision and offer new opportunities like the discovery of CP-violation in the leptonic sector.

Physics focus



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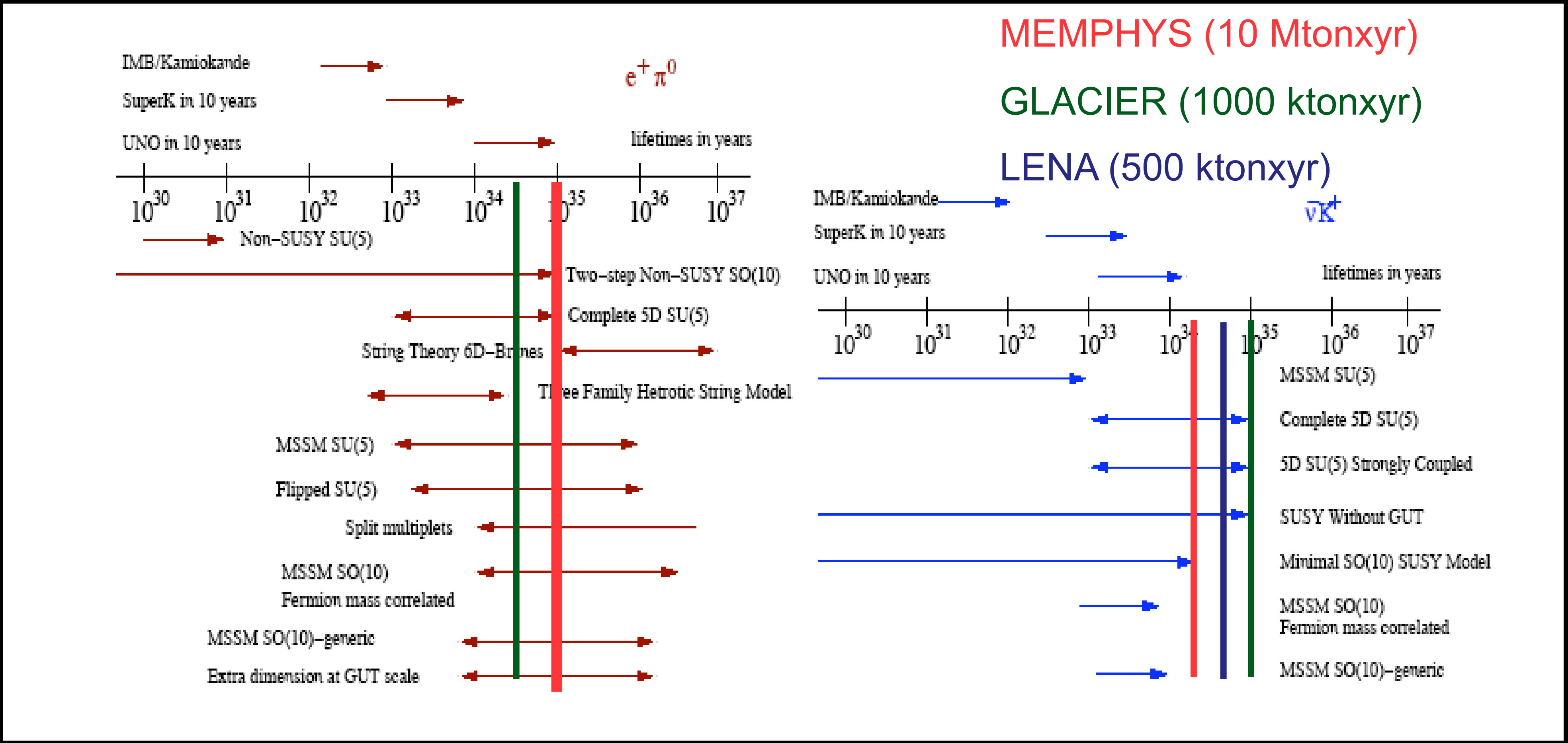
- High-energy accelerators like the LHC or the planned ILC cannot directly answer these fundamental questions about Nature. This was also recognized in the CERN European roadmap for particle physics: "*A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest.*"

Sensitivity to proton decay: comparison with theory



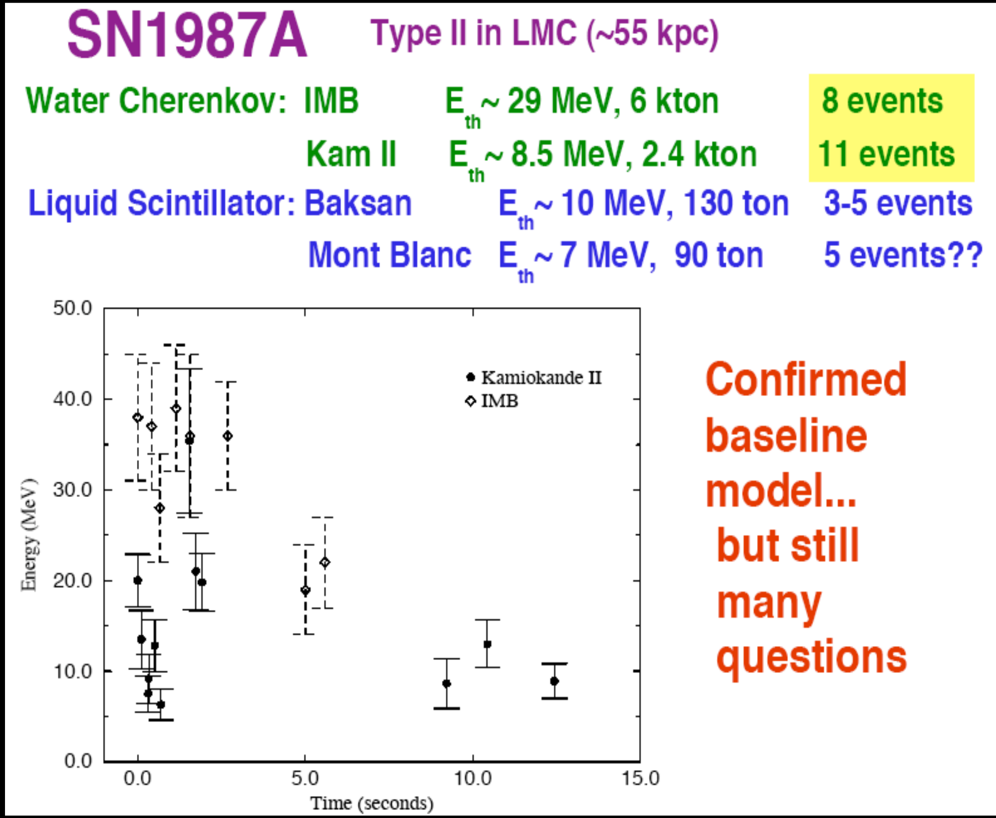
Higher dimension models (eg. 6D SO(10)) not included

Definitively not exhaustive.

Supernova type-II neutrinos

⇒Access supernova and neutrino physics simultaneously

⇒Decouple supernova & neutrino properties via different detection channels



1. **Supernova physics:**
   - Gravitational collapse mechanism
   - Supernova evolution in time
   - Burst detection
   - Cooling of the proto-neutron star
   - Shock wave propagation
   - Black hole formation?
2. **Neutrino properties**
   - Neutrino mass (time of flight delay)
   - Oscillation parameters (flavor transformation in SN core and/or in Earth): Type of mass hierarchy and θ_{13} mixing angle
3. **Early alert for astronomers**
   - Pointing to the supernova

ApPEC Roadmap, January 2007

Field/ Experiments	Cost scale (M€)	Desirable start of construction	Remarks
Dark Matter Search: Low background experiments with 1-ton mass	60-100 M€	2011-2013	2 experiments (different nuclei, different techniques), e.g. 1 bolometric, 1 noble liquid; more than 2 worldwide.

Proton decay and low energy neutrino astronomy: Large infrastructure for p-decay and ν astronomy on the 100kt-1Mton scale	400-800 M€	2011-2013	- multi-purpose
			- 3 different techniques; large synergy between them.
			- needs huge new excavation
			- expenditures likely also after 2015
			  - worldwide sharing
			  - possibly also accelerator neutrinos in long baseline experiments

The high energy universe:			
Gamma rays: Cherenkov Telescope Array CTA	100 M€ (South) 50 M€ (North)	first site in 2010	Physics potential well defined by rich physics from present gamma experiments
Charged Cosmic Rays: Auger North	85 M€	2009	Confirmation of physics potential from Auger South results expected in 2007
Neutrinos: KM3NeT	300 M€	2011	FP6 design study. Confirmation of physics potential from IceCube and gamma ray telescopes expected in 2008-2010
Gravitational Waves: Third generation interferometer	250-300 M€	Civil engineering 2012	Conceived as underground laboratory

Proton decay and low energy neutrino astrophysics

LAGUNA WG is a coordinated European effort

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  - Investigate physics complementarities and common R&D needs.
  - Provide a coherent and well-coordinated EU wide efforts. Work in synergy.
  - Solve common problems together.
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  - Solve common problems together.
  - Take into account the unique technological expertise in Europe and other existing or planned programs in the world.
- **Mature designs and credible proposals should emerge around 2010.**
- This effort, although oriented towards a potential infrastructure in Europe, also allows Europeans to contribute in a coherent way and possibly with better impact, to the on-going discussions worldwide.

The step to very large volume liquid detectors

- **Three complementary techniques are currently being investigated for next generation large volume underground rare event observatories**

1. Water Cerenkov imaging
   - Ongoing R&D effort on photodetection in Europe: MEMPHYS
   - Synergy with HK (Japan) and UNO (USA)
2. Liquid scintillator
   - Ongoing R&D on scintillator characterization in Europe: LENA
   - Connected to BOREXINO R&D programme and DOUBLE-CHOOZ
3. Liquid argon time-projection chamber
   - Technology pioneered in Europe by the ICARUS R&D programme
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     - Two new independent and on-going R&D efforts: GLACIER in Europe and LARTPC in USA
- **The construction of very large detectors of those technologies appears possible, but requires detailed design studies to optimize the underground implementation in very large scale and the most promising technologies under well controlled cost estimates.**
- **In parallel, design studies for site(s) to build the required infrastructure for these very large detectors under controlled cost boundaries, are mandatory.**

Large Underground detectors considered in LAGUNA

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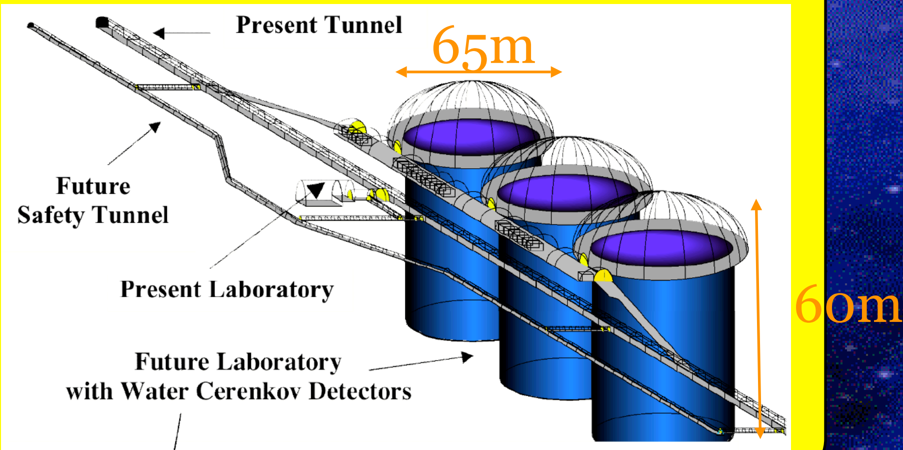
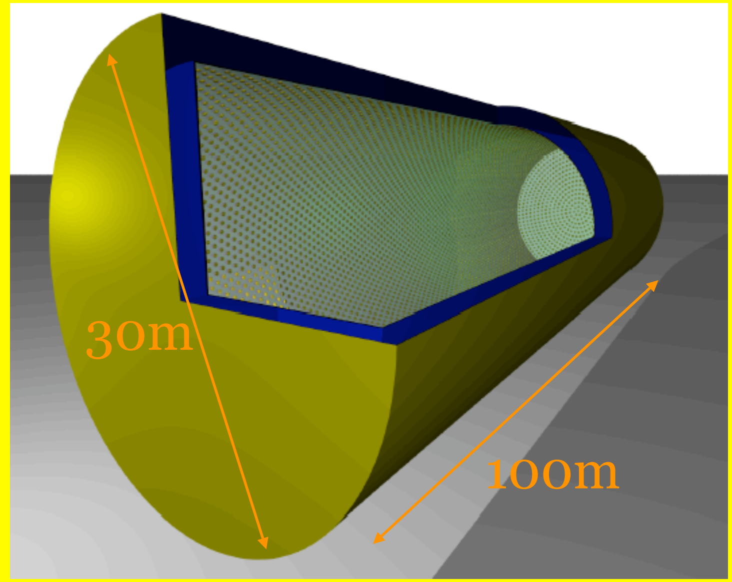
MEMPHYS



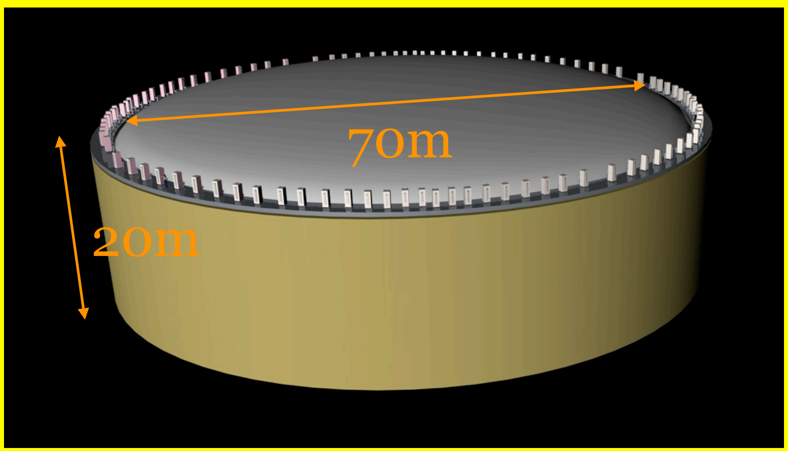
Water Cherenkov (≈0.5 → 1 Mton)

LENA



Liquid Scintillator (→ 50 kton)

GLACIER



Liquid Argon (≈10→100 kton)

LAGUNA WG constituency

- ≈60 members
- 22 institutes from CH, DE, ESP, FR, FIN, I, POL, UK
- University of Bern, CPPM, CUPP, University of Helsinki, University of Katowice, University of Krakow, IN2P3/CNRS-LAL, IN2P3/CNRS-LPNHE, University of Granada, University of Hamburg, Max-Planck-Institut für Kernphysik Heidelberg, University of Jyväskyla, Max-Planck-Institut für Physik München, Technische Universität München, University of Oulu, Institut de Physique Nucléaire Orsay, INFN/ University of Padova, APC-Paris, DAPNIA/CEA-Saclay, University of Sheffield, ETH-Zürich
- New interest was raised at Valencia meeting

- List of "participants" (contractors in FP6) for LAGUNA DS in the process of being defined. Includes:
  - All underground laboratories (CUPP, LNGS, LSC, LSM, IUS, SUNLAB)
  - All involved scientific partners
  - Some industrial partners

From LAGUNA WG to DS

- During the last months, an effort has been made to consolidate these ideas into a format compatible with a potential "design study".
- A series of working meeting were held
  - ☑ Munich, April 24th, 2006
  - ☑ Munich, June 2nd, 2006
  - ☑ Paris, July 21st ,2006
  - ☑ Zurich, October 12th, 2006
  - ☑ Paris, December 18th, 2006
  - ☐ Next: Chambery, March 2nd, 2007
- A scientific case document (≈30 pages) has been drafted.
- A list of Working Packages, in a suitable form for the FP7 DS, has been prepared.
- The list of milestones & deliverables with detailed tables of tasks has still to be elaborated.
- The potential FP7 DS document is being drafted (preliminary version) to be finalized until May 2007.

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- The deliverables contain the elaboration of “decision factors” like
  (i) technical feasibility (cavern, access, safety, liquid procurement, ...)
  (ii) cost optimization of infrastructure (digging, safety, ...)
  (iii) physics performance (e.g. depth, baseline, ...)
  (iv) ...

LAGUNA FP7 – DRAFT DRAFT DRAFT

Proposal full title	**A Design Study for Large Apparati for Grand Unification and Neutrino Astrophysics**
Proposal acronym	**LAGUNA**

DRAFT

EU contribution, Timescale:
5 M€ over 3-4 years (estimate)

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LAGUNA working packages

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- **WP7: Underground scientific programme assessment and optimization**
  - Physics potential of the facility, multidisciplinarity, other sciences

WP resources subdivision

DRAFT

WP1	Underground infrastructure	2.3+0.7 M€
WP2	Underground tanks	0.8+0.5 M€
WP3	Tank instrumentation	0.5+2.0 M€
WP4	Pure liquid procurement	0.5+0.5 M€
WP5	Safety and environment	0.25+0.25 M€
WP6	Underground science optimization and outreach	0.5+1.0 M€
WP7	Management and coordination	0.15+0.15 M€
TOTAL		5.0+5.1 M€

Where?

IUS

Institute of Underground Science in Boulby mine, UK

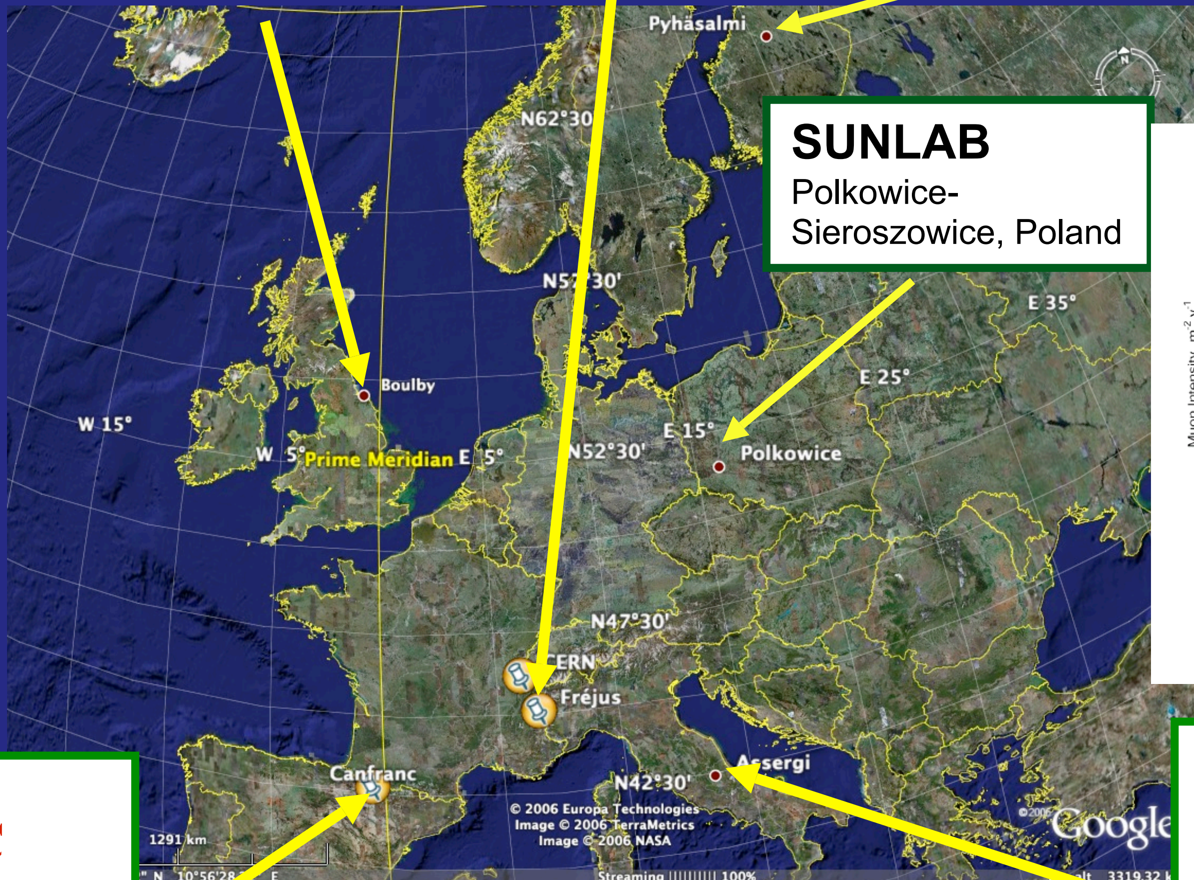
LSM

Laboratoire Souterrain de Modane, France

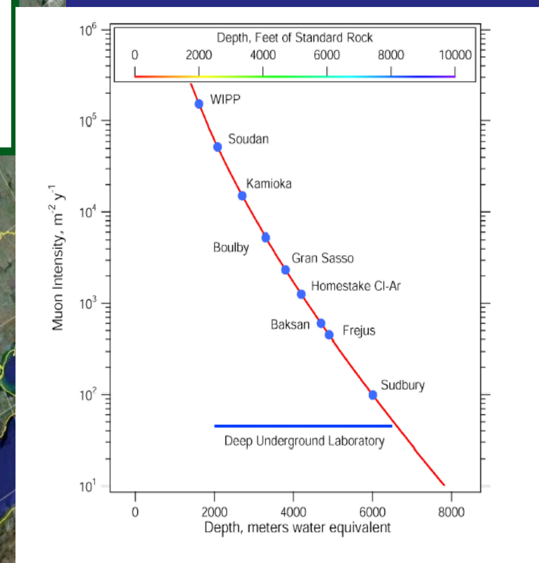
CENTRE FOR UNDERGROUND PHYSICS IN PYHÄSALMI MINE

Currently there is no available sight to host very large scale detectors in Europe!

- New facilities will have to be excavated or old one extended
- What depth?
- What other synergies? (beamline distance)
- What is the distance from reactors?



SUNLAB
Polkowice-Sieroszowice, Poland



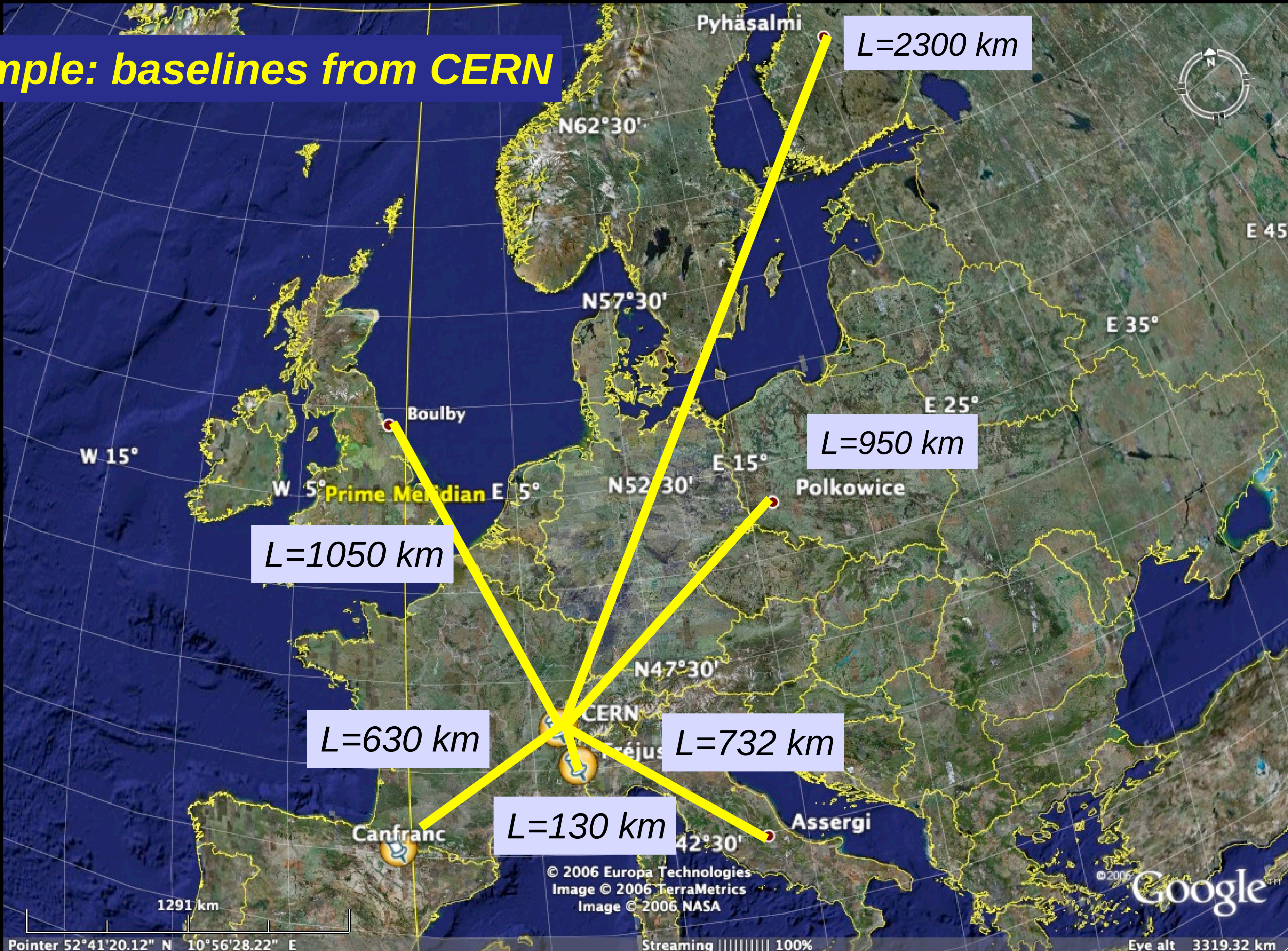
LSC

Laboratorio Subterraneo de Canfranc, Spain

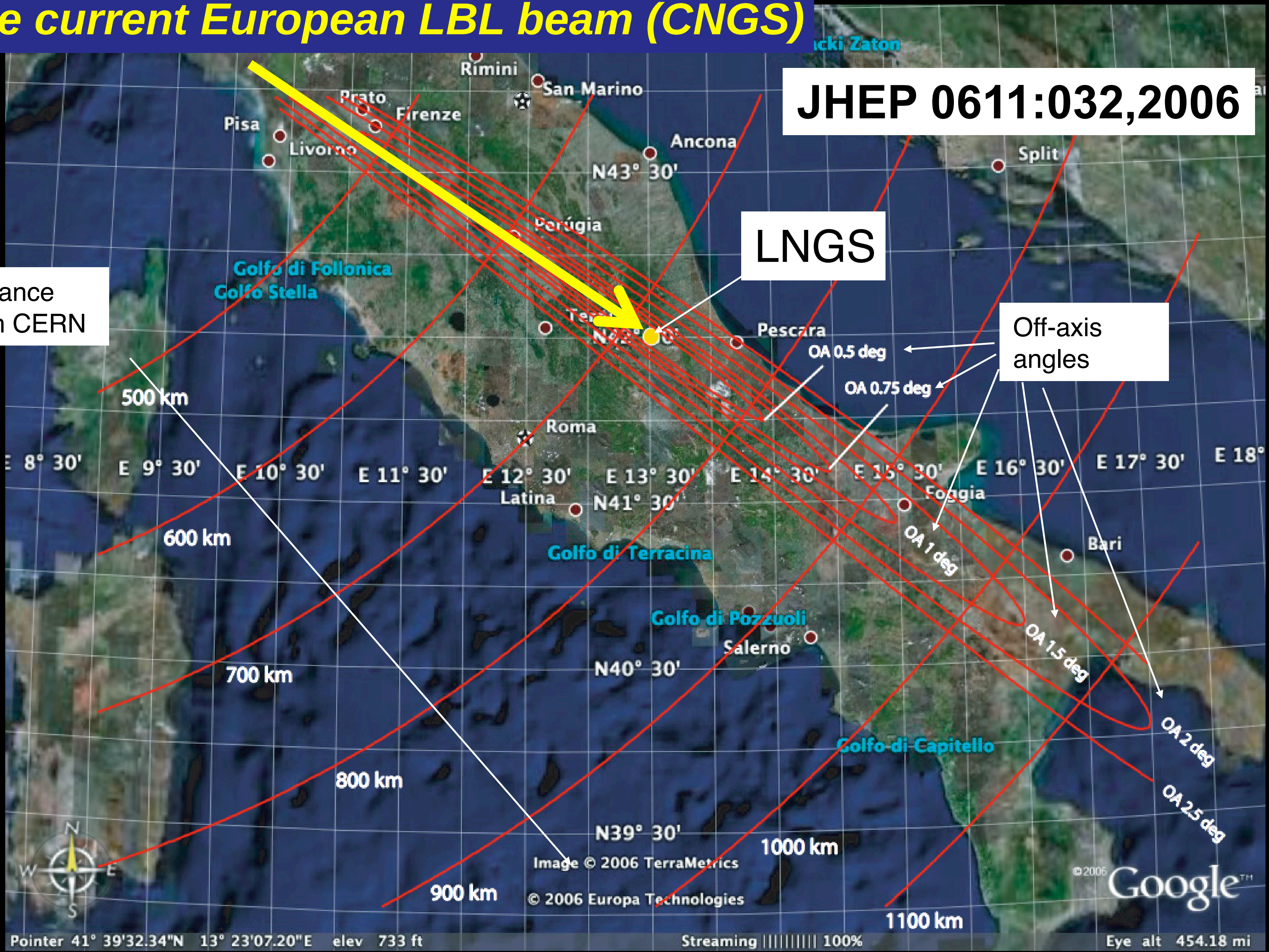
LNGS

Laboratori Nazionali del Gran Sasso, Italy

Example: baselines from CERN



The current European LBL beam (CNGS)



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- It should mature around 2010 and lead to possible construction decision soon after, when a few years of running of LHC and T2K&NovA&DOUBLE CHOOZ will have drawn the new landscape concerning supersymmetry, unification, and hopefully the last unknown neutrino mixing angle θ_{13}.