CERN Neutrinos to Gran Sasso

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- ➔ **“Neutrinos” and “Gran Sasso”**
- ➔ **CNGS:** **main components, layout, expected performance, cost, schedule**
- ➔ **Summary**

What are Neutrinos (ν) ?

- ⇨ elementary particles
- ⇨ come in three flavors (pistache, chocolat, vanilla)

- ⇨ electric charge: zero !
- ⇨ mass: very small zero?
- ⇨ interaction with matter: “very weak”

“ the elusive particle “

Leptons

	electric charge		electric charge
e	-1	ν_e	0
μ	-1	ν_μ	0
τ	-1	ν_τ	0

Where are the Neutrinos ?

- “all around us”
  - -> radioactive decay of atomic nuclei (e.g. in granite)

    $n \dashrightarrow p + e + \nu_e$

  - -> nuclear reactors
  - -> from the sun
  - -> accelerators… (high energy ν)

    $\pi \dashrightarrow \mu + \nu_\mu$

  - -> from reactions of cosmic rays in the atmosphere (ν_μ, ν_e)

    ….
- in the universe: some hundreds per cm^3 (big bang “leftover”)

Neutrino mass ?

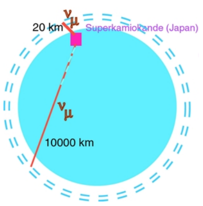
- Standard model of particle physics: ν masses ZERO
- “Direct” mass measurements -> upper limits

  (in decay experiments measuring kinetic energy of “the partner”)

  $m_{\nu e} < 5$ eV $m_{\nu\mu} < 170$ keV $m_{\nu\tau} < 18$ MeV
- What’s the problem ? **(DARK MATTER …)**
  - OBSERVATION 1 : SOLAR NEUTRINO “DEFICIT”

    only about 50% of the ν_e expected are actually observed

    ν_e disappear “en route” from the sun to the earth …?

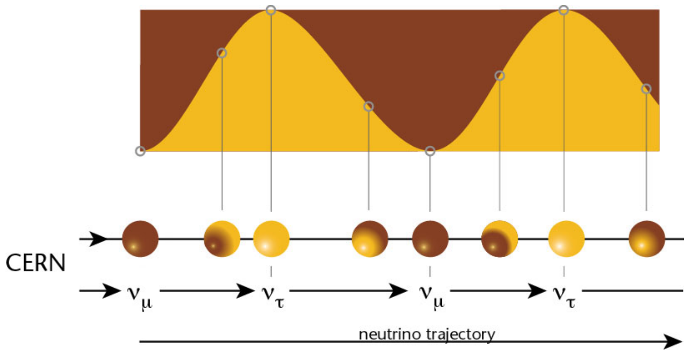


  - OBSERVATION 2 : ATMOSPHERIC NEUTRINO ANOMALY

    much less ν_μ “from below” observed w.r.t. expectations

    ν_μ disappear “en route” over 10’000 km … ?

Neutrino Oscillation



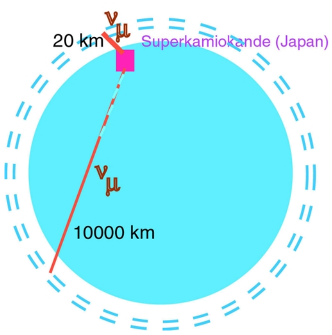
ν's change flavor ! Is this possible? -- Yes, "if neutrinos have mass"!

very simplified picture:

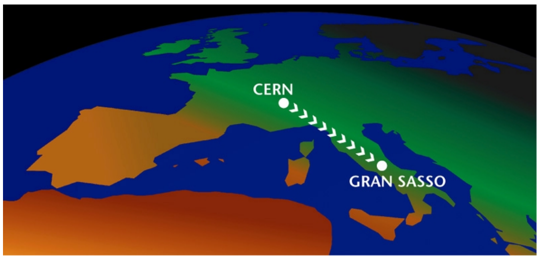
Probability(ν_μ-ν_τ) $\approx \sin^2(1.27\ \Delta m^2\ L / E)$

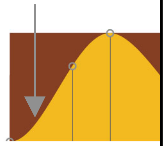
Δm^2 difference of mass between ν's (eV^2)
L distance source / detector (km)
E neutrino energy (GeV)

Example: $\Delta m^2 = 3\times10^{-3}\ eV^2$, E=10 GeV
---> $L \approx 4000$ km



4000 km -- Gran Sasso ?





In Dec. 1999, CERN council approved the CNGS project

- build an intense ν_μ beam at CERN-SPS
- search for ν_τ at Gran Sasso laboratory (730 km from CERN)

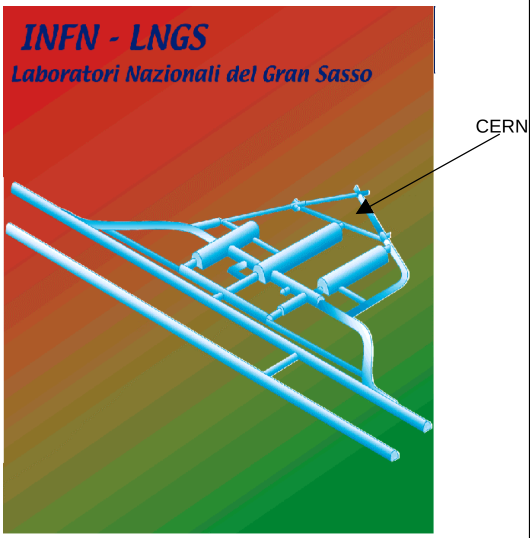
"long base-line" ν_μ -- ν_τ oscillation search

The Gran Sasso Laboratory

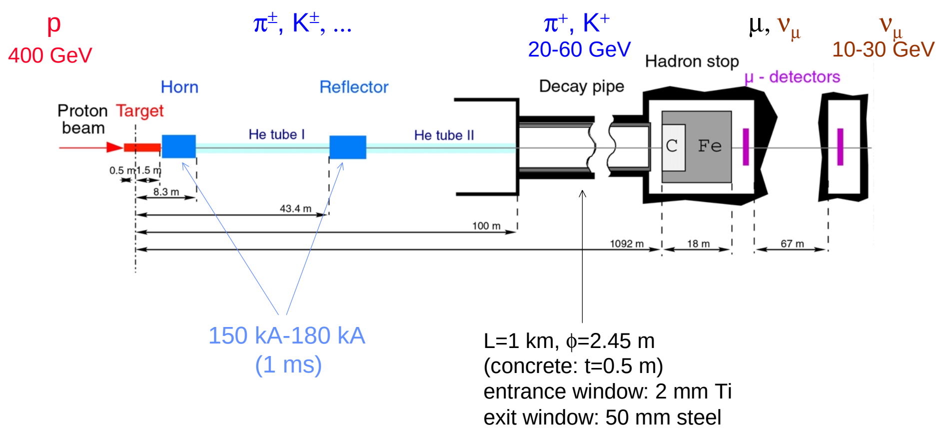
730 km might seem to short - but look at the details :
(Background low enough,
event rate still acceptable)
--> 730 km almost perfect

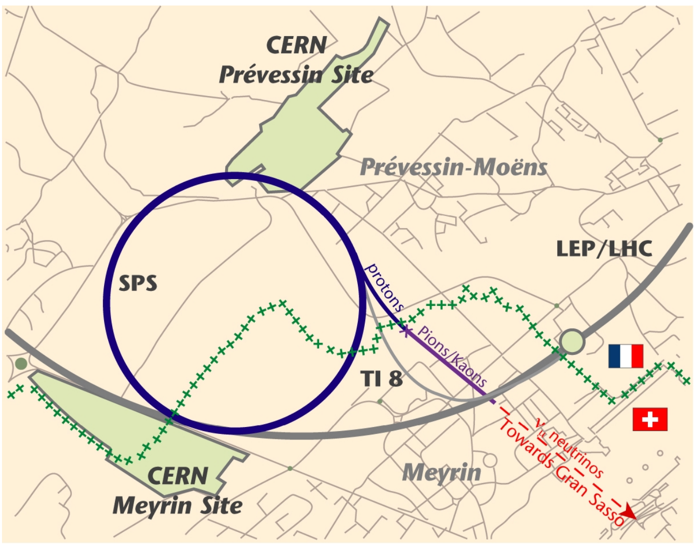
AND:

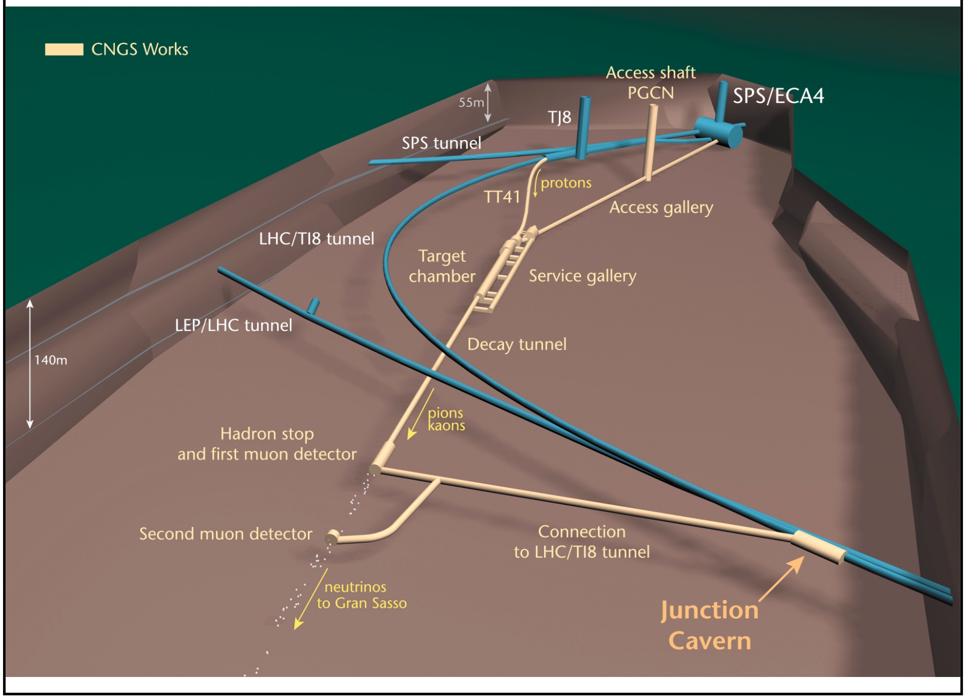
- existing laboratory with its infrastructure (since1987)
- large halls directed to CERN
- rock overburden: 1500 m of shielding
- tradition in very successful neutrino physics experiments (solar ν's)



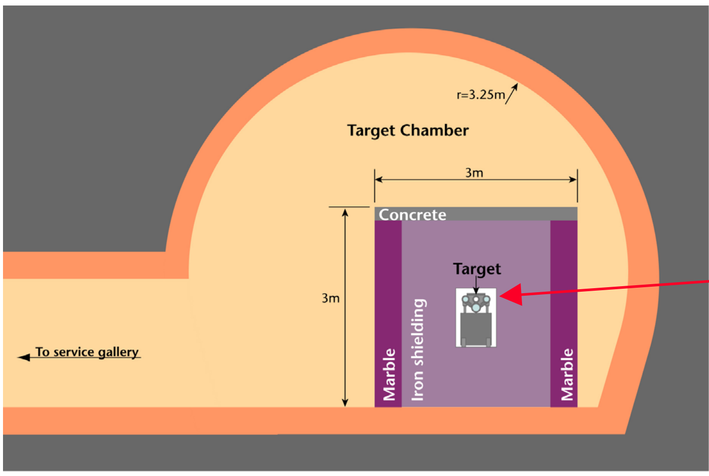
CNGS Overview





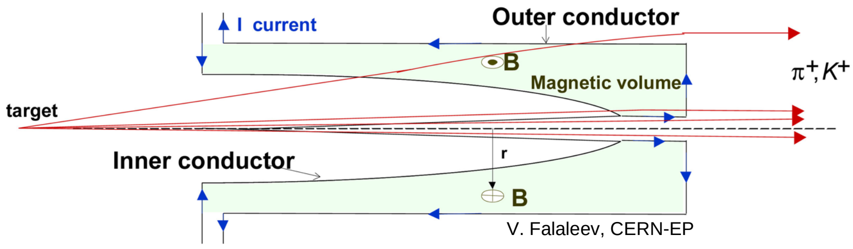


Target station



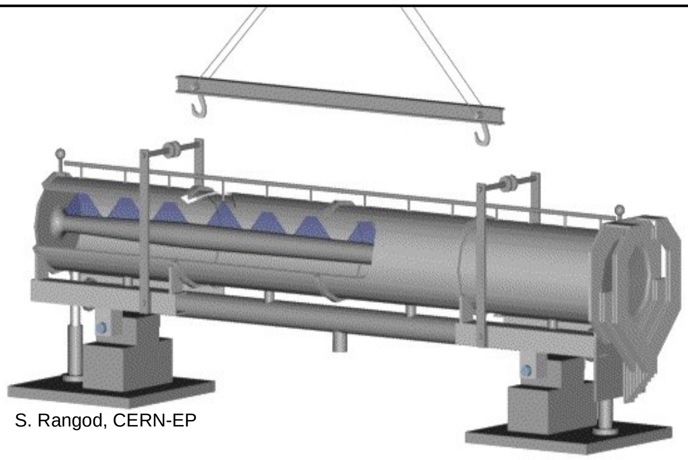
graphite cylinders
ϕ=4 mm, L=10 cm;
total length: 2 m;
helium gas cooled

Horn focusing: principle (S. van der Meer)



Inner conductor - paraboloid of revolution
Outer conductor - cylinder

over/under-focused particles: second horn ("reflector")

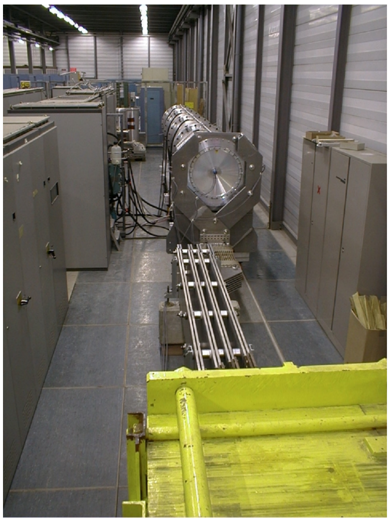


S. Rangod, CERN-EP

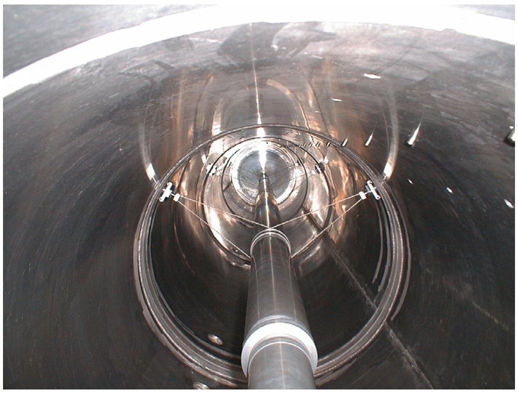
energy dissipated in the Horn / Reflector
by electrical current and beam : water cooling.

(overall length: 6.5 m, diameter of outer conductor: 0.7 m)

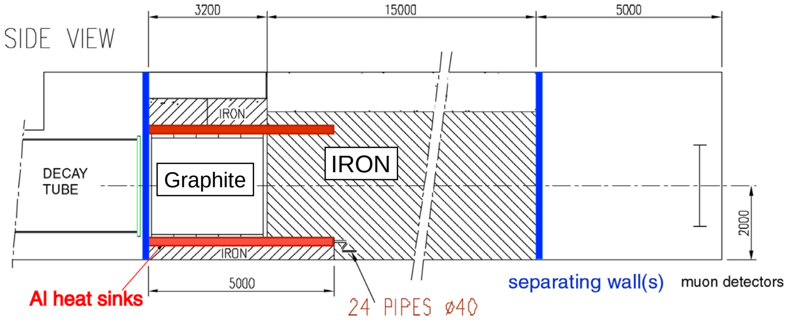
CNGS horn prototype tests in BA7/SPS



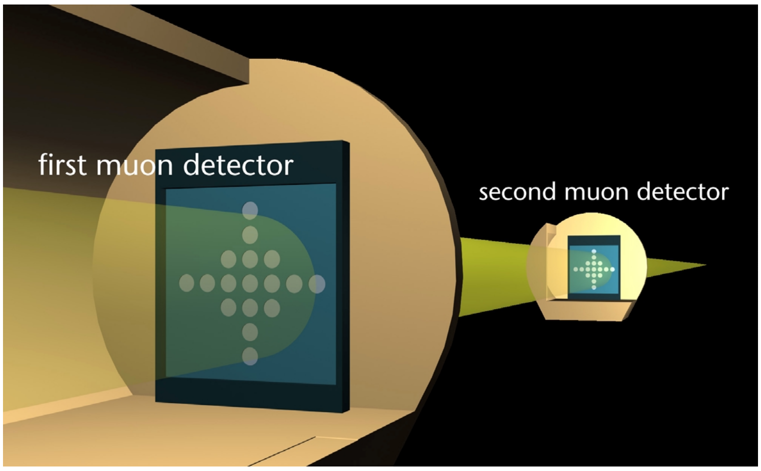
View inside the horn - “spider” support of inner conductor



Hadron stop (beam dump) area



Muon monitoring stations



Experiments at Gran Sasso

Note:

(1) after having travelled 730 km underground…
neutrinos are not easily "caught" in a detector
(2) the beam at Gran Sasso has diameter of about 2 km

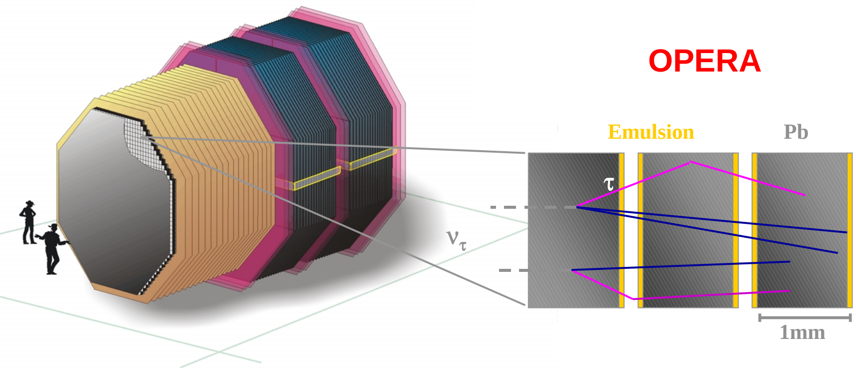
OPERA approved

Pb sheets and photographic emulsions;
1.8 kton target material (final config.)
bricks -> walls -> modules (incl. scintillator) -> S-modules
235'000 bricks in total - "hit" registered in electronic detectors
-> robot extracts <u>30 bricks per day</u> for shipment / analysis
computing power for analysis: "worldwide effort" !

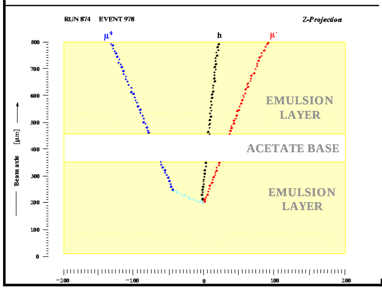
ICANOE under approval

Liquid argon time projection chamber;
4 kton target material (?)
initial module 600 tons, <u>now testing</u>
(this test is considered an important milestone)

OPERA



Neutrino interaction in emulsion:



- Sandwich of emulsion film and lead sheets
- Mass > 1 kton, resolution 1 μm
- Proven technique: **CHORUS (CERN), DONUT (Fermilab)**

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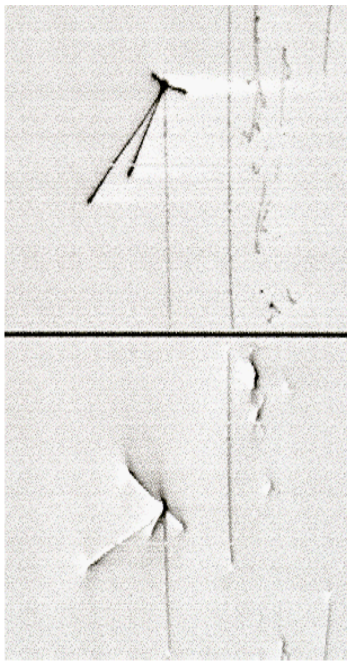
ICARUS

- General purpose detector for CNGS + solar and atmospheric neutrinos, proton decay
- ultrapure liquid Argon equipped with wire planes: true 3D image of tracks produced e.g by a ν_τ
- Technique proven with West Area neutrinos (ν_μ event -->)



CNGS: Expected Performance

neutrino beam performance

"detectable events"

No oscillation:

2450 ν_μ cc. events per kt per year

Assume **$\sin^2(2\theta)=1$** and $\nu_\mu - \nu_\tau$ is the correct hypothesis:

$\Delta m^2 = 5\times10^{-3}eV^2$: **56** ν_τ

$\Delta m^2 = 3\times10^{-3}eV^2$: **21** ν_τ

$\Delta m^2 = 1\times10^{-3}eV^2$: **2.3** ν_τ

cc. events per kt per year

including exp. inefficiencies

"expected events"

OPERA 1.8 kton x 5 years running:

$\Delta m^2 = 3.2\times10^{-3}eV^2$: **18.3** ν_τ **0.57 b.g.**

ICANOE 20 kton x year running:

$\Delta m^2 = 3.5\times10^{-3}eV^2$: **37** ν_τ **4.4 b.g.**

Cost of the CNGS facility*

*without detectors at Gran Sasso

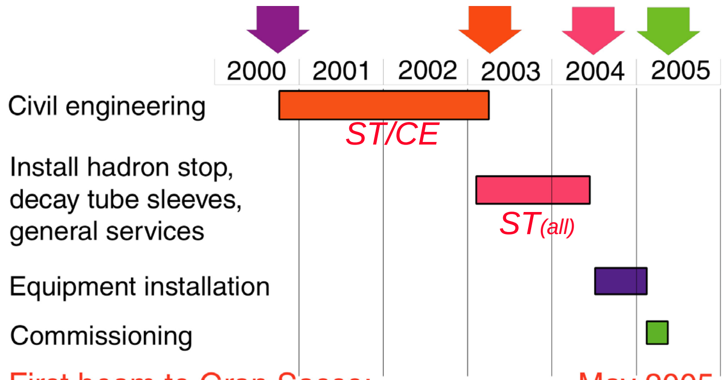
Civil Engineering (including decay tube)	41.6 MCHF
Equipment	19.6 MCHF
Infrastructure	7.3 MCHF
Contingency	2.5 MCHF
Total	71 MCHF

+ the value of recuperated equipment and investment for LHC: estimated 22 MCHF

Voluntary contributions announced:

Belgium	1 MCHF
France	1 MCHF
Germany	5 MCHF
Italy	47 MCHF
Comp. S. Paolo (Italy)	1.6 MCHF
Spain	4 MCHF
Switzerland (Dec. 2000)	1.5 MCHF
Total	61.1 MCHF

CNGS schedule / status

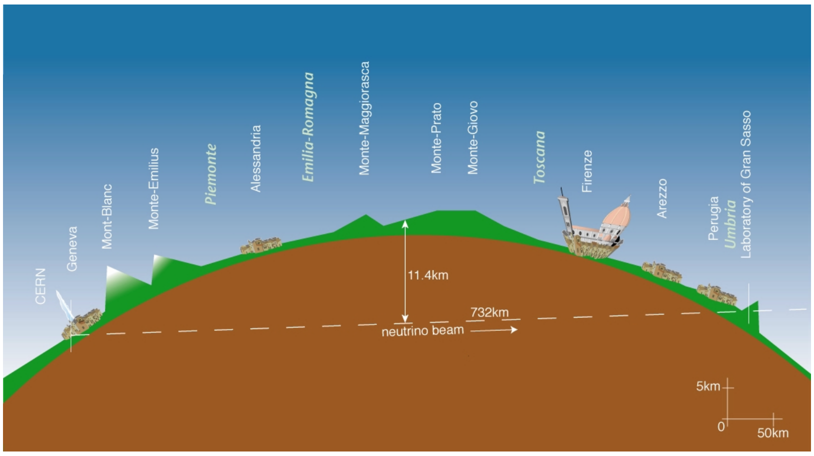


First beam to Gran Sasso: May 2005

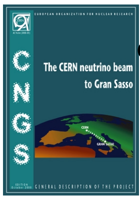
Summary

- ➔ Following the approval of CNGS in Dec. 1999, construction started in Sept. 2000.
- ➔ First CNGS beam for the ν_τ appearance search is expected in May 2005.

Thanks for your contribution to CNGS!



for more information:



CNGS general description

+ NEW CNGS www pages:
http://proj-cngs.web.cern.ch/proj-cngs

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