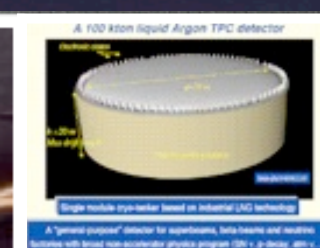
Towards a large underground detector: LAGUNA

http://laguna.ethz.ch

André Rubbia (ETH Zurich)





CHIPP Plenary
24-25 August 2009
Appenberg, Switzerland

LAGUNA Design Study

- **L**arge **A**pparatus for **G**rand **U**nification and **N**eutrino **A**strophysics
- Aimed at defining and realizing this research programme in Europe
- It includes a majority of European physicists interested in the construction of very massive detector(s) realized in one of the three technologies using liquids: water, liquid argon and liquid scintillator.
- EC contribution: 1.7 M€ to be mainly devoted to the sites infrastructure studies (FP7 “Design Studies” Research Infrastructures LAGUNA Grant Agreement No. 212343)
  21 beneficiaries in 9 countries: 9 higher education entities, 8 research organizations, 4 private companies (+4 additional universities)

Discuss and assess:
- rock engineering → feasibility
- needed infrastructure
- cost of excavation
- assembly of underground tank
- physics programme

Detector R&D to be funded at national level

	Title
WP1	Management
WP2	Underground infrastructures and Engineering
WP3	Safety, environmental and socio-economic issues
WP4	Science Impact and Outreach

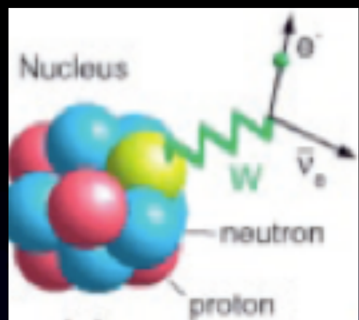
LAGUNA participants

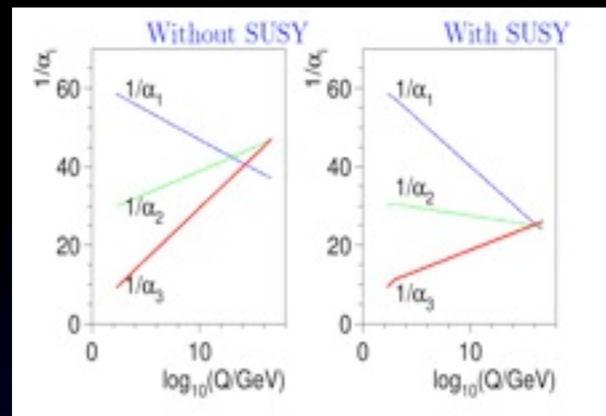
- 21 beneficiaries from 9 countries
- Coordinator ETHZ (“Switzerland coordinates Europe”)

Beneficiary no.	Beneficiary name	Beneficiary short name	Country	Date enter project	Date exit project
1. (coordinator)	Swiss Federal Institute of Technology Zurich	**ETH Zurich**	Switzerland	1	24
2.	University of Bern	**U-Bern**	Switzerland	1	24
3.	University of Jyväskylä	**U-Jyväskylä**	Finland	1	24
4.	University of Oulu	**UOULU**	Finland	1	24
5.	Kalliosuunnittelu Oy Rockplan Ltd	**Rockplan**	Finland	1	24
6.	Commissariat à l’Energie Atomique / Direction des Sciences de la Matière	**CEA**	France	1	24
7.	Institut National de Physique Nucléaire et de Physique des Particules (CNRS/IN2P3)	**IN2P3**	France	1	24
8.	Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V.	**MPG**	Germany	1	24
9.	Technische Universität München	**TUM**	Germany	1	24
11.	H.Niewodniczanski Institute of Nuclear Physics of the Polish Academy of Sciences, Krakow	**IFJ PAN**	Poland	1	24
15.	KGHM CUPRUM Ltd Research and Development Centre	**KGHM CUPRUM**	Poland	1	24
16.	Mineral and Energy Economy Research Institute of the Polish Academy of Sciences	**IGSMiE PAN**	Poland	1	24
17.	Laboratorio Subterraneo de Canfranc	**LSC**	Spain	1	24
27.	Universidad Autonoma, Madrid	**UAM**	Spain	1	24
19.	University of Durham	**UDUR**	United Kingdom	1	24
20.	The University of Sheffield	**USFD**	United Kingdom	1	24
21.	Technodyne International Ltd	**Technodyne**	United Kingdom	1	24
23.	University of Aarhus	**AU**	Denmark	1	24
24.	AGT Ingegneria Srl, Perugia	**AGT**	Italy	1	24
25.	Institute of Physics and Nuclear Engineering, Bucharest	**IFIN-HH**	Romania	1	24
26.	Lombardi Engineering Limited	**Lombardi**	Switzerland	1	24

LAGUNA Physics goals

(1) Grand Unification - proton decay





•In 4D SUSY SU(5), SO(10) dimension 6 operators “Msusy independent” depend essentially on unification mass generically predict $\tau_p = 10^{34}$-10^{36}y

•In 4D SUSY SU(5), SO(10) dimension 5 operators depend on sparticle spectrum (Msusy), family structure, triplet higgs mass generically predict τ_p= 3 $\times 10^{33}$- 3$\times 10^{34}$y

(3) Long baseline neutrino oscillations

θ_{13}, δ, sgn(ΔM^2)

$\nu_\mu \rightarrow \nu_e$

High intensity low energy conventional neutrino sources

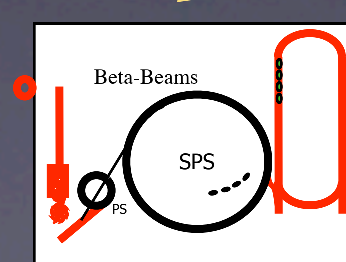
$\nu_e \rightarrow \nu_\mu$

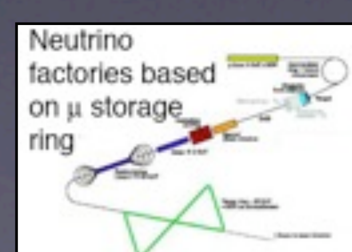
New neutrino production technology

>2020 ?

“superbeams” ?
MW power >2016

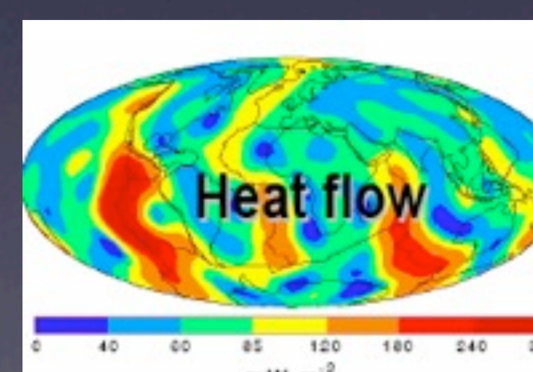
2/4 GeV p ? 50 GeV p ?
400 GeV ?

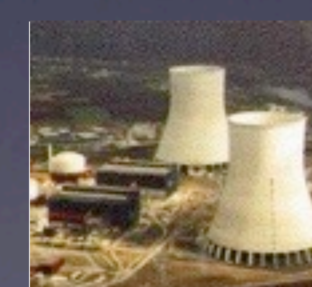




(2) MeV-GeV neutrino “astronomy”

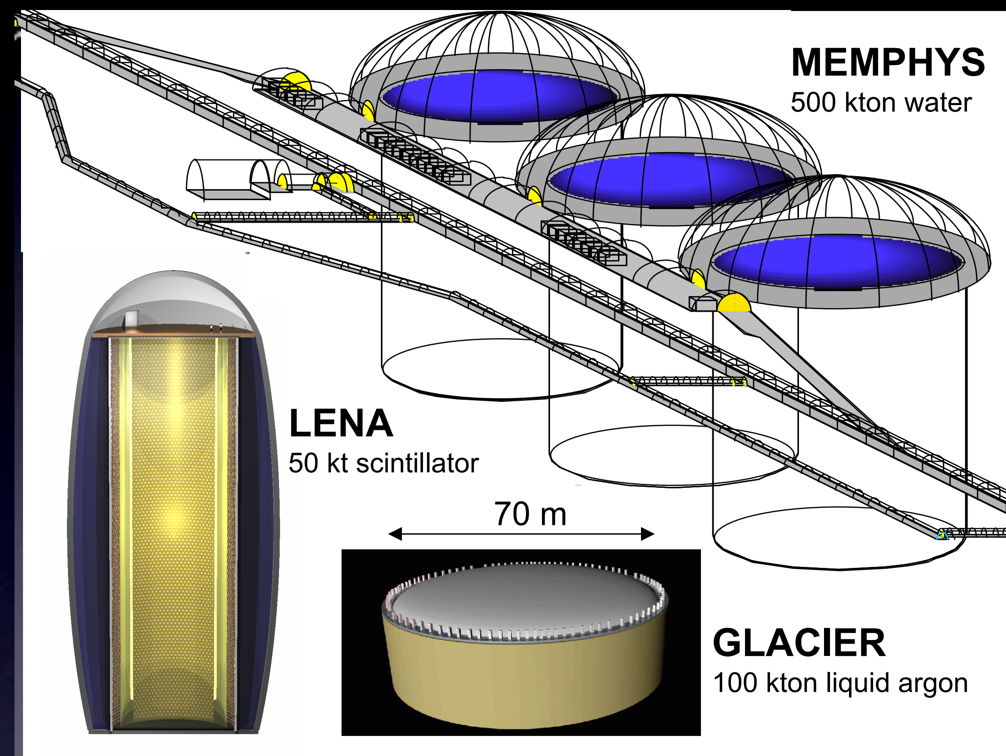
- Astrophysical origin:
  - ★ Sun’s interior (day&night)
  - ★ Supernova core collapse
  - ★ Diffuse supernova relic neutrinos
  - ★ Dark Matter annihilation
- Terrestrial origin:
  - ★ Atmospheric neutrinos
  - ★ Geo-neutrinos (Earth natural radioactivity)
  - ★ Nuclear reactor cores





LAGUNA ingredients

- A new far detector at a far site
  - three options considered (MEMPHYS, LENA, GLACIER) with total mass in the range 50-1000 kton
  - seven potential sites at different baselines from CERN:



- Water Cerenkov [**MEMPHYS**]
- Liquid scintillator [**LENA**]
- Liquid Argon TPC [**GLACIER**]

Name	Type	Envisaged Depth (m.w.e)	Distance from CERN (km)	Energy 1st osc. max (GeV)
Fréjus (F)	Road tunnel	$\simeq$ 4800	130	0.26
Canfranc (ES)	Road tunnel	$\simeq$ 2100	630	1.27
Caso (IT)	Green field	$\simeq$ 1500	665 ($\simeq 1.0^o$OA)	1.34
Polkowice (PL)	Mine	$\simeq$ 2400	950	1.92
Boulby (UK)	Mine	$\simeq$ 2800	1050	2.12
Slanic (RO)	Salt mine	$\simeq$ 600	1570	3.18
Pyhasalmi (FI)	Mine	$\simeq$ 4000	2300	4.65

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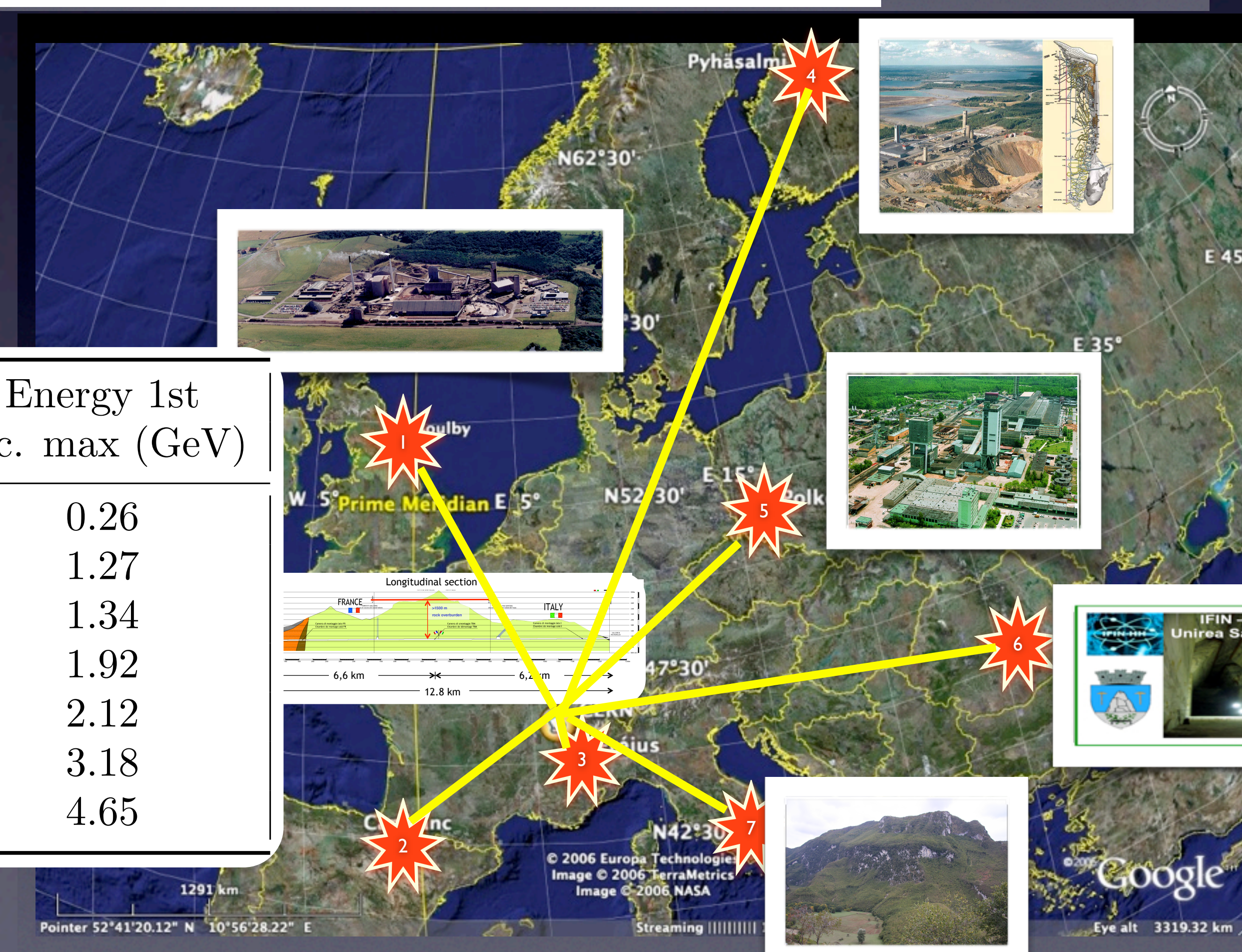
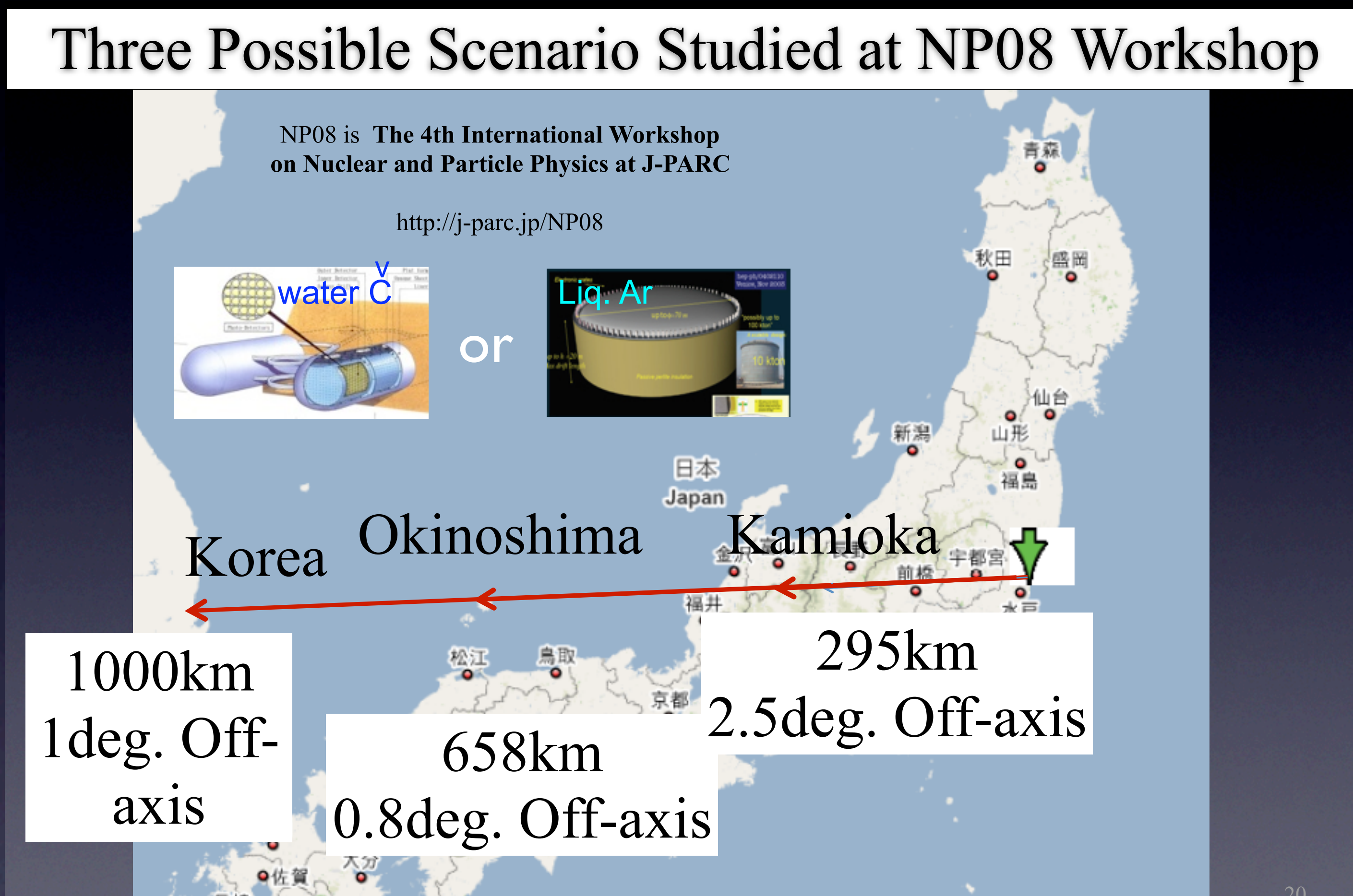


Synergy with worldwide programs

Future at JPARC



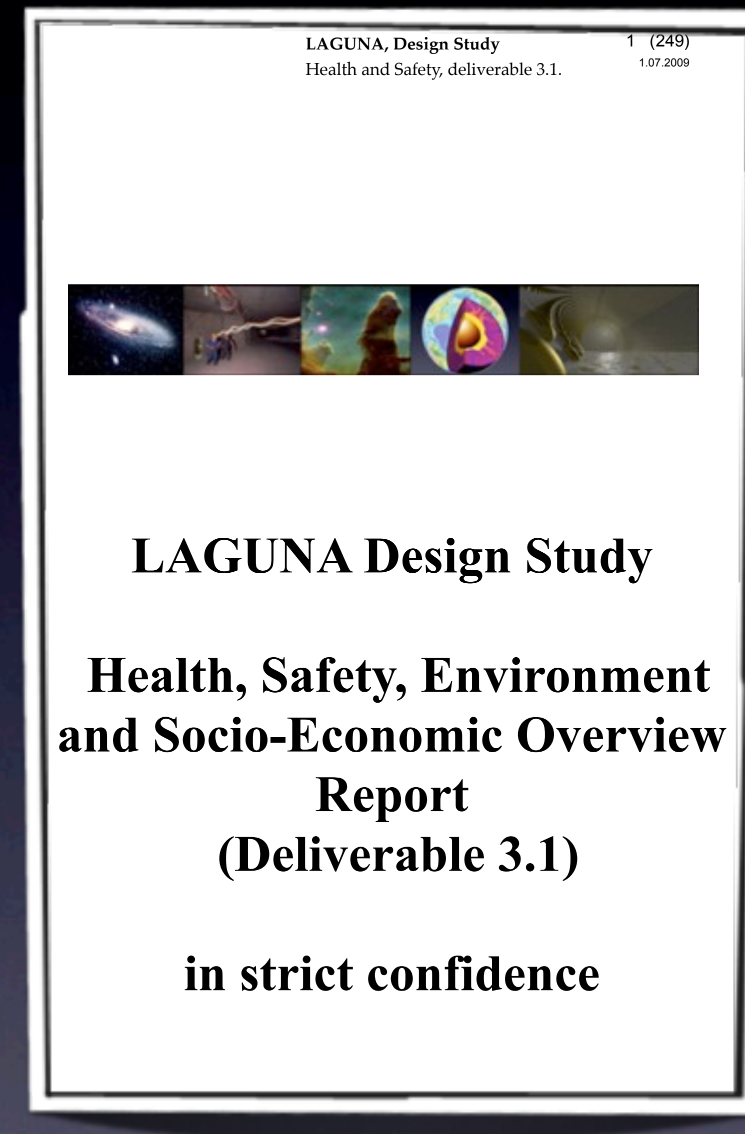
FNAL-DUSEL (USA)

Basic ingredients considered:

- very high intensity beams (> 1 MW)
- a new very large far underground neutrino detector based on Water Cerenkov or Liquid Argon technology (“megaton-scale”)

LAGUNA deliverables

- In total: 16 deliverables (reports)
- LAGUNA-WP3.1 Health, Safety, Environment and Socio-Economic Overview Report
  - 249 pages, delivered on schedule
  - report on the Health and Safety issues for each of the seven LAGUNA sites
  - define list of local authorities and responsible entities and establish contact with them
  - address basic environmental issues
  - address impact on local area
  - identify potential show-stoppers


LAGUNA, Design Study 1 (249)
Health and Safety, deliverable 3.1. 1.07.2009

LAGUNA Design Study

Health, Safety, Environment and Socio-Economic Overview Report
(Deliverable 3.1)

in strict confidence

- Next deliverables:
  - 1st year report (due Sept. 2nd)
  - WP2.1-2.8 seven site specific interim reports due in November 2009

LAGUNA meetings

Several general meeting + regular phone conferences
Visit of all potential sites

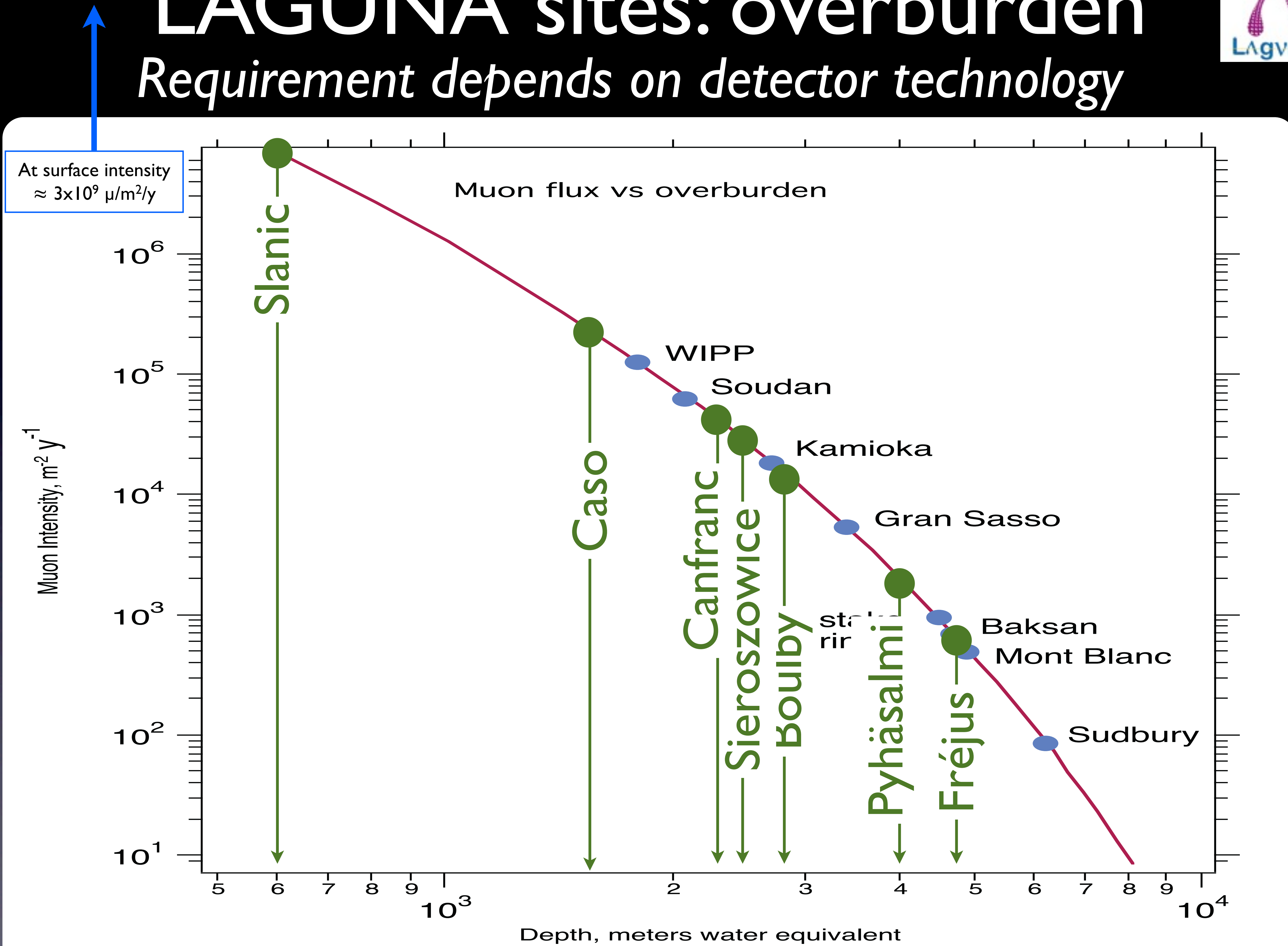
- Kick-off meeting July 3rd-4th 2008, Zurich
  Kickoff meeting of LAGUNA Institut für Teilchenphysik (IPP) Building HPK Room D 24 ETHZ Hönggerberg Campus, Swiss Federal Institute of Technology CH-8093 Zürich
- WP2 intermediate meeting September 10th 2008, Paris
- General meeting #2 November 5-7th, Bucharest
- WP2 Inermediate Meeting January 26th and 27th 2009, Munich
- General meeting #3 , Poland, March 31, 2009 to April 2, 2009
- General meeting #4 September 2-4th 2009 Finland

Several different options are being systematically assessed and compared

In the following I will illustrate a few examples (I apologize for not being able to cover all options studied in LAGUNA)

LAGUNA sites: overburden

Requirement depends on detector technology



LAGUNA sites: overburden

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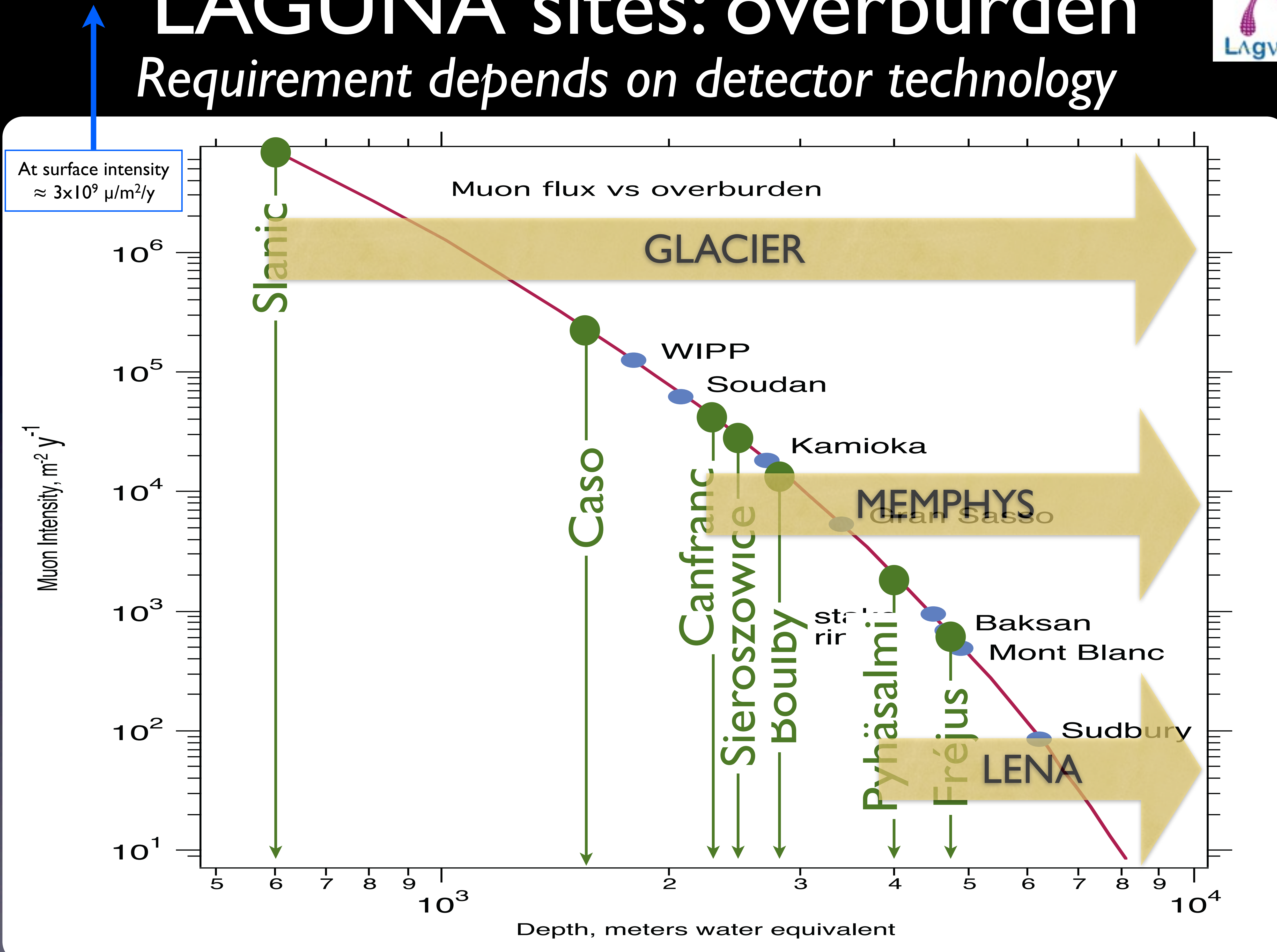
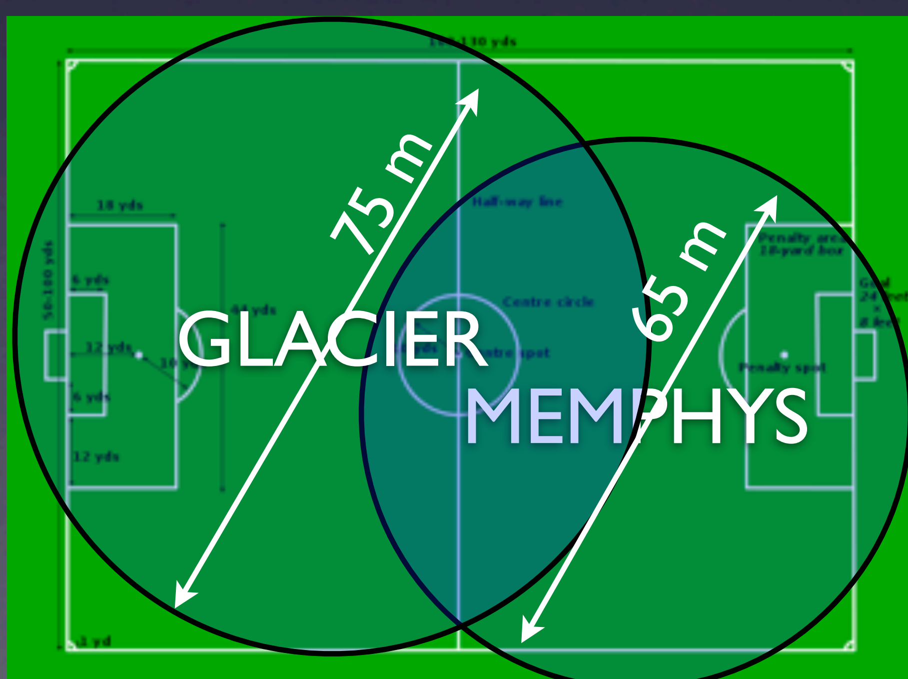


Main detector caverns (MDC)

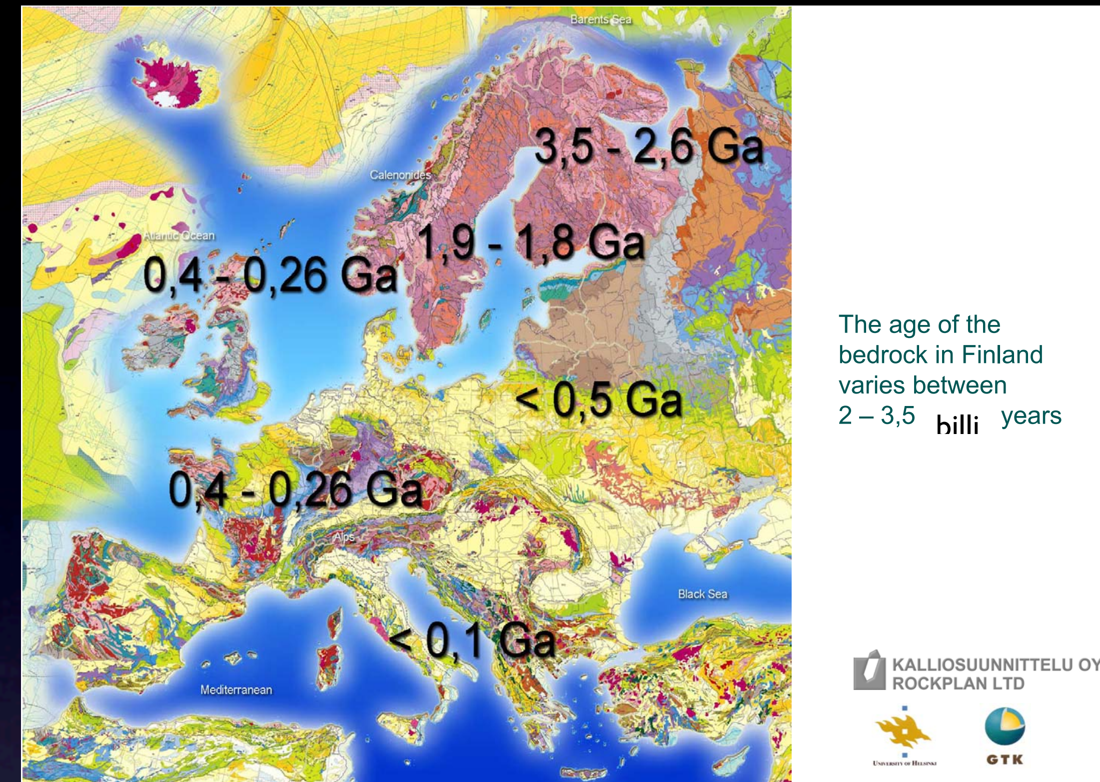
	MEMPHYS	LENA	GLACIER
Overburden	>2000 mwe	>4000 mwe	>600 mwe
#tanks	3 to 5	1	1 preferred
Dimensions of tank	cylinder 65m Ø x 65m height	SS cylinder of 30m Ø x105 m height, inside a external tank of ~ cylindrical shape, of at least 34m Ø for water-buffer.	cylinder: 72,4m Ø x 26,5m height dome: 12,7m height x 144,8m Ø
Cavern	65m Ø x 70m height + dome	Egg-shaped to house external tank	cylinder: 75,1m Ø x 26,5m height + dome

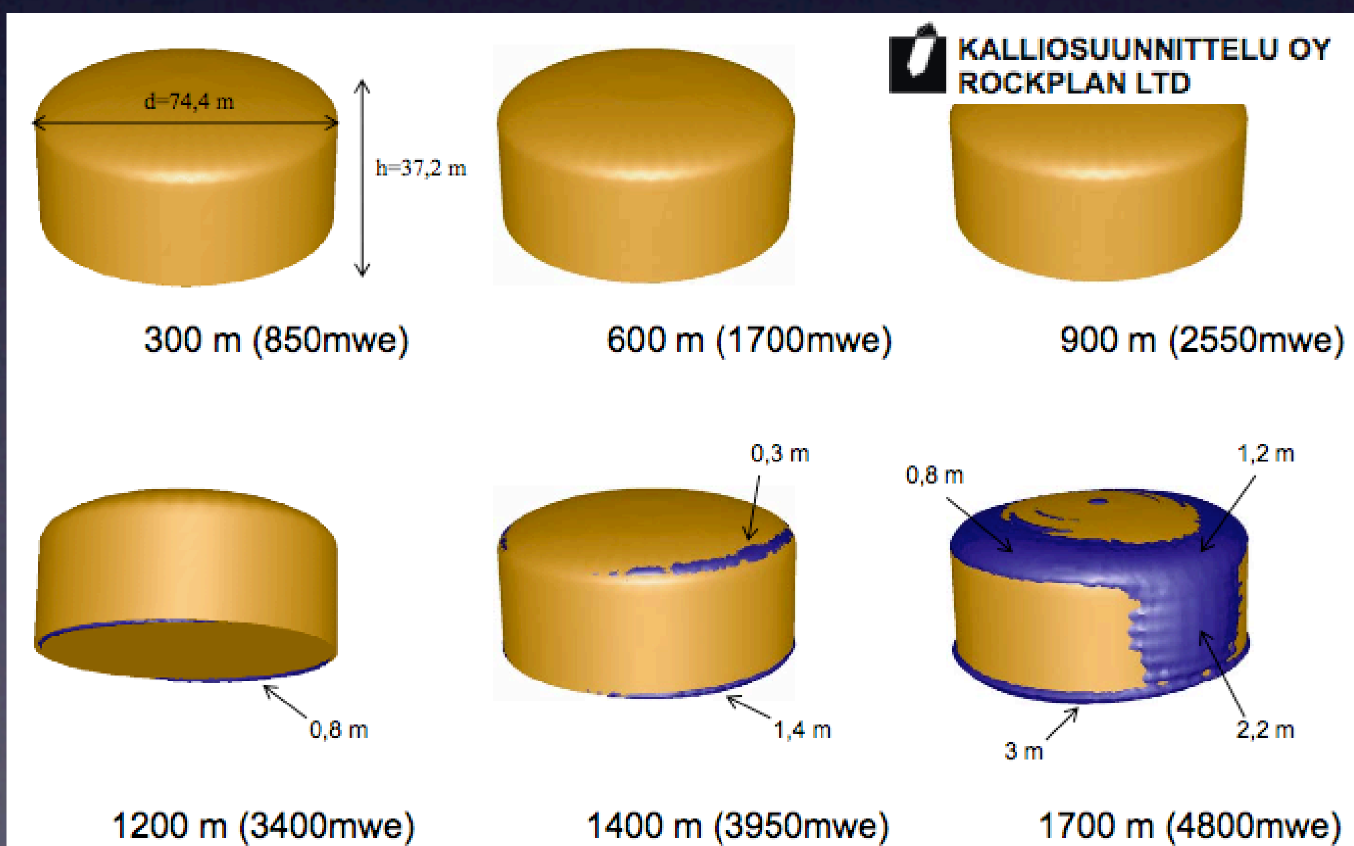


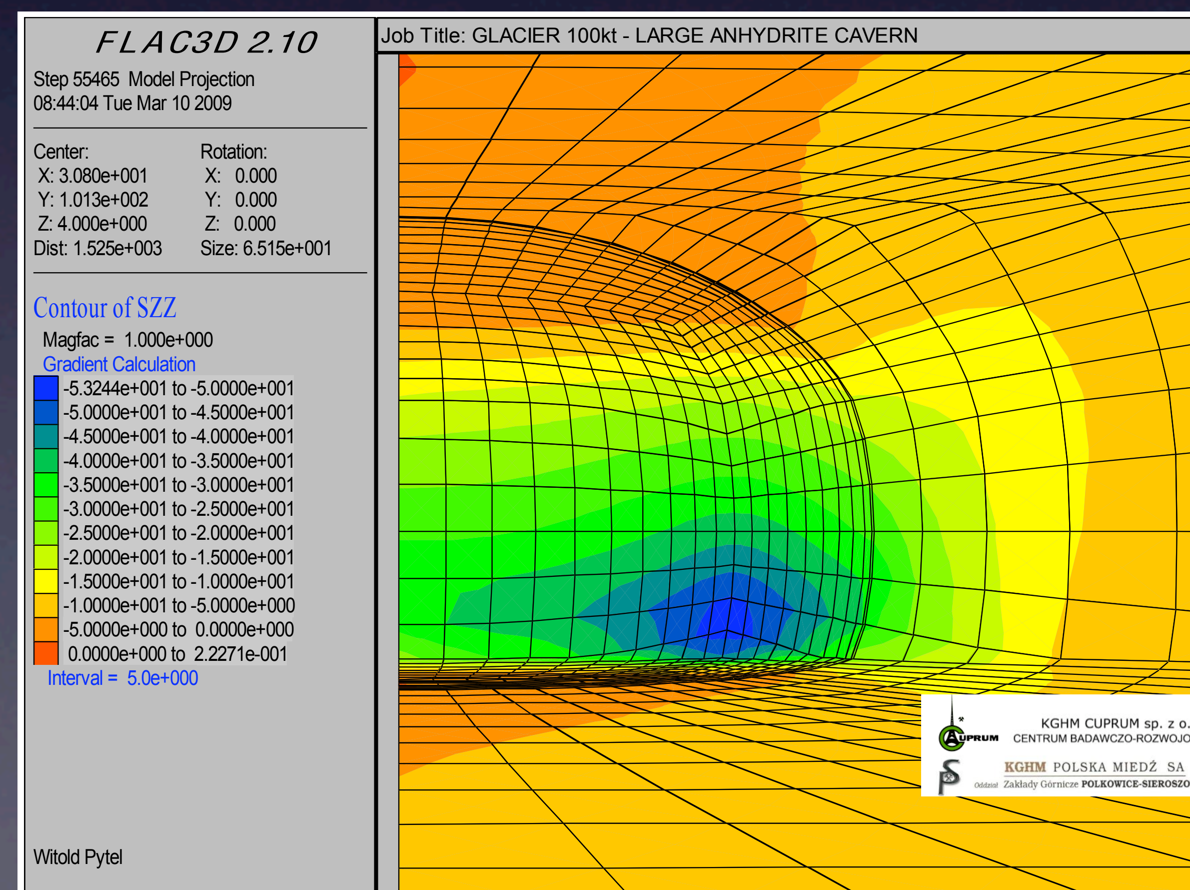
Geomechanical studies

Systematic comparison of assumed rock parameters for the different regions

Numerical modelling based on these parameters



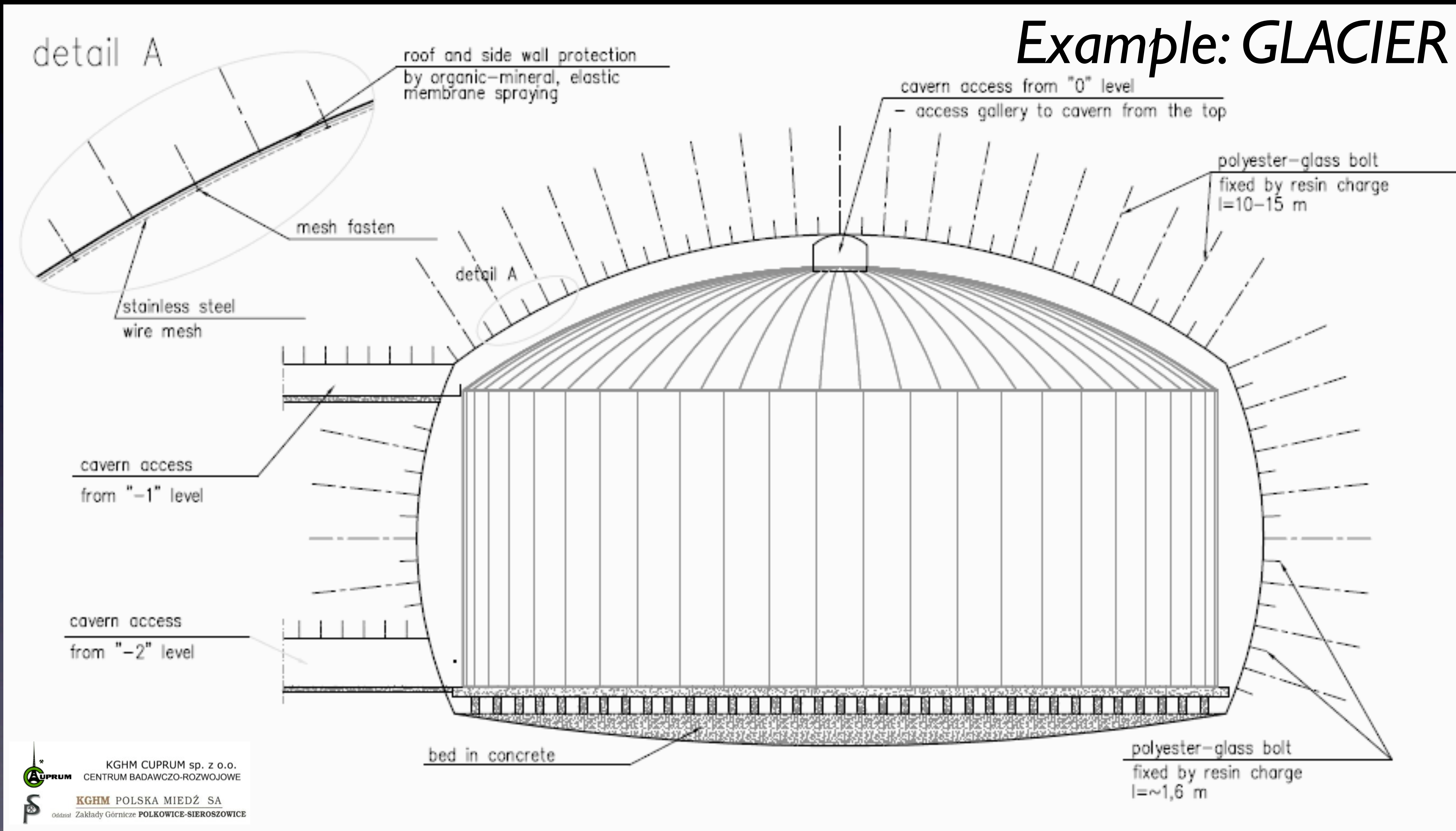




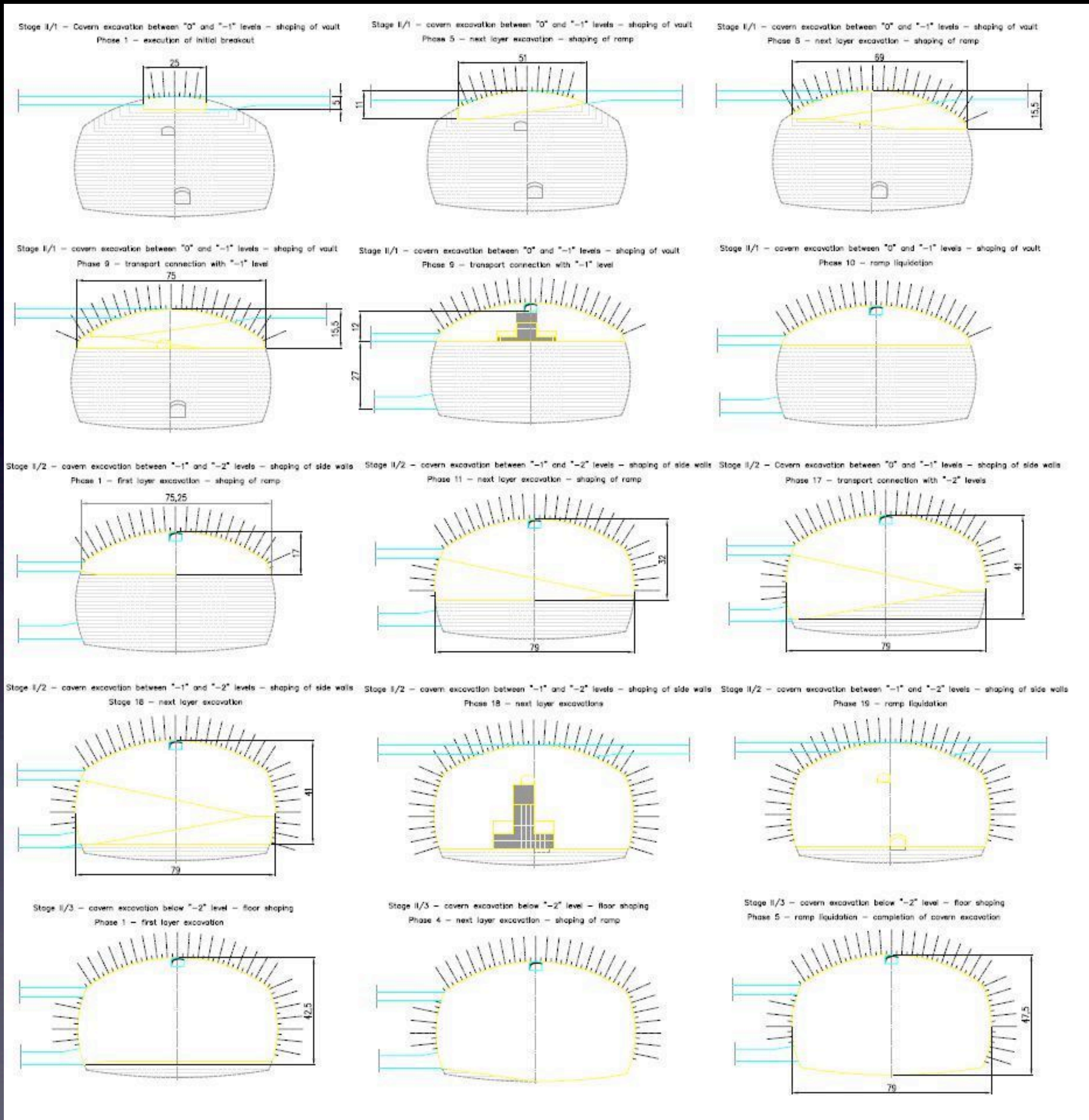
e.g. rock spalling vs depth

Detailed MDC concept

Example: GLACIER



Sequence of excavation

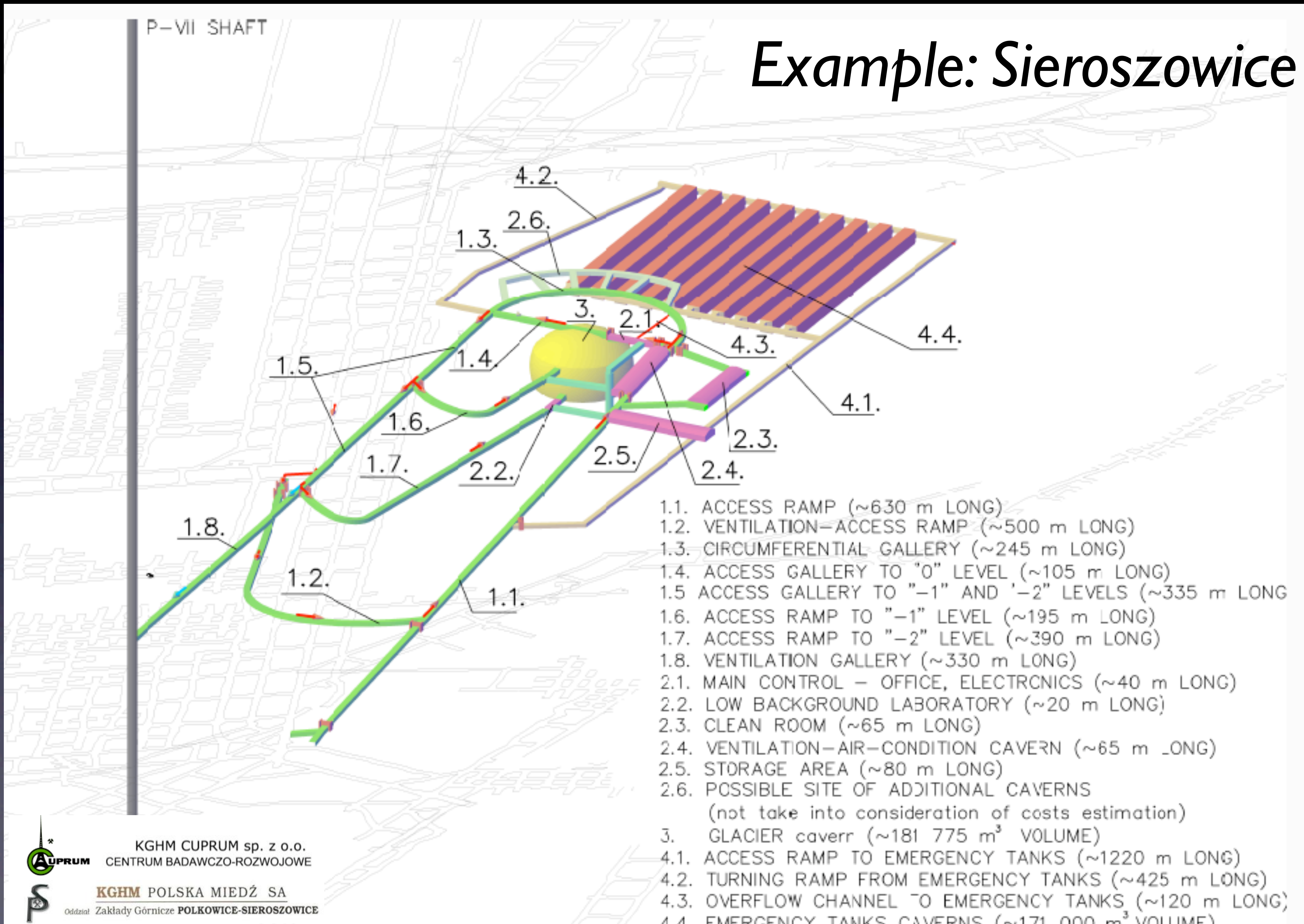


Ensure stability of excavation at all phases of progress

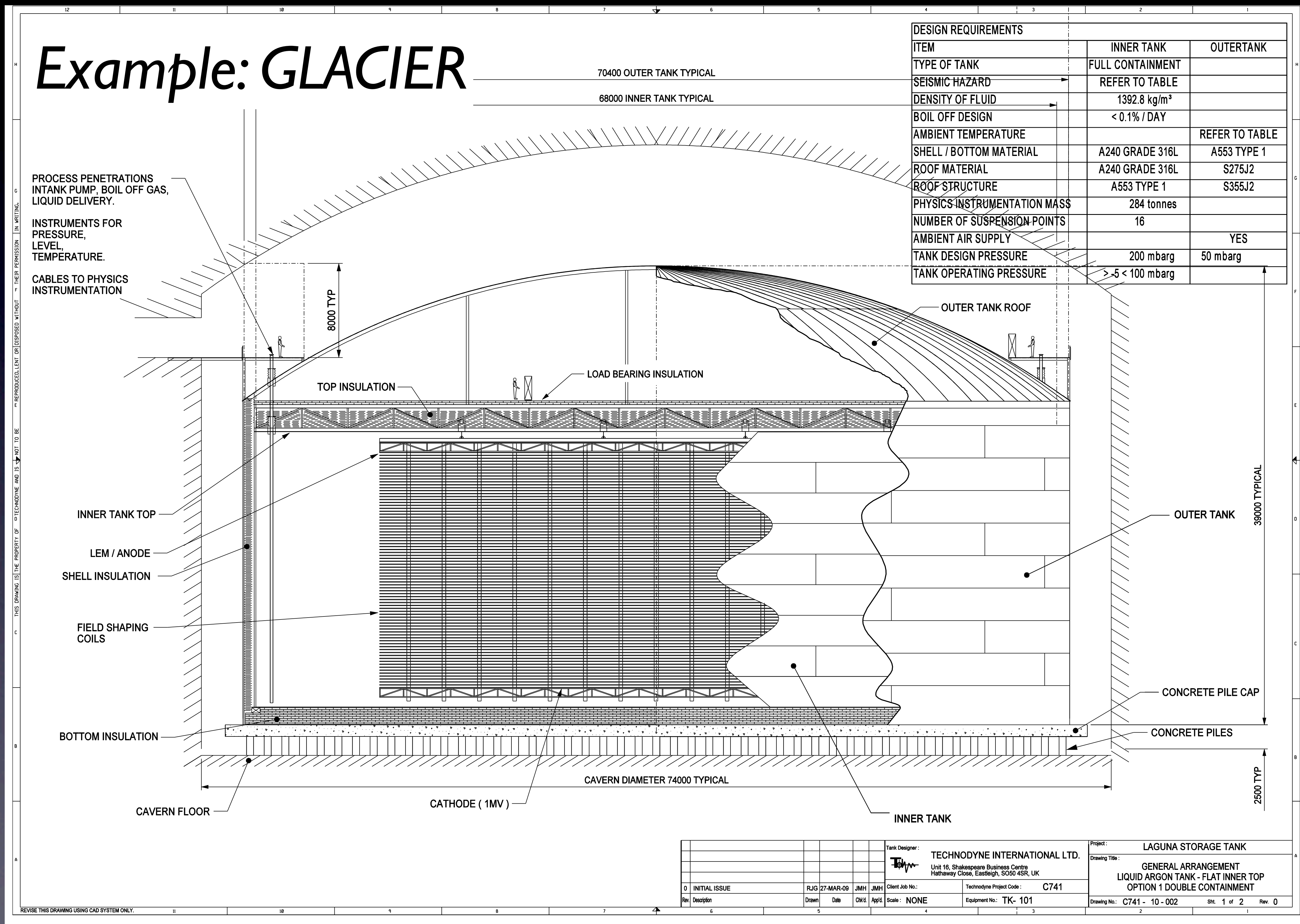
Define sequence of excavation and required amount of rock bolting reinforcement

MDC and required infrastructure

Access, ventilation, storage, emergency storage, ...



Detailed tank design (Technodyne)

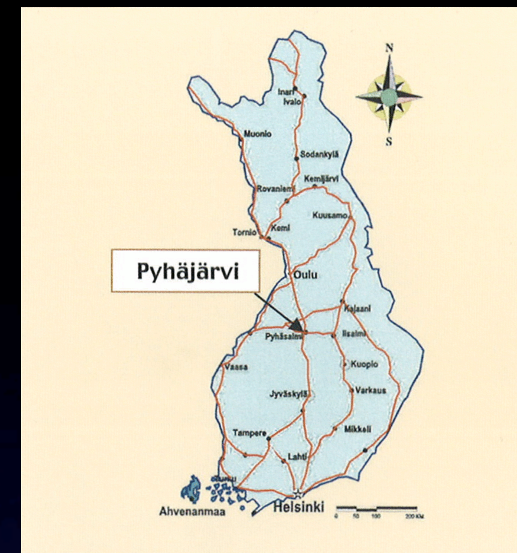


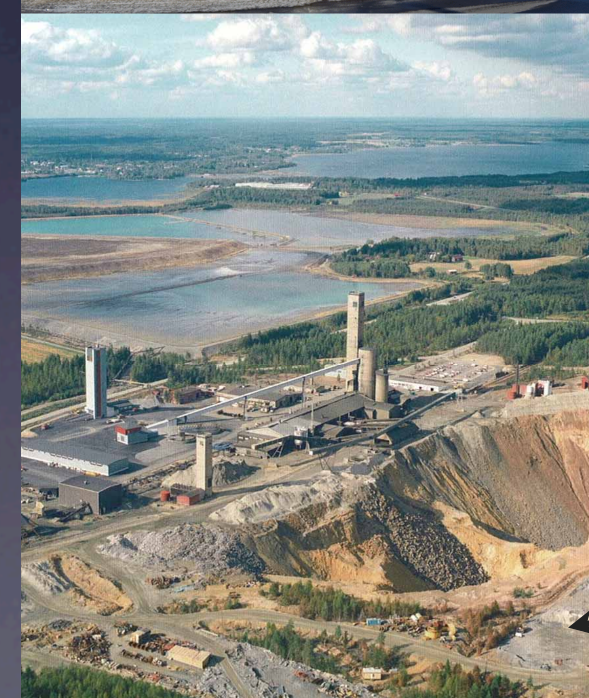
DESIGN REQUIREMENTS		
ITEM	INNER TANK	OUTERTANK
TYPE OF TANK	FULL CONTAINMENT	
SEISMIC HAZARD	REFER TO TABLE	
DENSITY OF FLUID	1392.8 kg/m³	
BOIL OFF DESIGN	< 0.1% / DAY	
AMBIENT TEMPERATURE		REFER TO TABLE
SHELL / BOTTOM MATERIAL	A240 GRADE 316L	A553 TYPE 1
ROOF MATERIAL	A240 GRADE 316L	S275J2
ROOF STRUCTURE	A553 TYPE 1	S355J2
PHYSICS INSTRUMENTATION MASS	284 tonnes	
NUMBER OF SUSPENSION POINTS	16	
AMBIENT AIR SUPPLY		YES
TANK DESIGN PRESSURE	200 mbarg	50 mbarg
TANK OPERATING PRESSURE	> -5 < 100 mbarg	

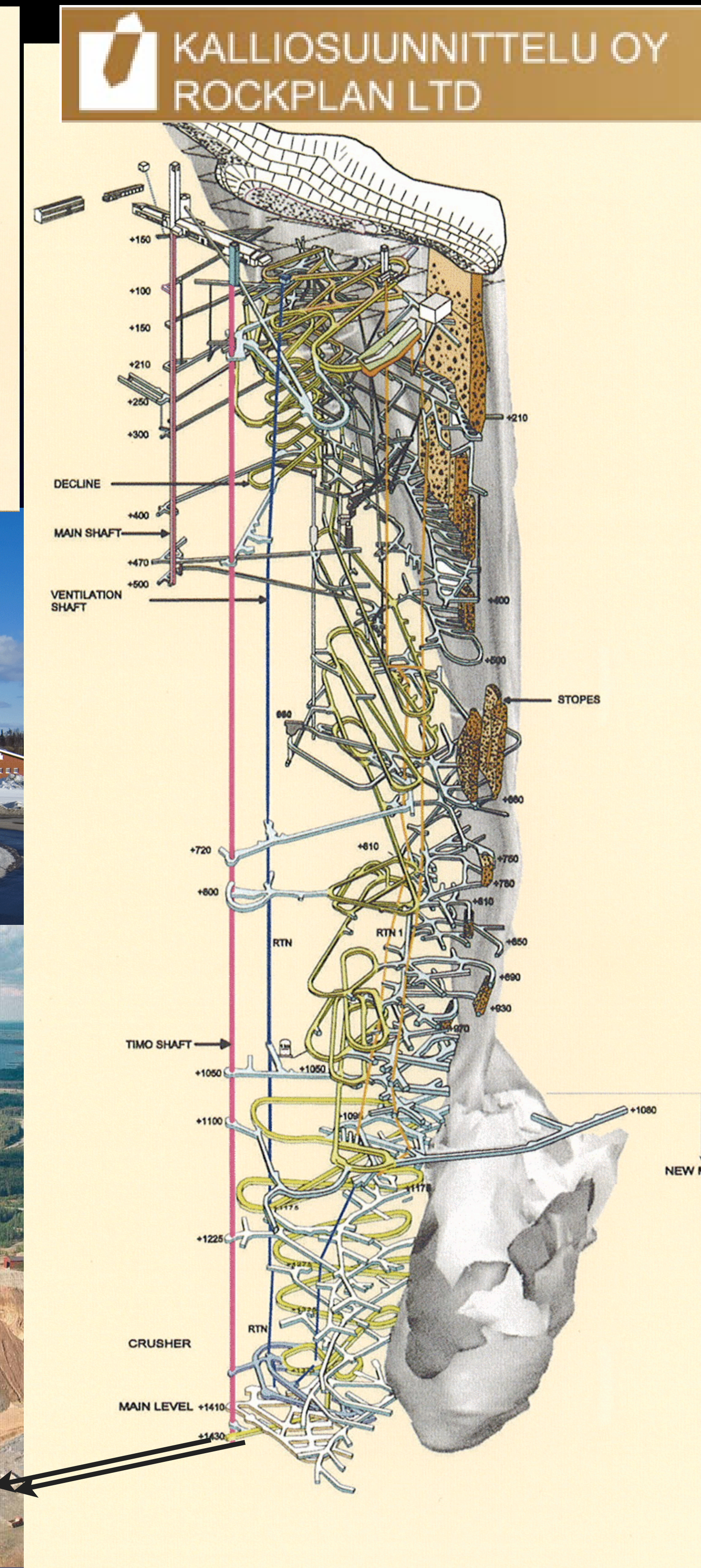
Pyhäsalmi, Finland

- Region of Pyhäjärvi, Finland
- Mine owned by Inmet Mining based in Toronto, Canada
- One of the deepest sites (4000mwe)
- Farthest from CERN (2300km) - large matter effects in neutrino oscillations

- Letter of Intent set up with mine owners, LAGUNA accepted
- Main rock mechanical calculations done
- Lay out design in progress
- Rock excavation related aspects of ventilation in progress
- Safety, environmental: first risk analysis done, main focus safety during excavation (collapse, fire, environment)
- Project introduced to local and national political bodies. Socioeconomic impact analysis in progress.



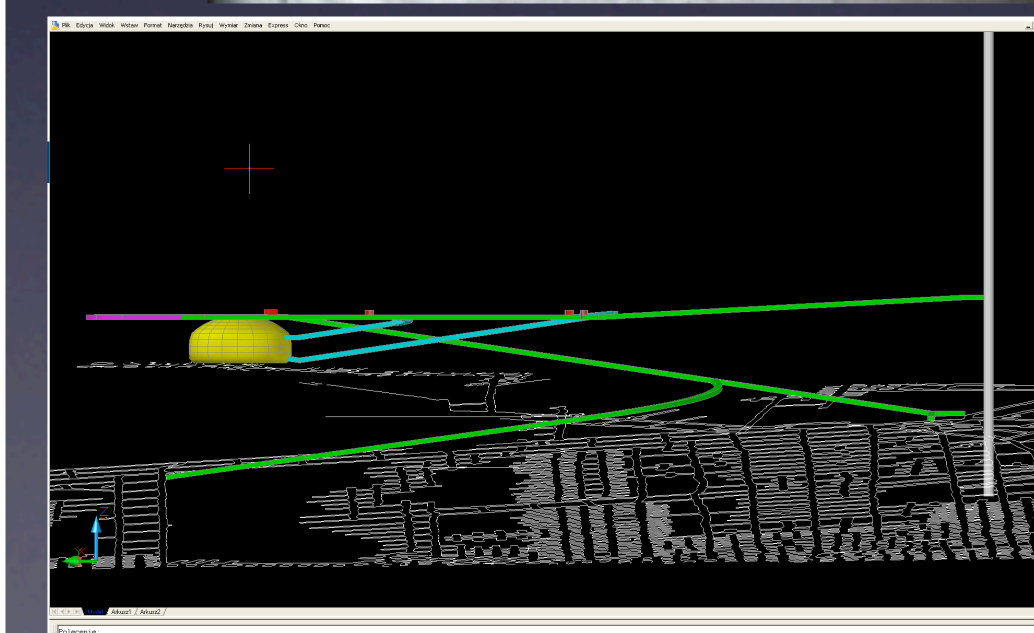




Sieroszowice UNderground LAB, Poland

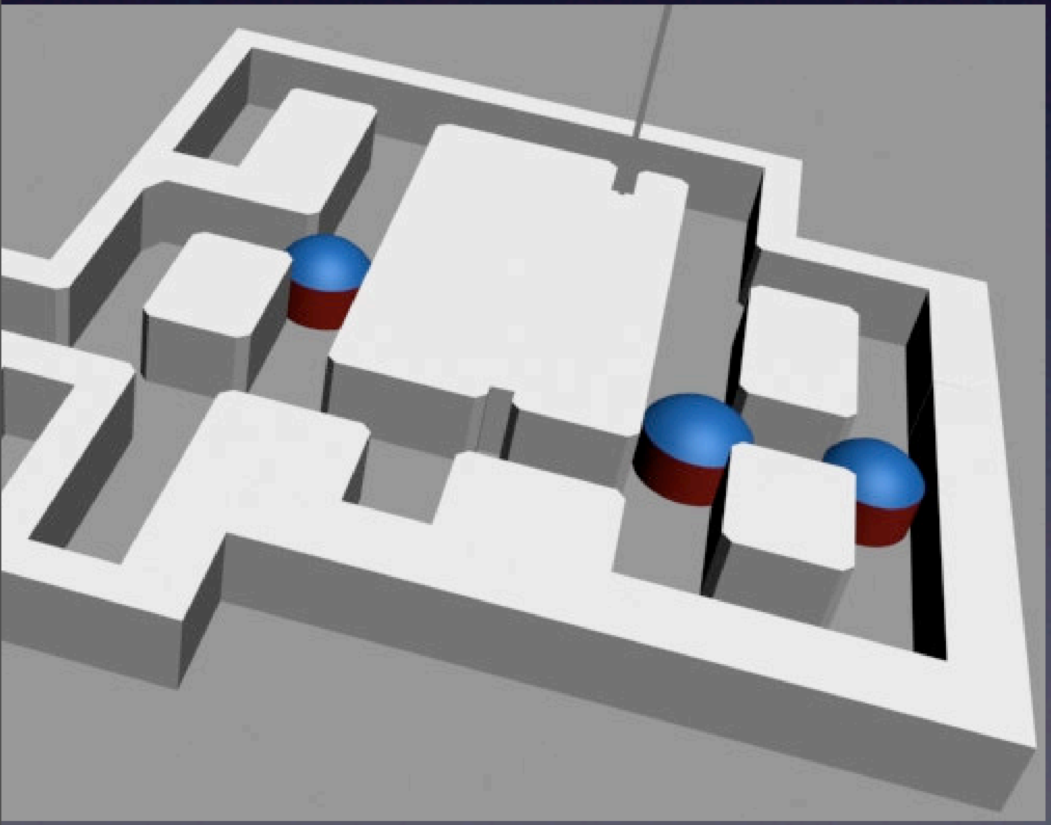
- Located Near Wrocław, south-west of Poland
- Mine owned by KGHM Cuprum
- Strong support from mine company
- Main rock mechanical calculations done
- Anhydrite / Dolomite P-VII shaft (658 m depth) position selected
- Safety, environmental: first risk analysis done, no ventilation issues, shaft has large capacity
- Project introduced to local and national political bodies. Socioeconomic impact analysis in progress (LAGUNA selected as one of the 4 Polish national priorities in fundamental science)
- Distance from CERN = 950 km

	Surrounding rocks	Tectonic stress	Cavern vertical convergence after 40 years (m)	Cavern horizontal convergence after 40 years (m)	Cavern stability
GLACIER	Salt rock Depth: 983.5 m (borehole S-383)	No	-3.23	-1.25	Bed separation within floor strata
		Yes	-3.23	-1.14	as above
	Anhydrite Depth: 1112,5 m (borehole S-384)	No	0.0025	0.024	Slight spalling of wall surface
		Yes	0.002	0.001	as above
	Anhydrite Depth: 617.5 m (P-VII Shaft)	No	irrelevant	irrelevant	Stable
		Yes	as above	as above	Damages within wall and floor strata
	Anhydrite/Dolomite Depth: 658 m (P-VII Shaft)	No	as above	as above	Stable
		Yes	as above	as above	Insignificant local spalling in the lower corner (floor)
LENA	Anhydrite Depth: 1369 m (borehole S-460)	No	-0.004	0.09	Stable
		x-x	-0.563	-0.003	as above
		y-y	-0.789	-0.002	as above



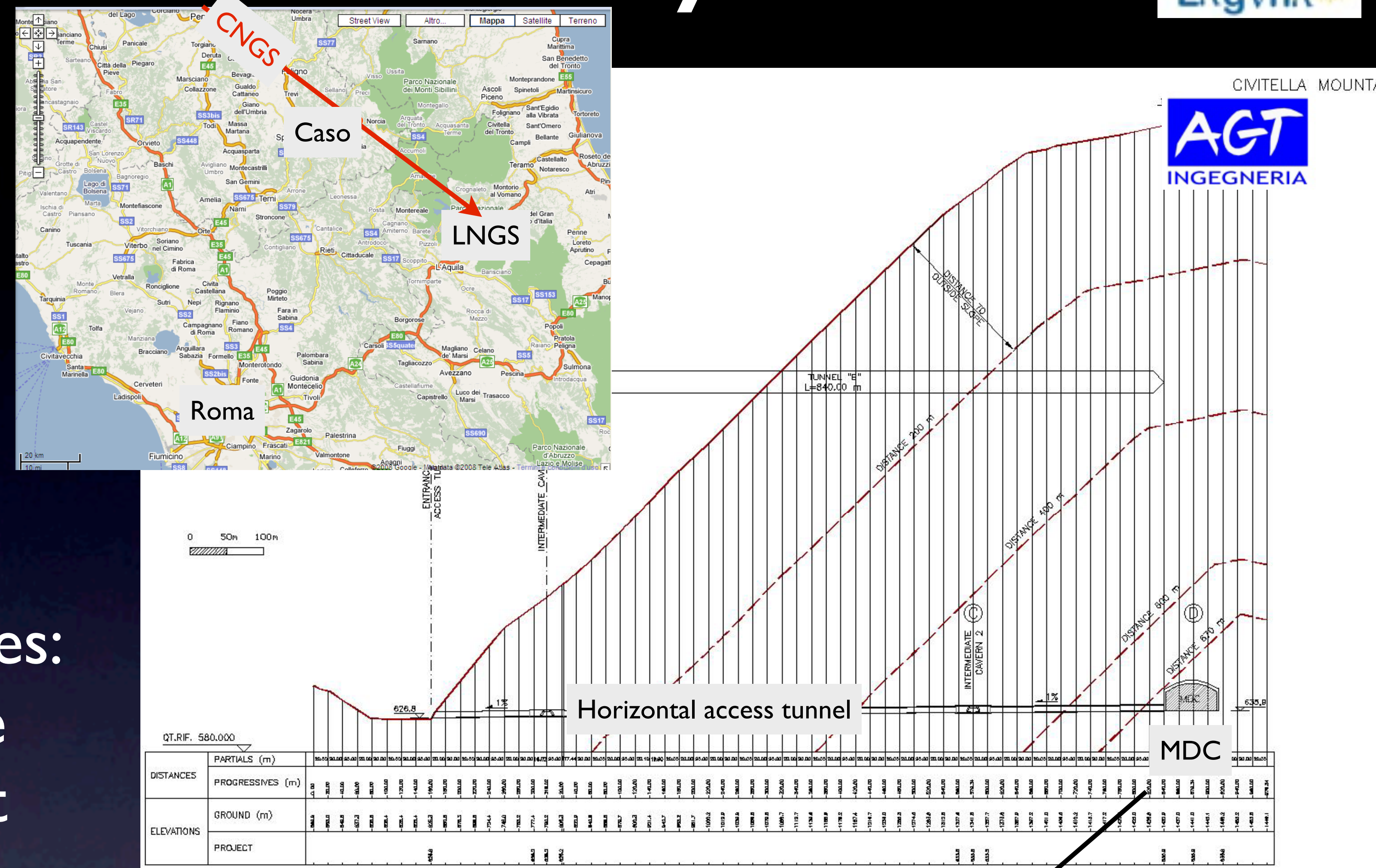
SLANIC salt mine, Romania

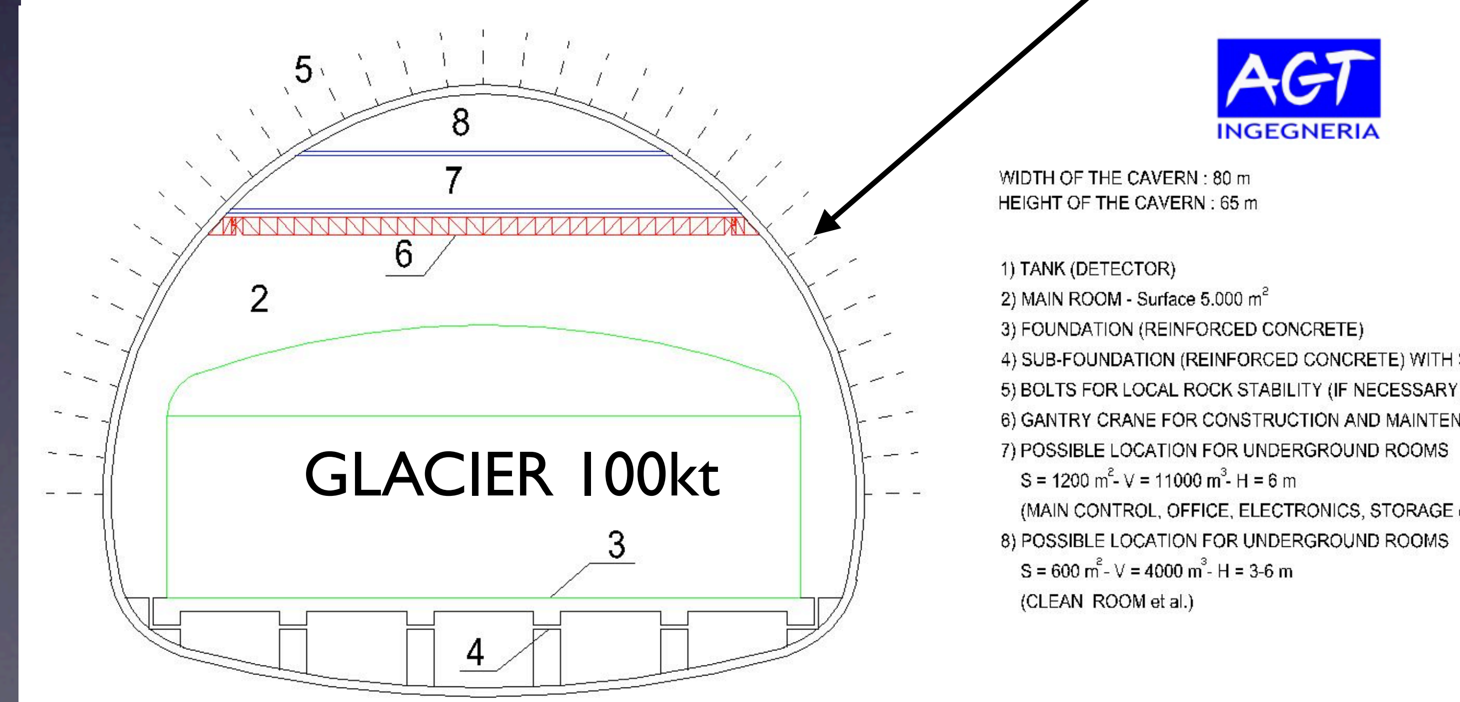
- An existing, shallow site (600 mwe) with low natural radioactivity
- Temperature ≈13°C, humidity 65-70%
- Excavated volume 2.9 million m^3 (!)
- Floor area 70000 m2
- Height of excavated rooms 52-57 m
- CERN distance = 1570 km
- Local community supportive
- Possibility to reuse existing caverns



Shallow site in Umbria, Italy

- Shallow site for GLACIER
- 1deg off-axis w.r.t CNGS
- Overburden ≈ 1500 mwe
- Horizontal tunnel access
- Distance CERN ≈ 665 km
- Study performed by AGT Ingegneria
- Contact with regional authorities:
  - Regione Umbria → at the moment unofficial support
  - A.R.P.A. Umbria (Regional Environment Agency) → Environment & Hazard issues
  - Fire Service (Provincial Headquarters) → Safety & Hazard issues
- No significant show-stoppers have been identified.



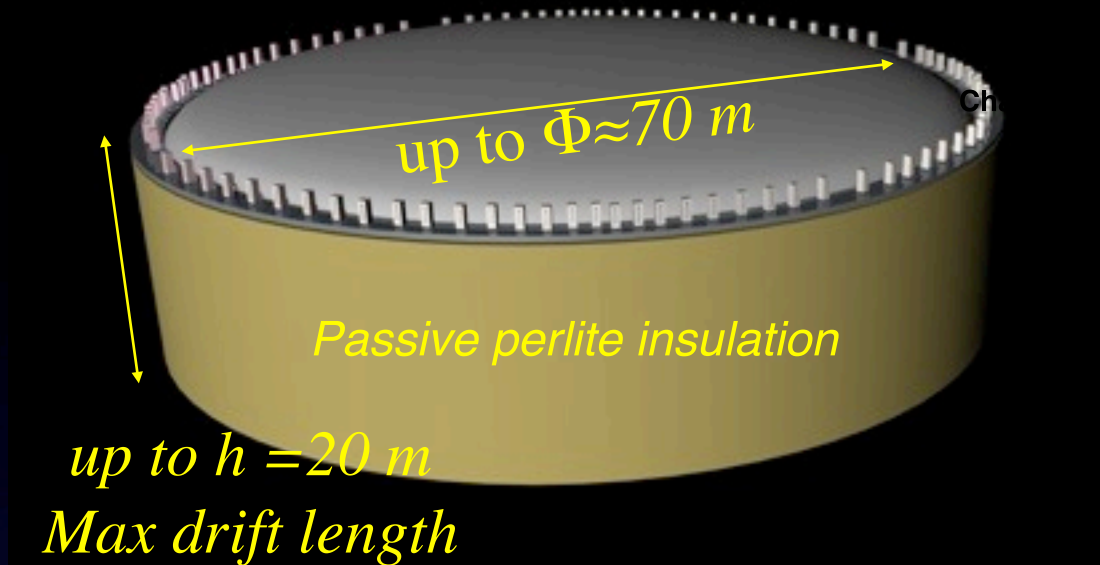


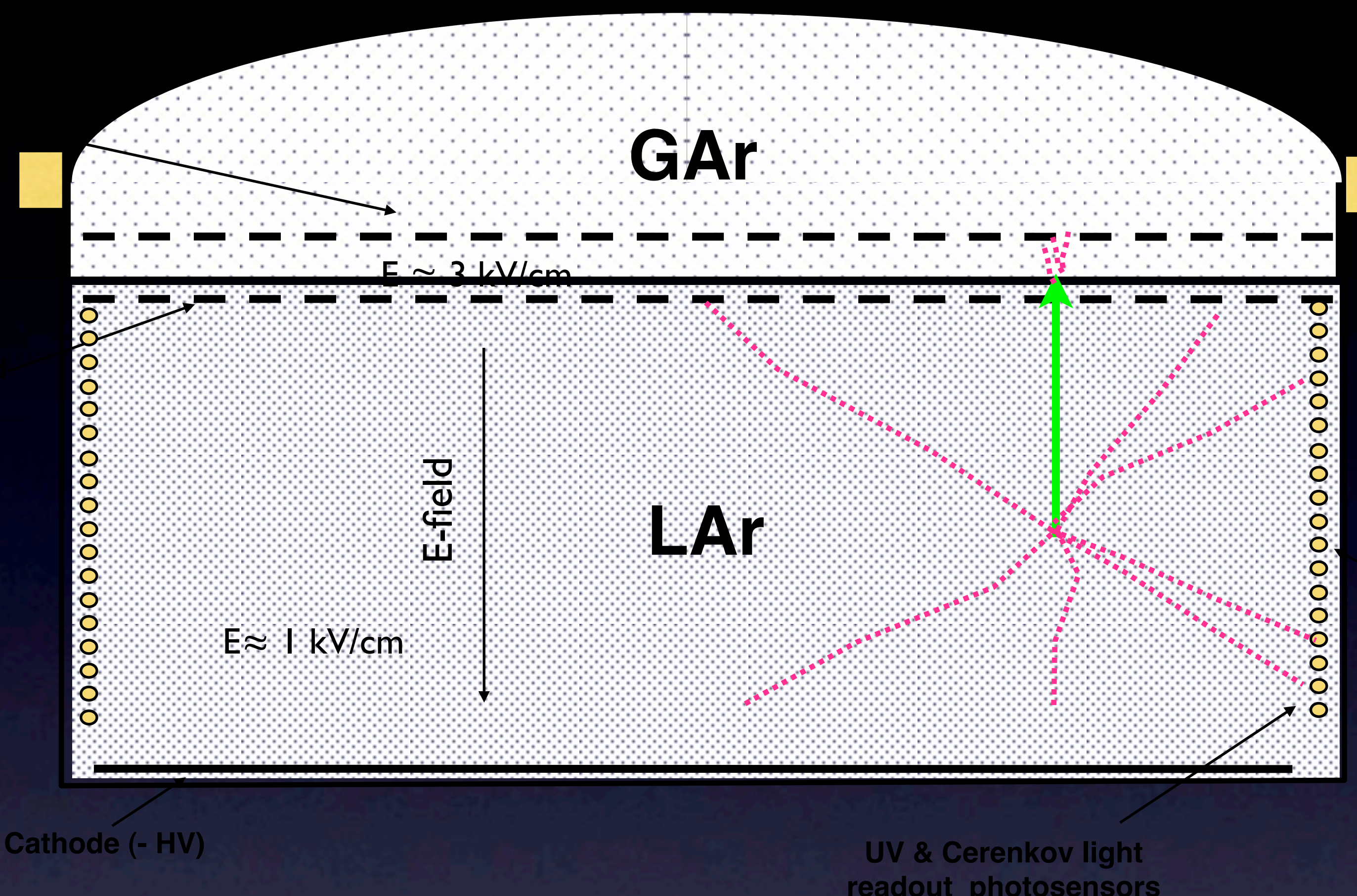
A word on the detectors

LAGUNA EC funding is mainly focused at site infrastructure studies
Detector R&D must be supported by other means and in particular at the national level

GLACIER: Giant Liquid Ar Charge Imaging ExpeRiment

AR, hep-ph/0402110, Venice 2003





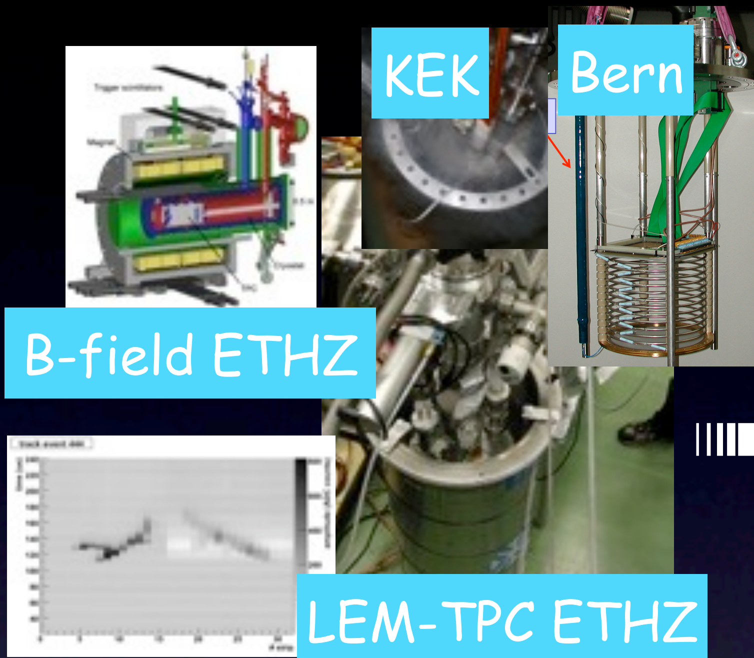
- Based on novel concept of LAr LEM-TPC (double phase)
  - ➠ *F. Resnati's talk*

- Main focus of detector R&D in Switzerland
- Interest expressed in liquid Argon option from several European institutes in particular from France, Poland and United Kingdom
- Formal ETHZ-KEK Collaboration formed in 2008, focused at LAr R&D towards 100 kton detector, currently considering:
  - 250L detector at KEK
  - Test beams in charged and neutral particles
  - 1000 ton detector

Step-by-step R&D strategy

Will assess if 100 kton is within reach

- Small prototypes ➠ ton-scale detectors ➠ 1 kton ➠ ?

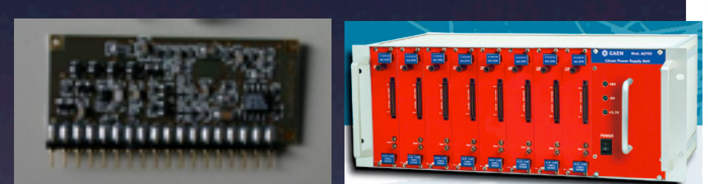


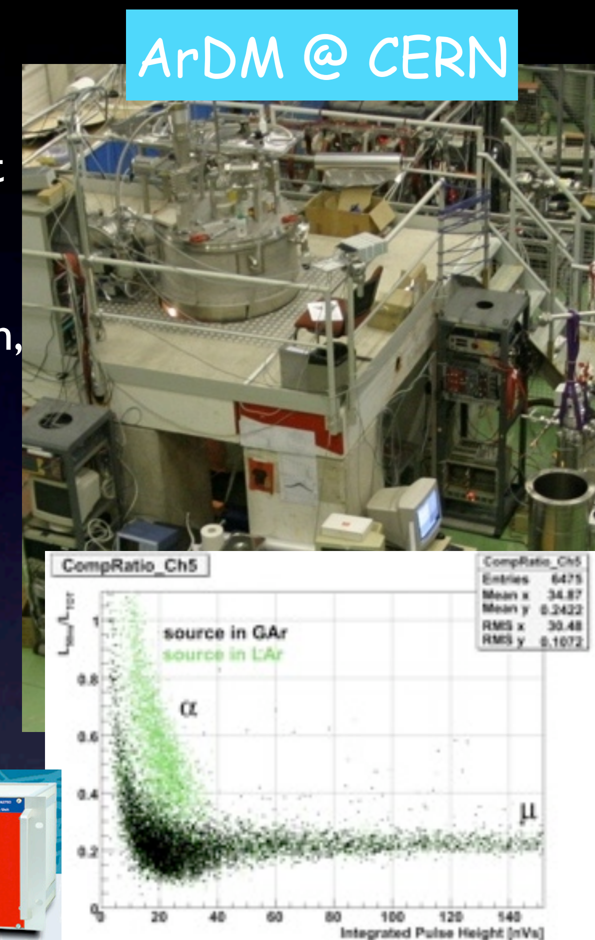
proof of principle double-phase LAr LEM-TPC on 0.1x0.1 m² scale

➠

LEM readout on 1x1 m² scale UHV, cryogenic system at ton scale, cryogenic pump for recirculation, PMT operation in cold, light reflector and collection, very high-voltage systems, feed-throughs, industrial readout electronics, safety

already in operation at CERN in Blg 182 (CERN RE18)





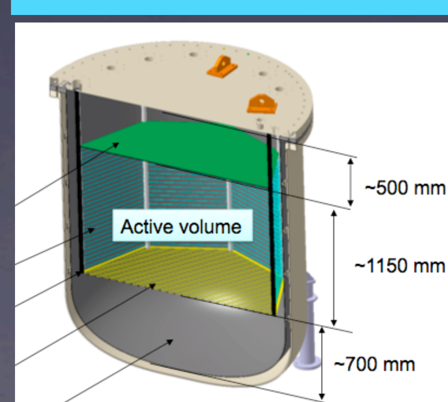
➠

direct proof of long drift path up to 5 m

➠

Application of LAr LEM TPC to neutrino physics: particle reconstruction & identification (e.g. 1 GeV e/μ/π), optimization of readout and electronics, possibility of neutrino beam exposure, purity tests in non-evacuate vessel

Test beam
1 to 10 ton-scale



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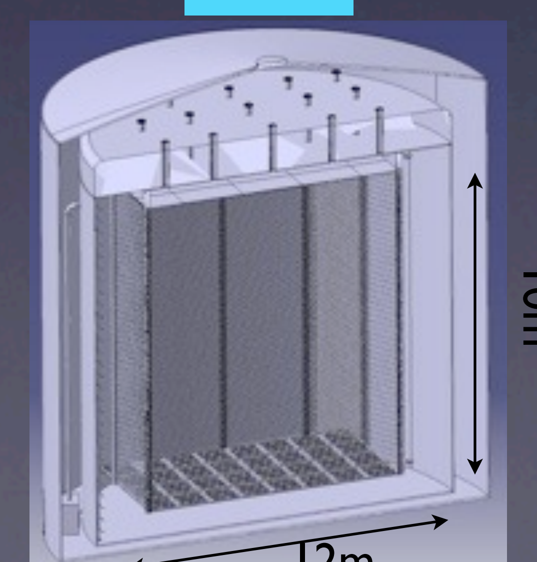
full engineering demonstrator for larger detectors, acting as near detector for neutrino fluxes and cross-sections measurements, large scale application, ...

1 kton



Conclusions

- LAGUNA (FP7 DS, GA 2008-2010) addresses the feasibility of a new large underground infrastructure in Europe able to host next generation neutrino physics and astroparticle physics and proton decay experiments.
- One of the seven priorities of the ASPERA roadmap
- Seven sites are presently being considered and three detector technologies (WC, LAr, LScint). The LAGUNA study will foster convergence at the European level and should lead to a common proposal towards the next step (a detailed study leading to preparation of the experiment)
- LAGUNA mainly towards a European context is also strongly linked to other project world-wide (Japan, USA) that consider the same physics goals
- Swiss interest strongly biased towards liquid Argon option.
- Tight collaboration on LAr R&D with KEK (Japan) since 2008.

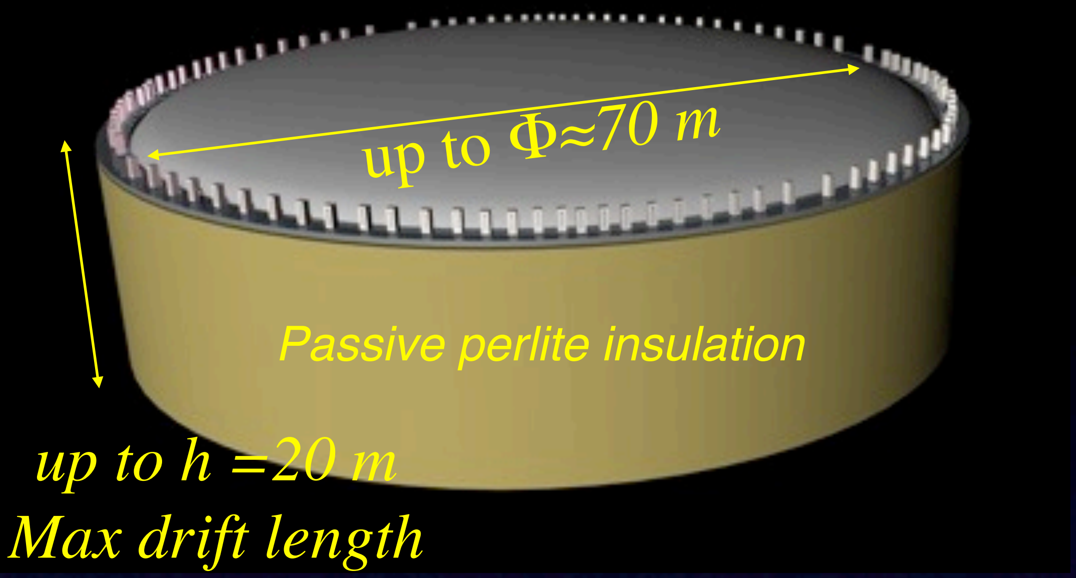
Acknowledgements

- FP7 Research Infrastructure "Design Studies" LAGUNA (Grant Agreement No. 212343)

Thank you.

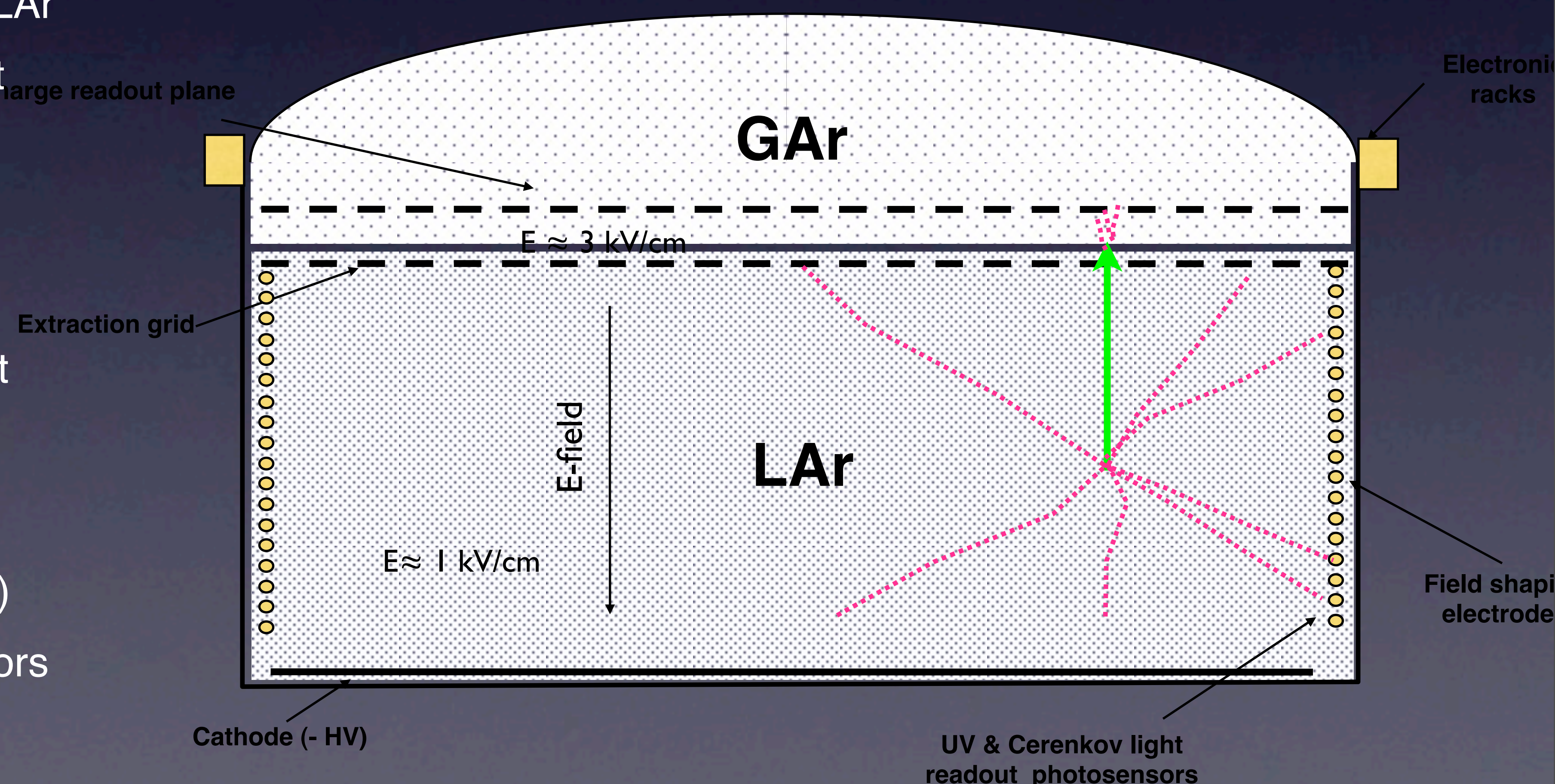
GLACIER: Giant Liquid Ar Charge Imaging ExpeRiment

AR, hep-ph/0402110, Venice 2003



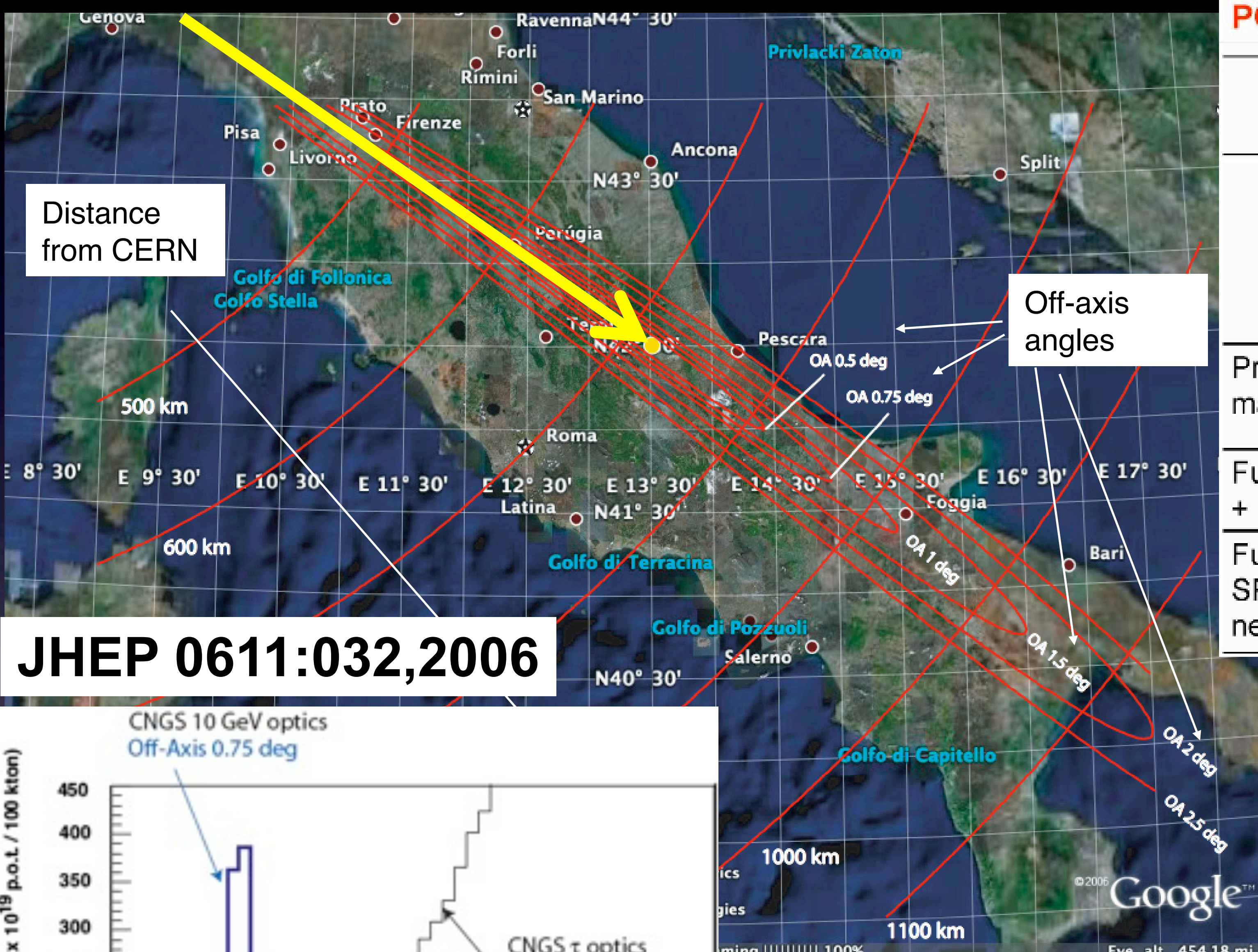
- Single module cryo-tank based on industrial LNG technology
- Cylindrical shape with excellent surface / volume ratio
- Simple, scalable detector design, possibly up to 100 kton
- Single very long vertical drift with full active mass
- A very large area LAr LEM-TPC for long drift paths
- Possibly immersed visible light readout for Cerenkov imaging
- Possibly immersed (high Tc) superconducting solenoid to obtain magnetized detector
- Reasonable excavation requirements (<250‘000 m^3)

- Passive insulation heat loss ≈ 80kW@LAr
- LEM+anode readout with 3mm readout pitch, modular readout, strip length modulable, 2.5×10^6 channels
- Purity < 0.1 ppb (O_2 equiv.) in non-evacuable vessel
- Immersed HV Cockcroft-Walton for drift field (1 kV/cm)
- Readout electronics (digital F/E with CAEN; cold preamp R&D ongoing; network data flow & time stamp distrib.)
- WLS-coated 1000x 8” PMT and reflectors for DUV light detection

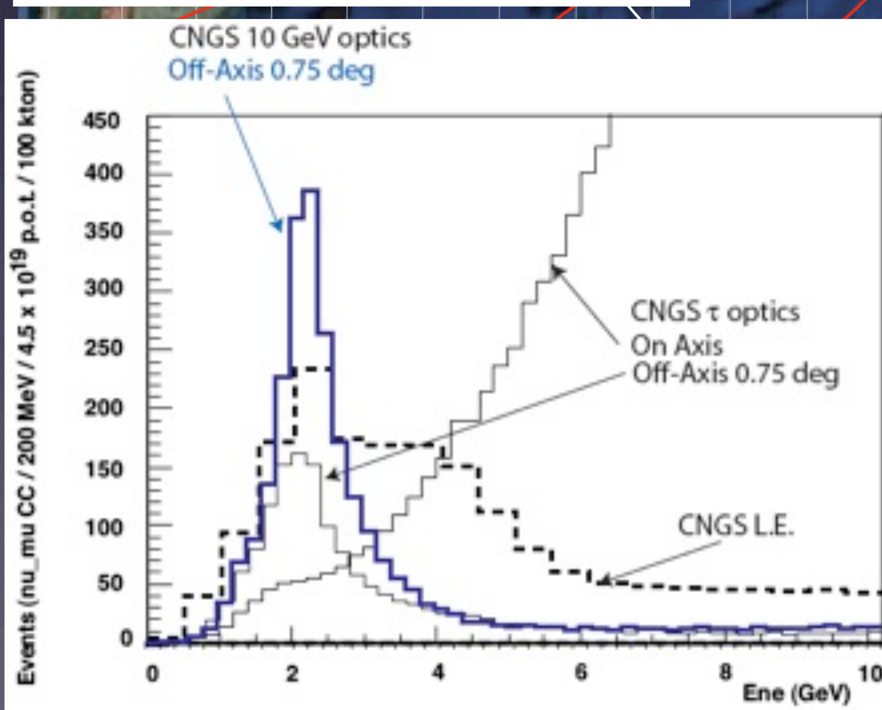


Criteria: Upgraded CNGS

- The physics potential of an intensity upgraded CNGS beam coupled to a new off-axis detector has been first addressed in JHEP 0611:032, 2006

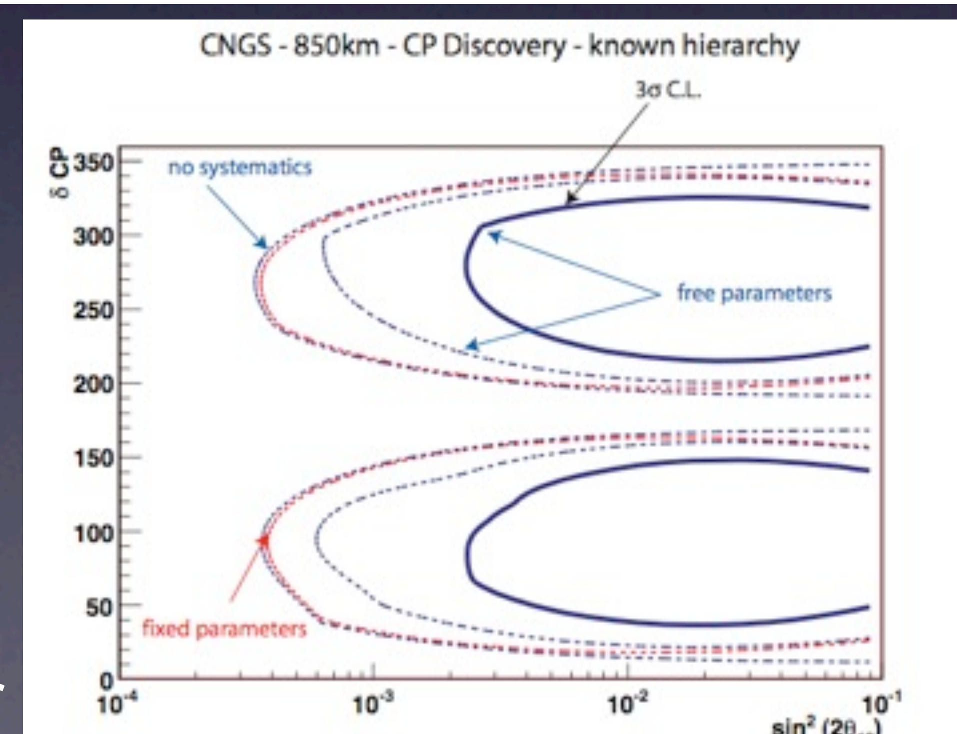


JHEP 0611:032,2006



POT/year [10^{19}] for 200 days of operation with 80% machine efficiency

	SPS cycle length	6 s		4.8 s	
	Injection Energy	14 GeV		26 GeV	
	Beam sharing / Max SPS intensity @ 400GeV [$x10^{13}$]	0.45	0.85	0.45	0.85
Present injectors + machines' improvement	4.8	5	9.4		
	5.7	5.9	11.1		
Future injectors (>2016) + SPS RF upgrade	7			9	17.1
Future injectors + new SPS RF system + CNGS new equipment design	10			12.9	24.5



100 kton
7 yrs ν + 7 yrs $\bar{\nu}$
2.4 x 10^{20} pots/yr

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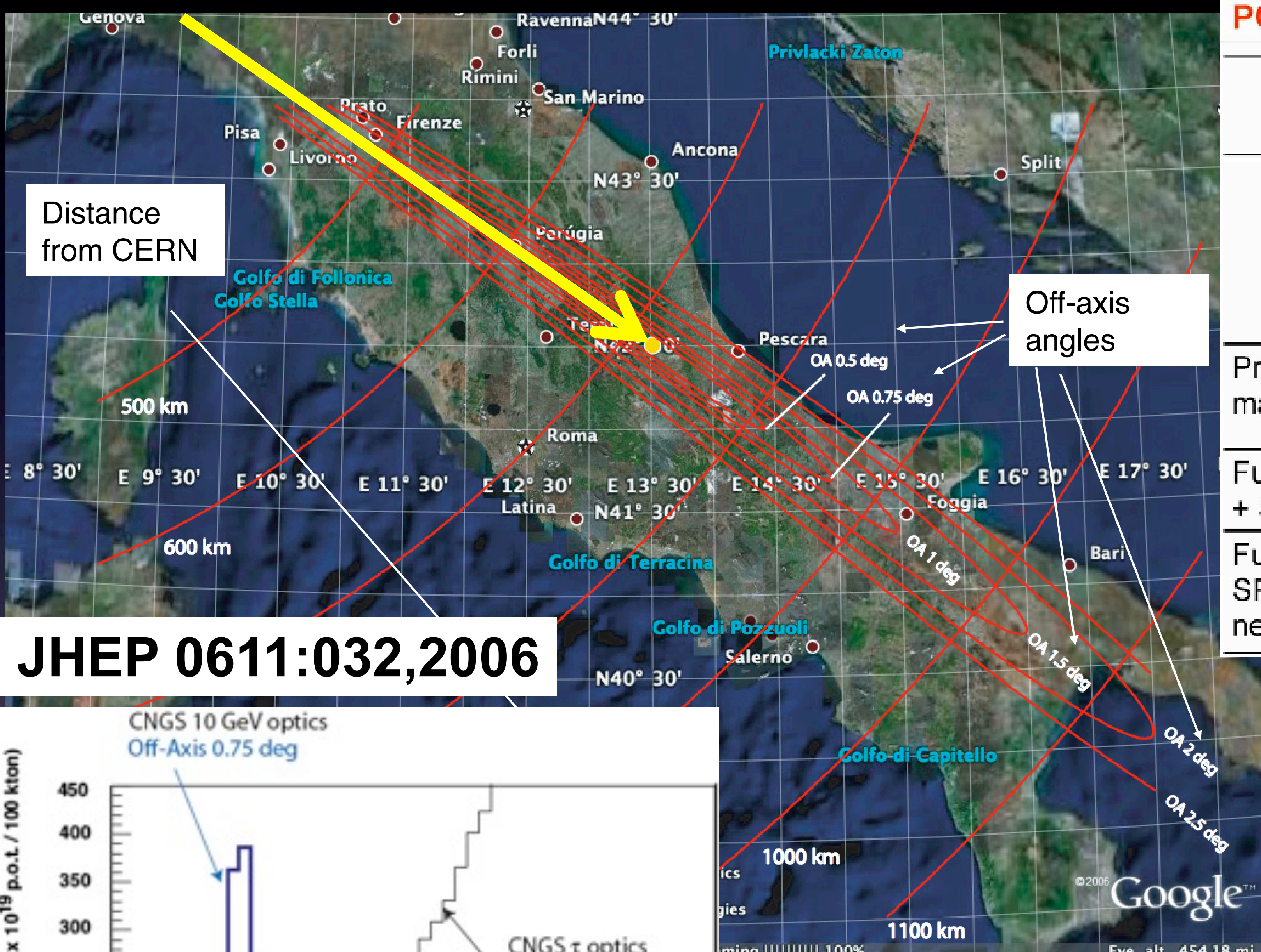

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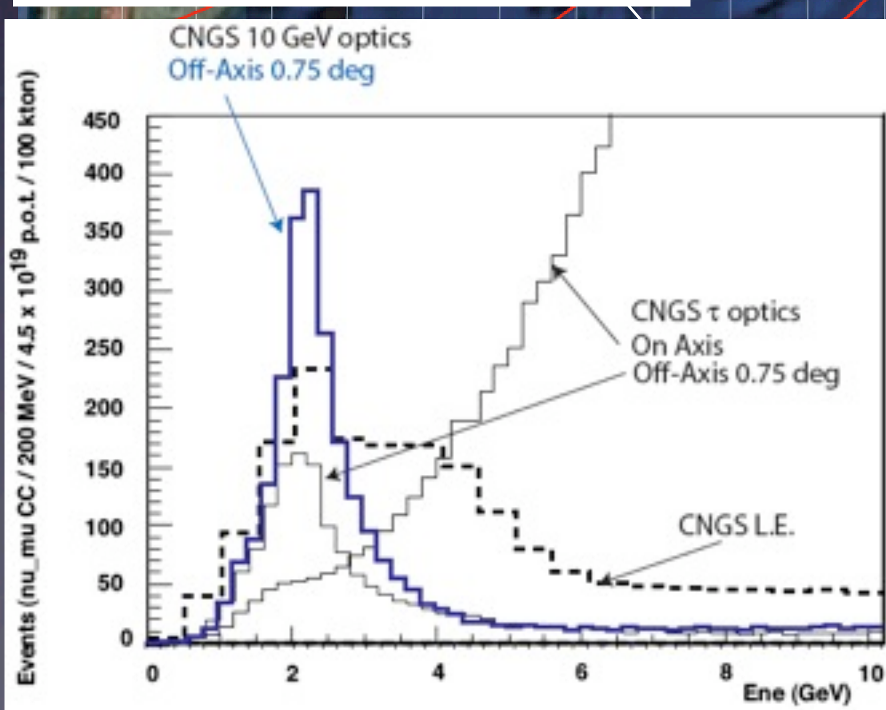

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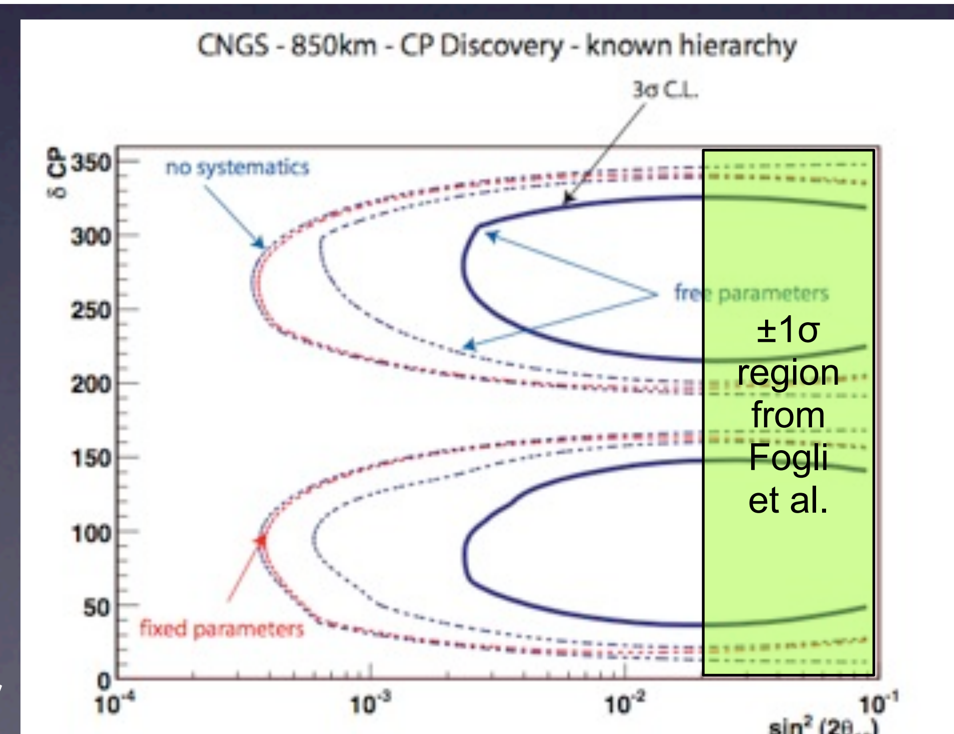


Long baseline neutrino oscillation

	J-PARC			CERN SpS				CERN PS2	
	design [2]	upgrade [72]	ultimate [2]	CNGS dedicated	+ [61]	1 [73]	2 [73]	SLHC	ν?
Proton energy E_p	30 GeV/c		40 GeV/c	400 GeV/c				50 GeV/c	
$ppp(\times 10^{13})$	33	67	> 67	4.8	14	4.8	15	12.5	25
T_c (s)	3.64	2	< 2	6	6	6	6	2.4	1.2
Efficiency	1.0	1.0	1.0	0.55	0.83	0.8	0.8	1.0	1.0
Running (d/y)	130	130	130	220	220	240	280	200	200
N_{pot} / yr ($\times 10^{19}$)	**100**	**380**	**$\simeq$ 700**	**7.6**	**33**	**12**	**43.3**	**90**	**360**
Beam power (MW)	0.6	1.6	4	0.5	1.5	0.5	1.6	0.4	1.6
$E_p \times N_{pot}$ ($\times 10^{22}$ GeV·pot/yr)	4	11.5	28	3	13.2	4.7	17.3	4.5	18
Relative increase		$\times 3$	$\times 7$	$\times 2$	$\times 7$	$\times 3$	$\times 10$	–	$\times 4$
Timescale	$\simeq$ 2014	>2014?	?	> 2008	>2016 ?			>2018 ?	

KEK roadmap

JHEP 0611, 032 (2006)

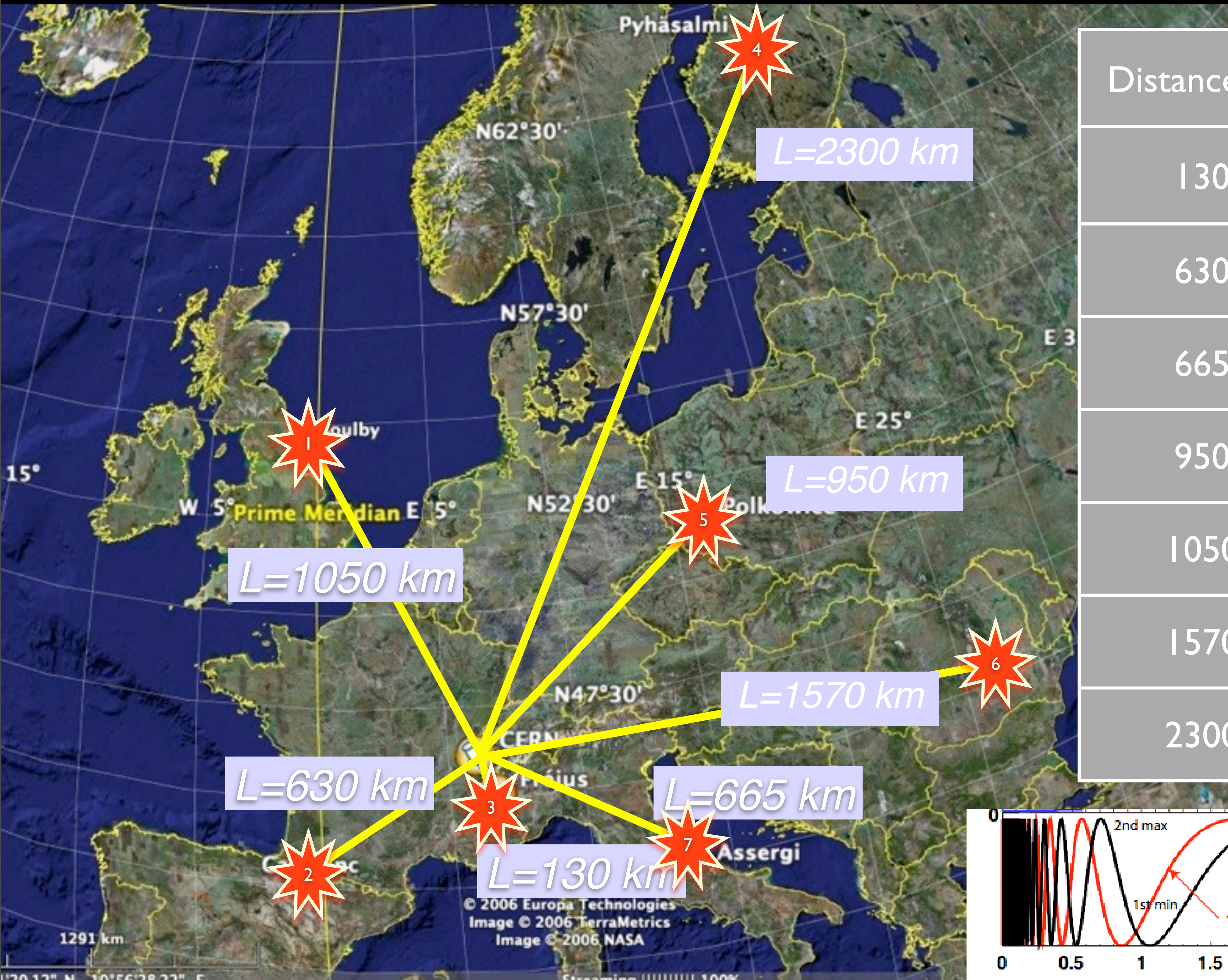
MODULAr (2008)

LHC injection upgrade

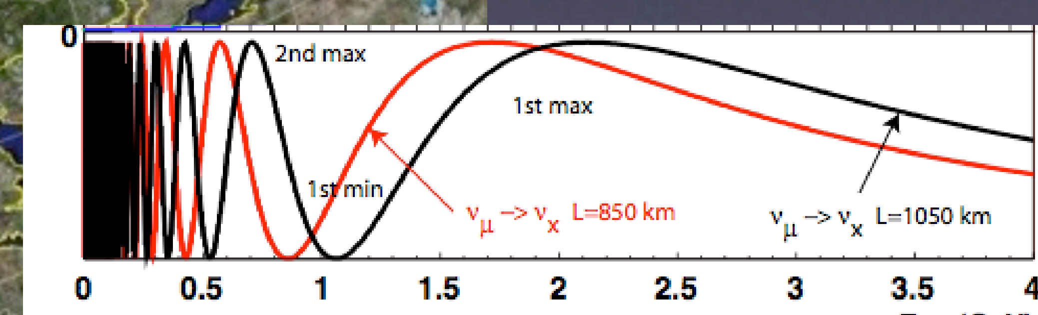
under study

- *Increase SPS integrated intensity to CNGS by a factor x3-x10 compared to baseline 4.5x10^{19} pots/yr ?*
- *and/or increase baseline PS2 parameters by a factor x4 to satisfy potential next generation ν experiments ?*

Criteria: distance from CERN

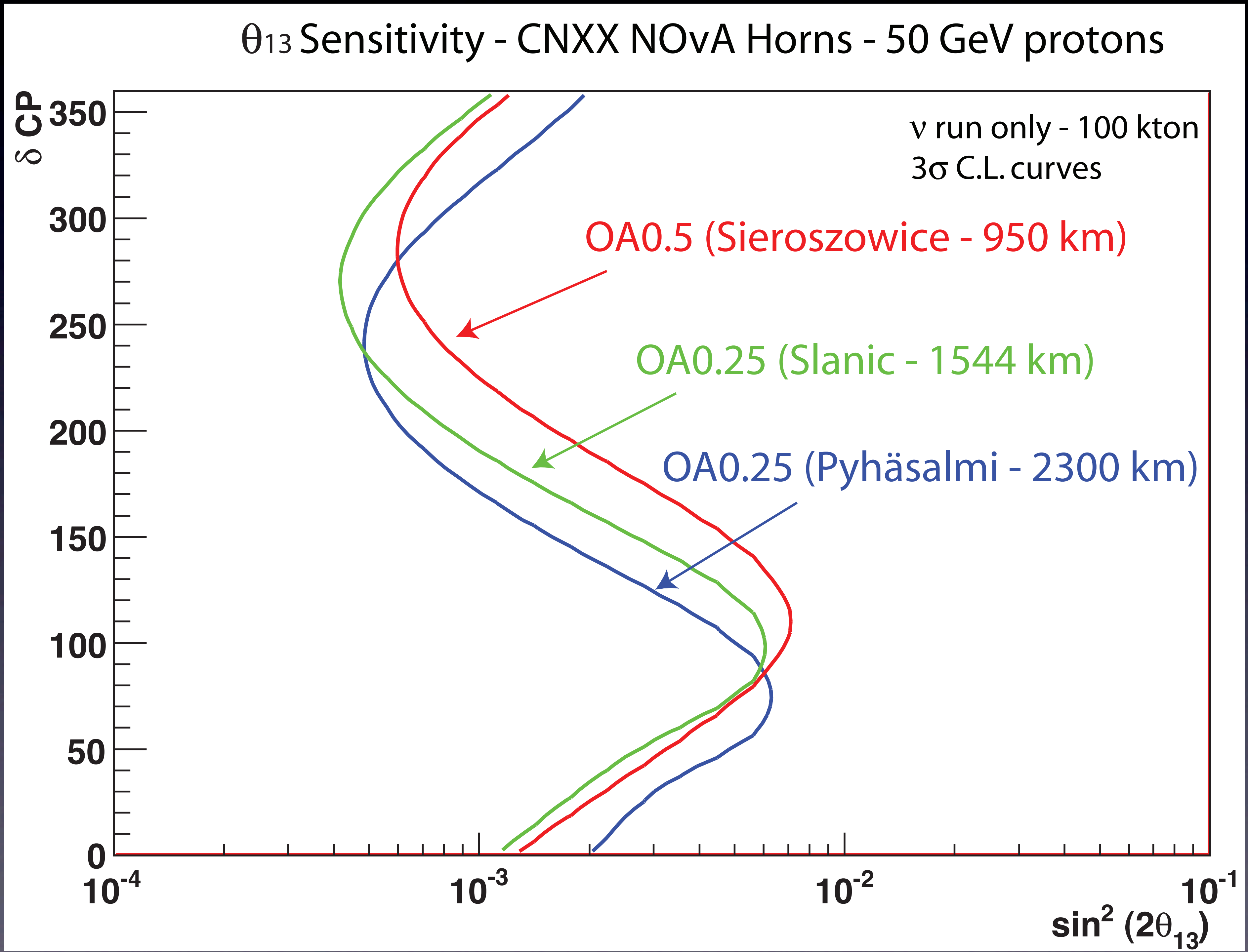


Distance/km	1st oscillation max (GeV)
130	0.26
630	1.27
665	1.34
950	1.92
1050	2.12
1570	3.18
2300	4.65



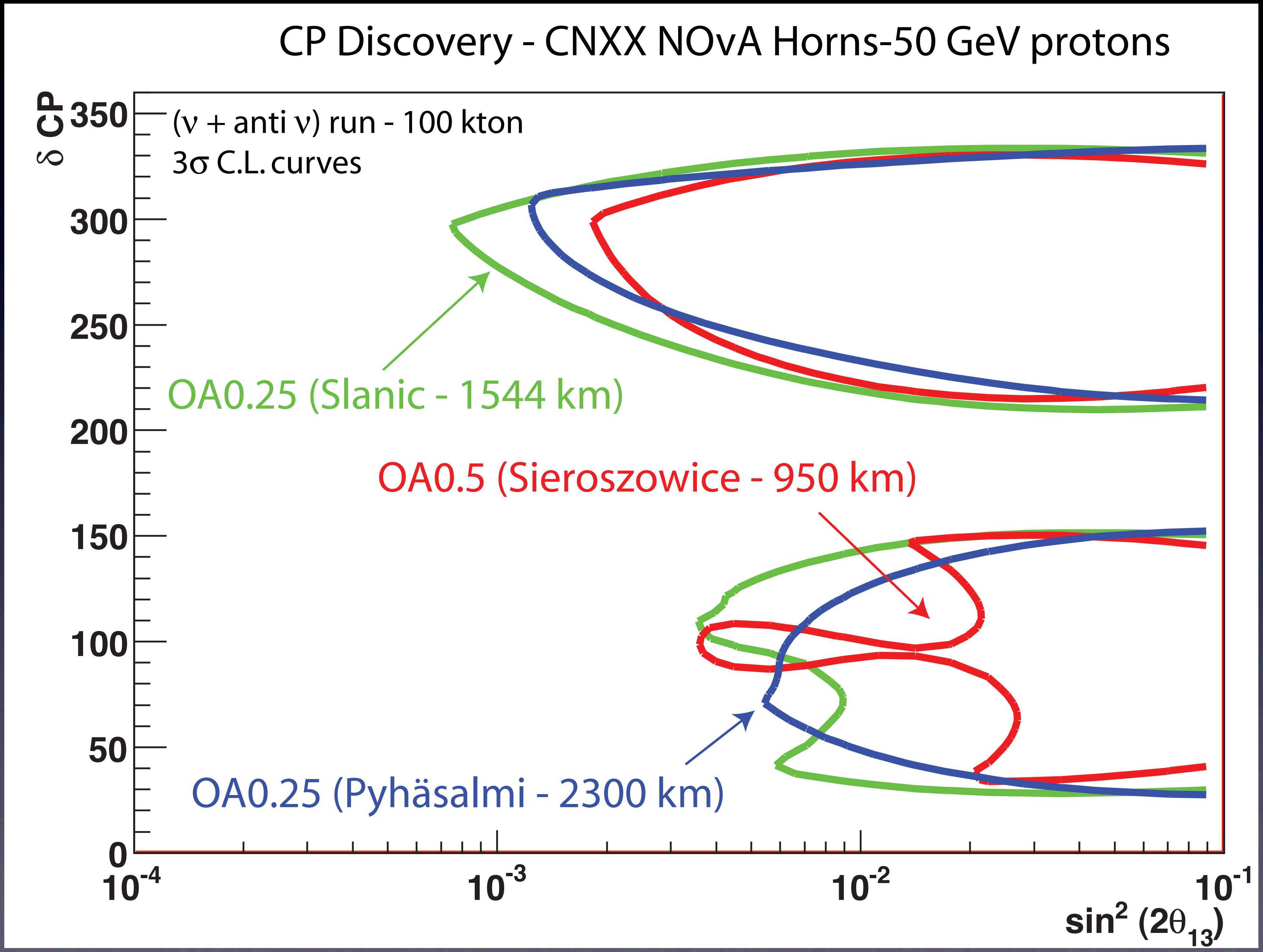
θ_{13} sensitivity

100 kton
5 yrs ν
3 x 10^{21} pots/yr @ 50 GeV



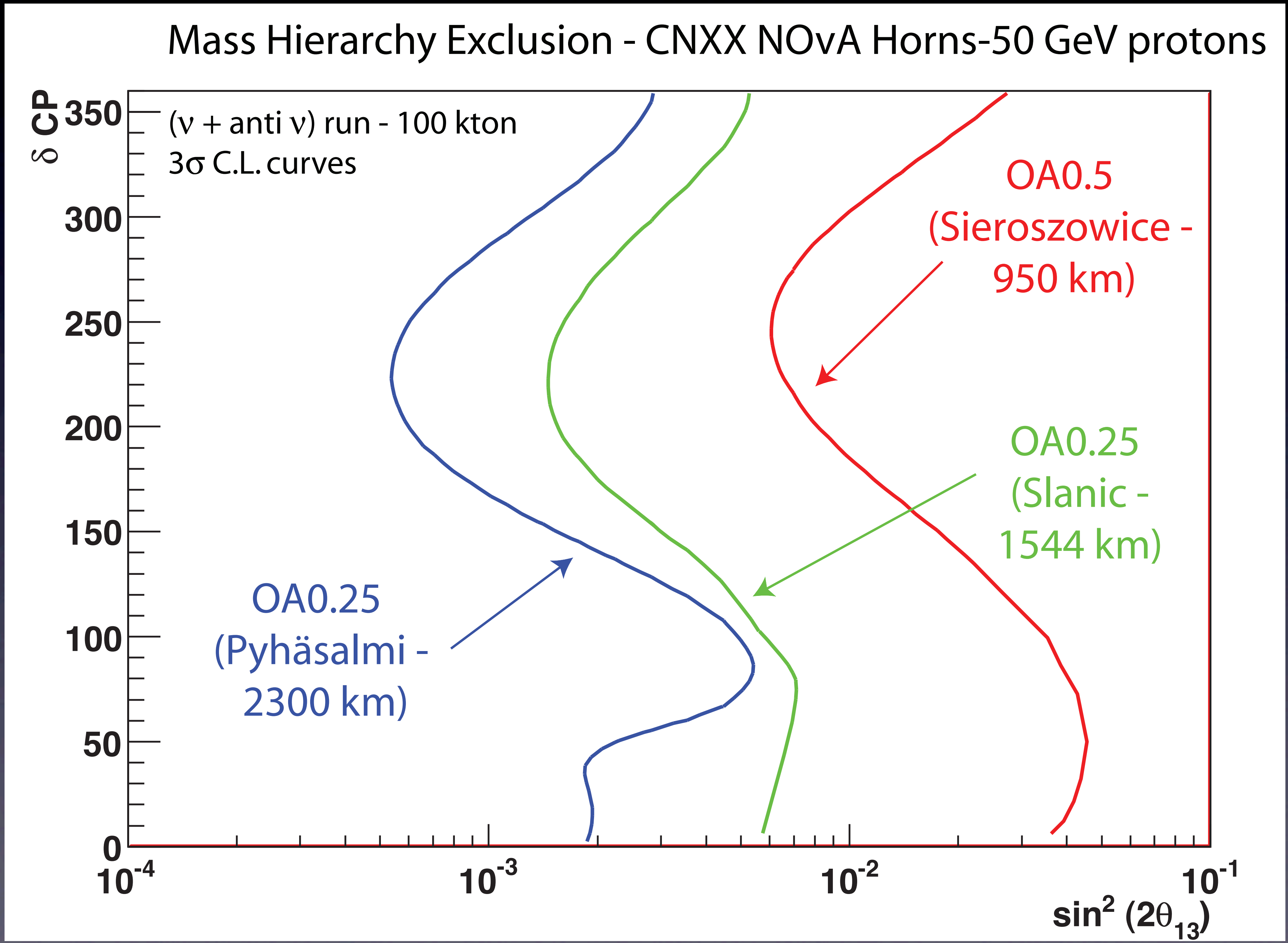
δ_{CP} sensitivity

100 kton
5 yrs ν + 5 yrs $\bar{\nu}$
3 x 10^{21} pots/yr @ 50 GeV



Mass hierarchy sensitivity

100 kton
5 yrs ν + 5 yrs $\bar{\nu}$
3 x 10^{21} pots/yr @ 50 GeV

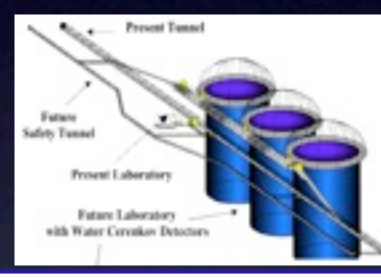


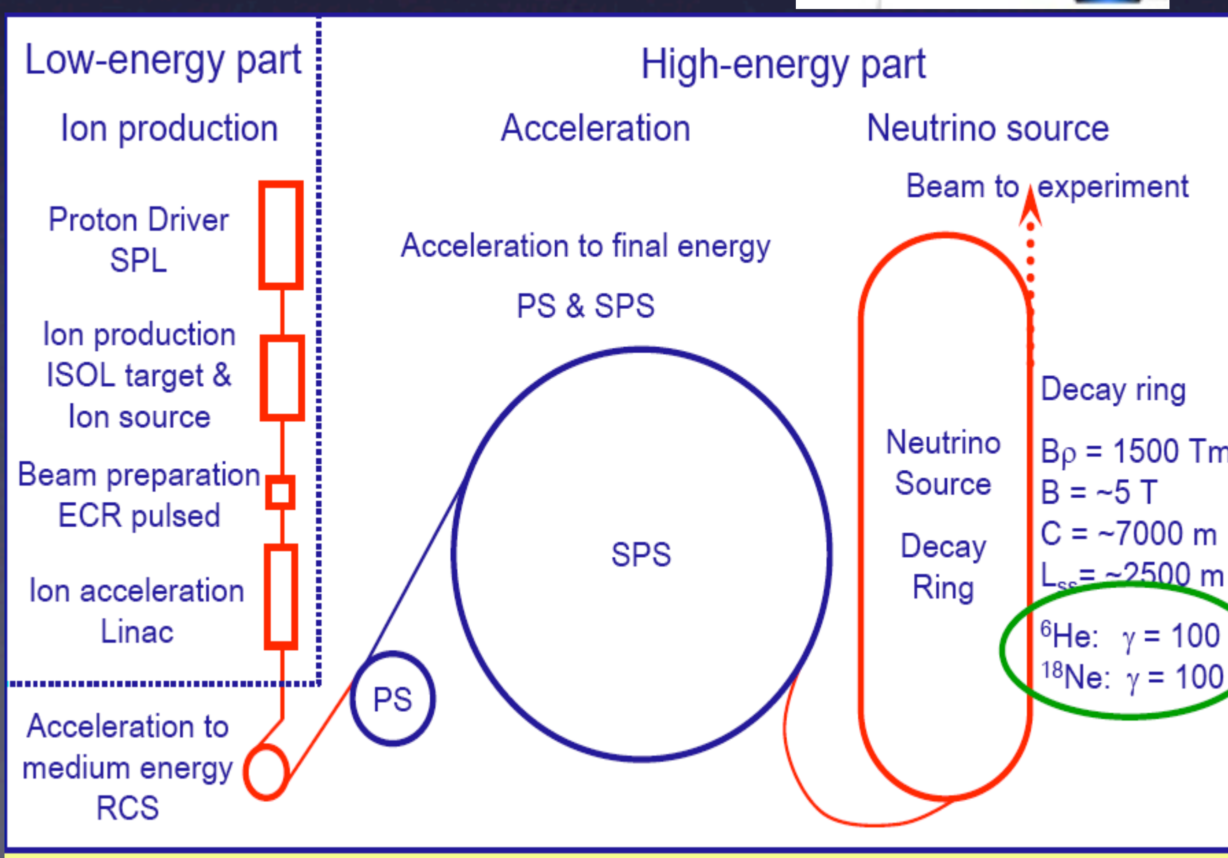
A. Rubbia

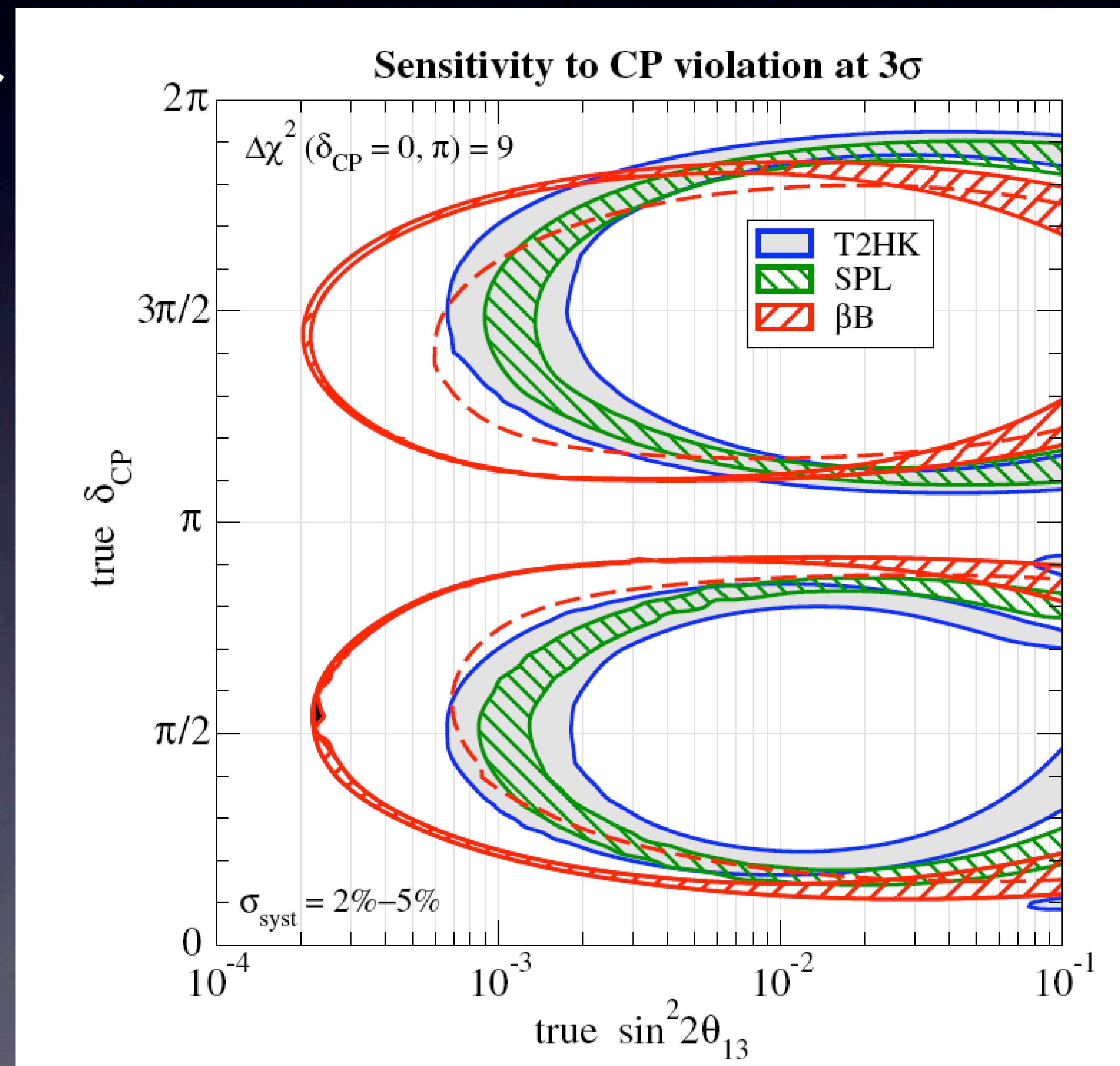
Neutrinos from β beams: case study

- Acceleration of 6He (antineutrinos) and 18Ne (neutrinos) nuclei
- Design of the complex in the context of EURISOL DS (FP6)
- Large investments required at CERN (source + storage ring)
- Counting experiment ?

Combine superbeam and β-beam for redundant test of CP, T, and CPT







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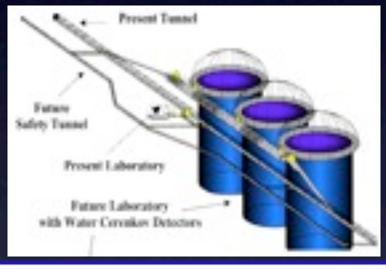
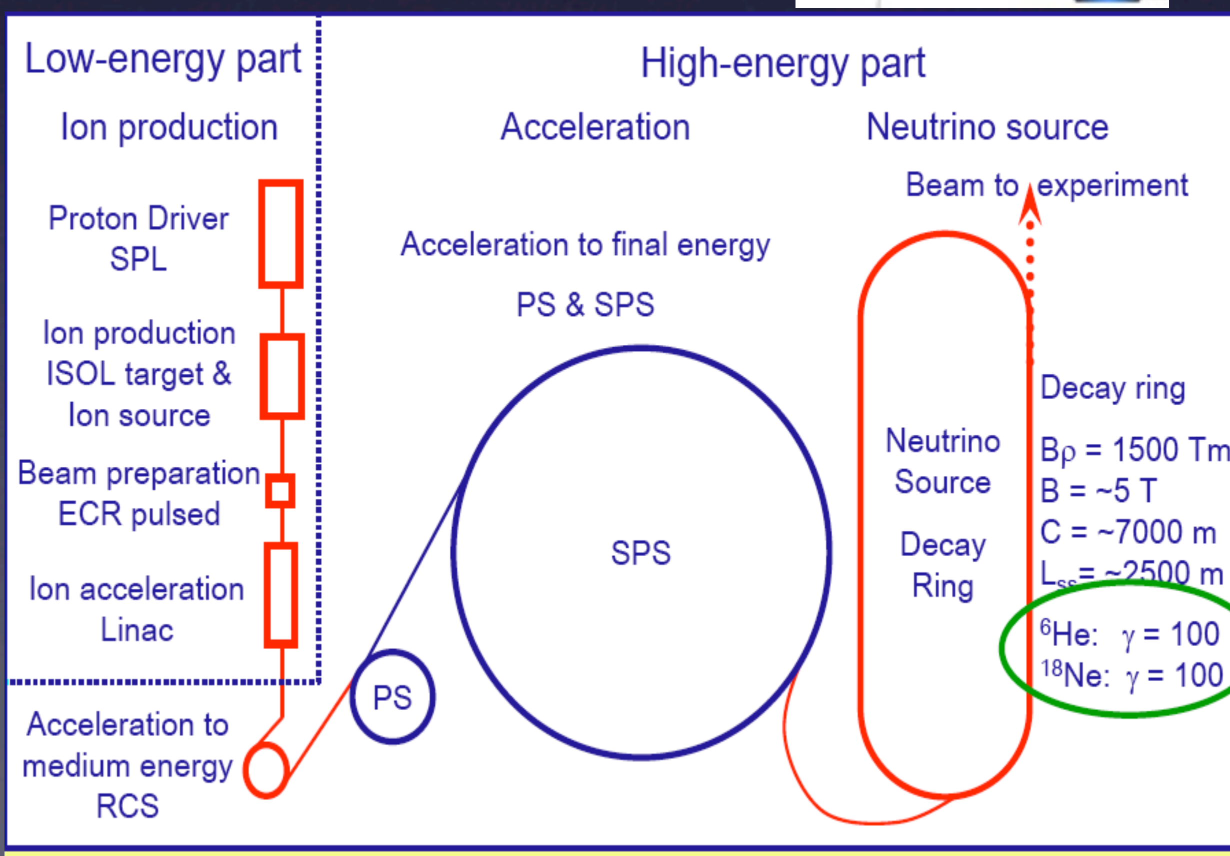
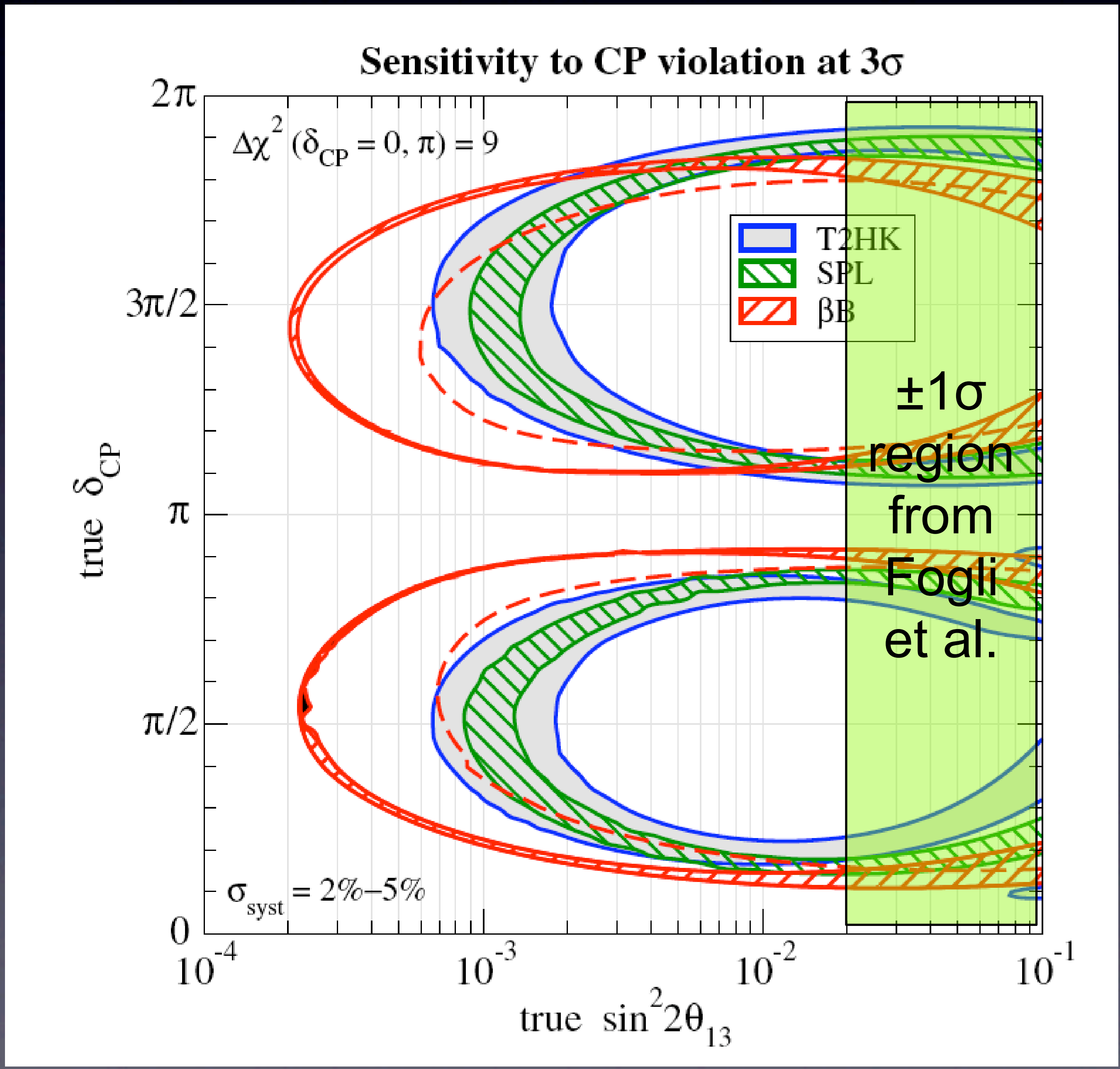
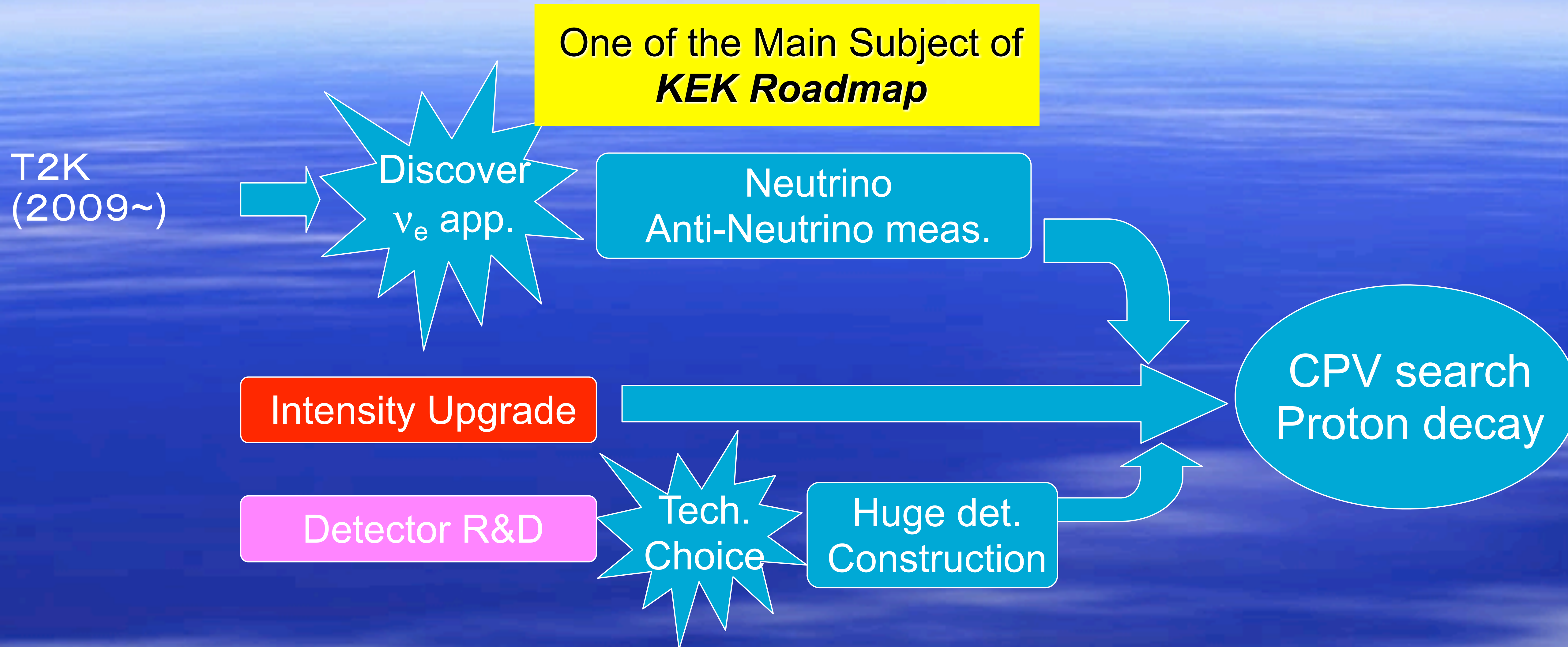






Neutrino Intensity Upgrade

Quest for the Origin of Matter Dominated Universe



Possible Timeline

Presented by KEK DG at KEK Roadmap Review Committee 9,10-March 2008

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Neutrino Intensity Upgrade

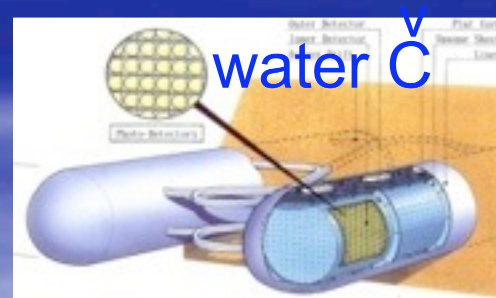
Quest for the Origin of Matter Dominated Universe

One of the Main Subject of *KEK Roadmap*

T2K (2009~) → Discover ν_e app. → Neutrino Anti-Neutrino meas. → CPV search Proton decay

Intensity Upgrade → CPV search Proton decay

Detector R&D → Tech. Choice → Huge det. Construction → CPV search Proton decay



Possible Timeline

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	4	4	4	4	4	4	4	4	4	4
Linac(400MeV)		?			? →	400MeV				
T2K										
MR Intensity Upgrade					?		?	→	1.66MW	
Detector R&D										

Presented by KEK DG at KEK Roadmap Review Committee 9,10-March 2008

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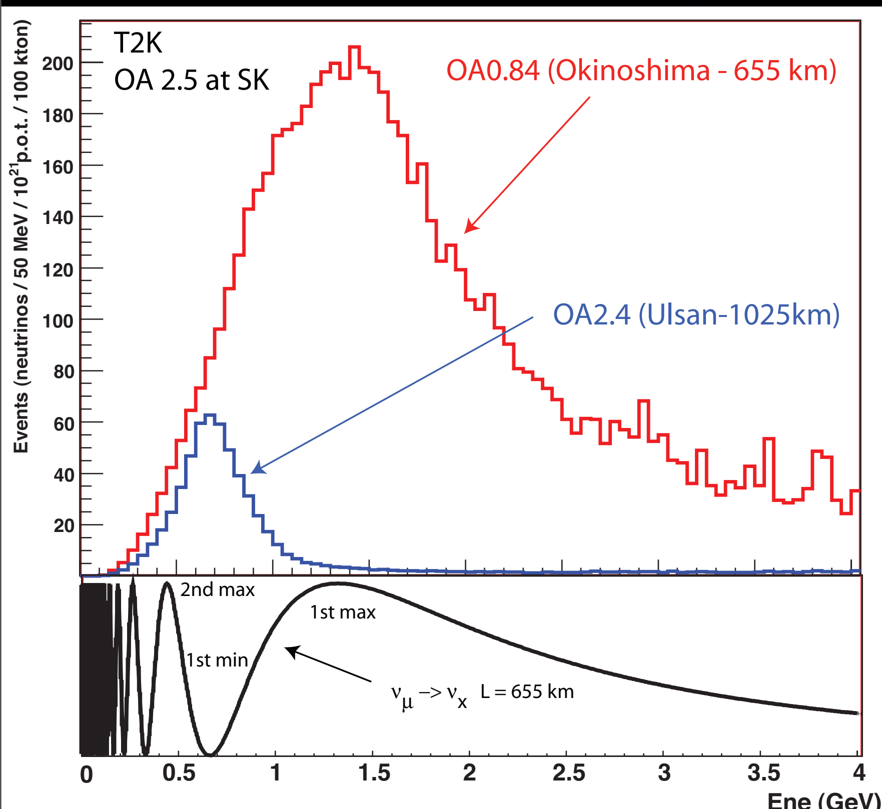
The Asian example beyond T2K

Three Scenarios Studied at NP08 Workshop



NP08 is **The 4th International Workshop on Nuclear and Particle Physics at J-PARC**

http://j-parc.jp/NP08

One JPARC superbeam & three baselines at different OA angles !

1000km
2.5deg. off-axis

658km
0.8deg. off-axis

295km
2.5deg. off-axis

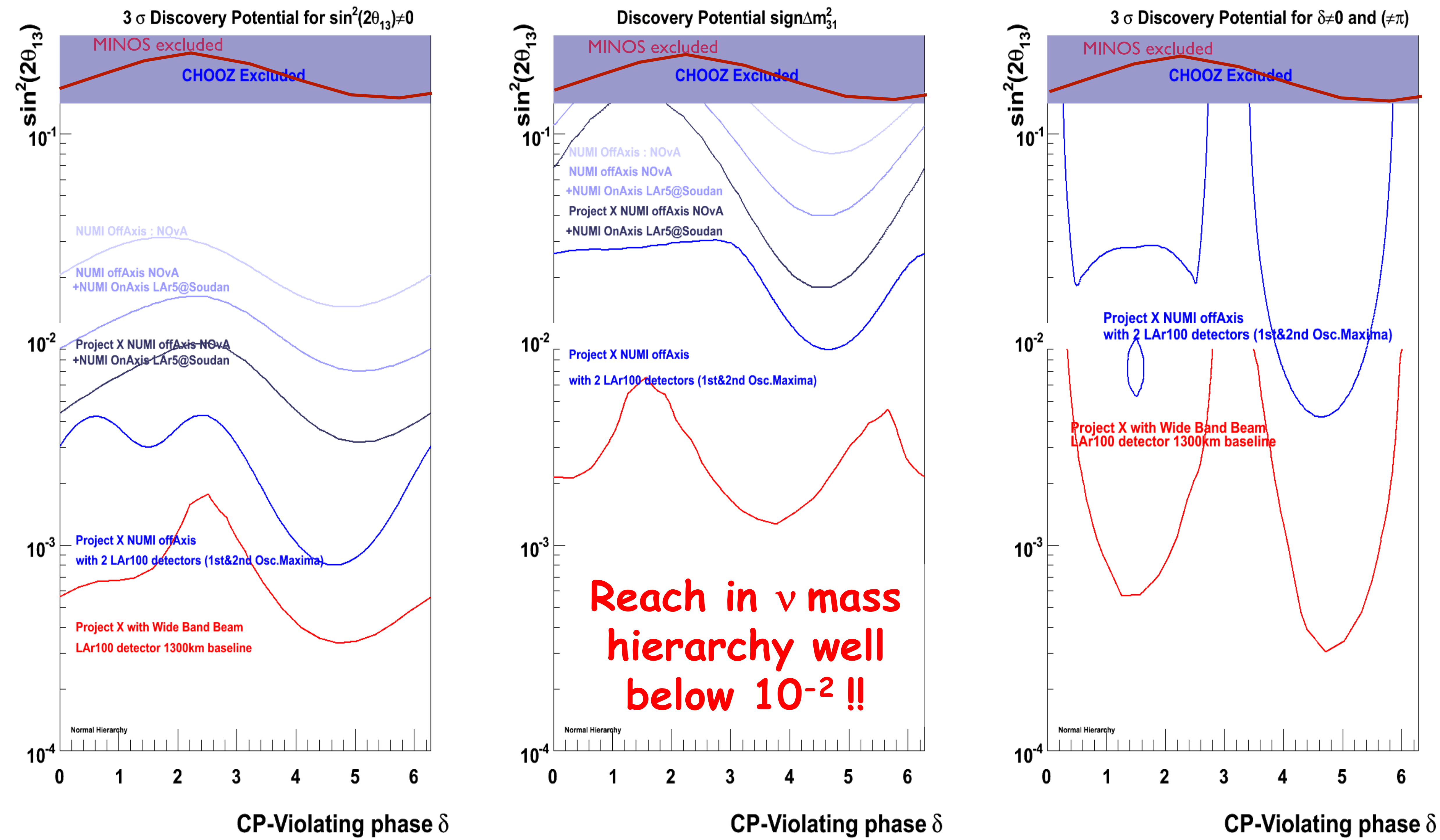
arXiv:0804.2111

Three Scenarios studied

	Scenario 1 Okinoshima	**Scenario 2 Kamioka**	**Scenario 3 Kamioka Korea**
Baseline(km)	660	295	295 & 1000
Off-Axis Angle(°)	0.8(almost on-axis)	2.5	2.5 1
Method	ν_eSpectrum Shape	Ratio between ν_e $\bar{\nu}_e$	Ratio between 1st 2nd Max Ratio between ν_e $\bar{\nu}_e$
Beam	5Years ν_{μ}, then Decide Next	2.2 Years ν_{μ}, 7.8 Years $\bar{\nu}_{\mu}$,	5 Years ν_{μ}, 5 Years $\bar{\nu}_{\mu}$,
Detector Tech.	Liq. Ar TPC	Water Cherenkov	Water Cherenkov
Detector Mass (kt)	100	2×270	270+270

Study is continuing to seek optimum choice

Physics Reach : FNAL to DUSEL with 0.1 Mton LAr



NOvA - NOvA+5ktLAr - NOvA+5ktLAr+PX - NOvA+100kt LAr +PX

100ktLAr (OR 300kt WC) +New WBB+PX at DUSEL

N.Saoulidou

EoI in test beam CERN NA

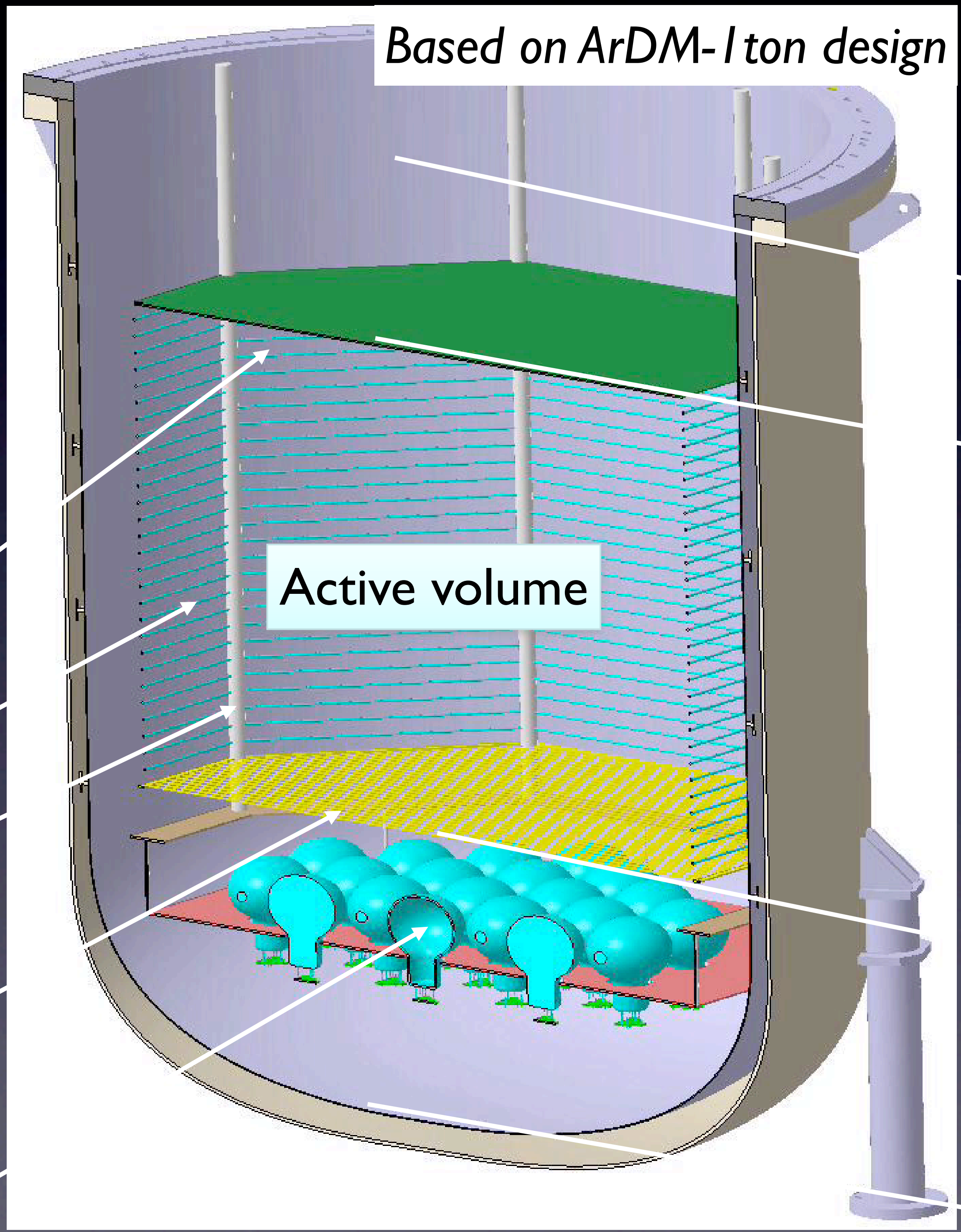
IPN Lyon, ETHZ, Warwick, Bern, INR, KEK, Silesia (Katowice), IPHC Strasbourg, Sheffield, Liverpool, Imperial College, RAL, IFJ-PAN Krakow, CEA/SACLAY

Experimental assessment of physics performance:

- particle identification and reconstruction (e/μ/π/π0)
- calorimetric response (em & had)
- neutrino interactions reconstruction

+ purity tests in non-evacuated vessel, readout electronic, DAQ, software, ...

Readout area: ≈ 2.5 m^2
Drift length: ≈ 1.15 m
Instrumented volume : ≈ 2.8 m^3
Instrumented mass: ≈ 3.9 tons



Thoughts on 1 kton near detector

- Tentative location under investigation: near JPARC along T2K neutrino beam