

# Prospects for the accelerator neutrino physics in Europe

A. Zalewska

Epiphany 2010 conference, 7.01.2010

- The SPC neutrino panel and neutrino workshop at CERN
- Possible synergy between the LHC injection chain and neutrino physics

## European neutrino community:

- CNGS programme, T2K experiment, NuMI programme
- DoubleChooz (and Daya Bay) reactor experiments
- Non-accelerator neutrino experiments: searches for  $0\nu 2\beta$  decays, neutrino mass from end-point, neutrino telescopes, solar and atmospheric neutrinos, low energy neutrinos from other astrophysical sources, ...
- R&D programmes for future neutrino accelerator facilities
- R&D programmes for detectors

# The *SPC* neutrino panel and the neutrino workshop at CERN

## Specific Request from Council to the Scientific Policy Committee

### Relations between CERN and the ongoing development work regarding future neutrino facilities

„The UK delegation to the CERN Council notes that there is no European-wide strategy to engage in the precise determination of neutrino oscillation parameters for the period beyond ~2015, after the T2K and NOvA experiments. Within the context of ["Questions from Council to the SPC"](#), it requests that the SPC gives its views on several issues pertaining to the physics of neutrinos"

Coordination of the European particle physics was one of the original mandates of the CERN Council - re-establishing this role since a special Council meeting in Lisbon, 14<sup>th</sup> of July, 2006, at which a European strategy for particle physics was adopted. Now special European strategy sessions of the CERN Council, agreement signed between CERN and EC in July 2009 concerning CERN's role in deciding on future infrastructures in particle physics.

## *The European strategy for particle physics*

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*"4. [...] it is vital to strengthen the advanced accelerator R&D programme; a coordinated programme should be intensified, to develop the CLIC technology and high performance magnets for future accelerators, and to play a significant role in the study and development of a high-intensity neutrino facility.*

*6. Studies of the scientific case for future neutrino facilities and the R&D into associated technologies are required to be in a position to define the optimal neutrino programme based on the information available in around 2012; Council will play an active role in promoting a coordinated European participation in a global neutrino programme.*

## Questions from the CERN Council

### Question 1

-What is the view of the SPC on the importance of precise measurements of the neutrino oscillation parameters, in particular the *CP* violating phase and mass hierarchy?

### -Question 2

One of the most promising techniques for such measurements is the neutrino factory and there is currently an International Design Study (IDS) to produce a conceptual design report for a neutrino factory by 2012. This is not site specific. What is the view of the SPC on the overall value of the IDS for the future of the subject? Should CERN take a more active role in enabling the study to reach its goals, irrespective of where such a facility would be sited?

### Question 3

What other high intensity neutrino facilities are technically possible and how would they address the measurements above?  
What should be the involvement of CERN in studies of these facilities, in particular with regard to the planned LHC upgrades?

### Question 4

What is the view of the SPC on the merit of a European strategy in this phase of neutrino experimentation and whether it should have a place on the future CERN road map?

# The SPC panel on Future Neutrino Facilities

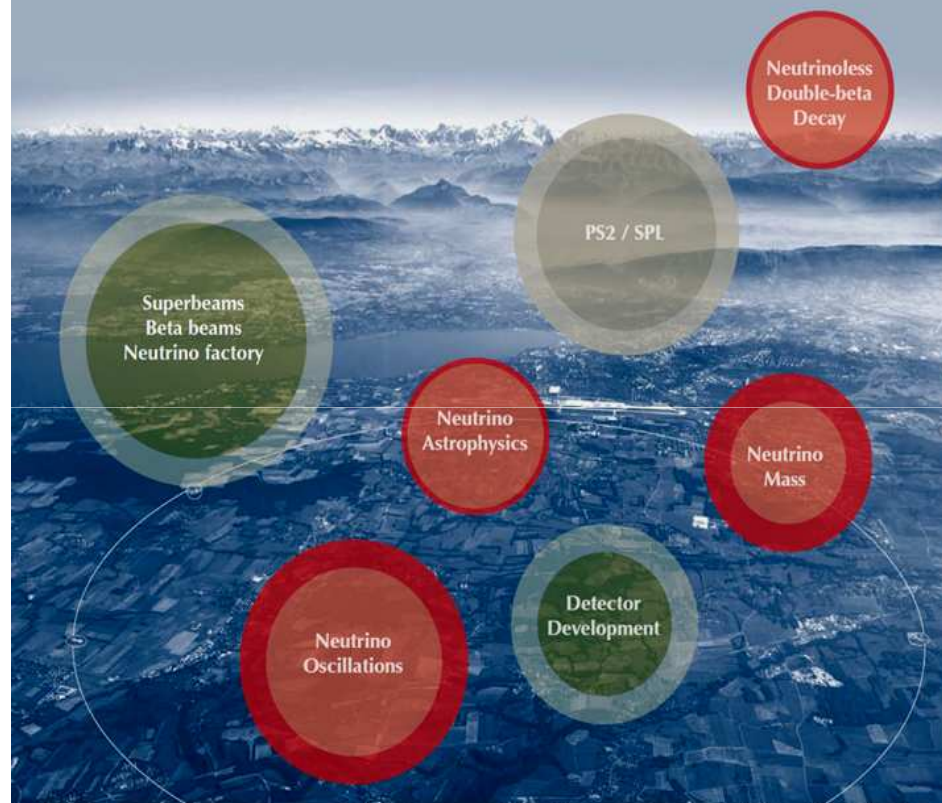
- Created in December 2008 with a mandate to prepare the report with answers to the Council questions. The panel members:

Roy Aleksan, Alain Blondel, Peter Dornan, Karlheinz Meier (till 31.07.2009), Tatsuya Nakada (from 1.08.2009), Agnieszka Zalewska (chair), Fabio Zwirner.

- The current state of the European neutrino physics (e.g. the CNGS programme) was discussed during the CERN workshop on „New Opportunities in the Physics Landscape at CERN“, 10-13 May 2009. A special workshop on „European Strategy for Future Neutrino Physics“ was organized in October, 1-3.

# EUROPEAN STRATEGY FOR FUTURE NEUTRINO PHYSICS

1-3 October 2009 | Main Auditorium



Workshop to discuss the possibilities  
for future neutrino investigations in  
Europe and the links to CERN

CERN yellow report from the workshop will include talks,  
transcripts from discussions and poster contributions.

#### Sessions

- Introductory Session - Peter Dornan
- Theory Session - Silvia Pascoli
- Accelerator Session - Ilias Efthymiopoulos, David Wark
- Detector Session - Dario Autiero, Anselmo Cervera Villanueva
- Summary and Conclusion - Alain Blondel
- Poster Session - Ewa Rondio

Contact [neutrino-workshop@cern.ch](mailto:neutrino-workshop@cern.ch)

#### Organizing Committee

Agnieszka Zalewska (co-chair), Sergio Bertolucci (co-chair),  
Roy Aleksan, Alain Blondel, Peter Dornan, Ilias Efthymiopoulos,  
Karlheinz Meier, Steve Myers, Tatsuya Nakada, Ewa Rondio,  
Steinar Stapnes, Fabio Zwirner

**ECFA**

European Committee  
for Future Accelerators



A.Zalewska, Epi  
7.1.201

# The Workshop on European Strategy for Future Neutrino Physics

- CERN, 1-3 October, common organization of the CERN management, SPC and ECFA, support of EUCARD/Neu2012
- **Success** -more than 250 registered participants, 48 posters, positive reactions → was needed, we should not loose impact ...
- **Five sessions:** introduction with an overview of the current state of neutrino physics, theory, detectors, accelerators (two parts), summary and conclusions including a round table discussion
- **Talks** are available from the workshop web page  
<http://indico.cern.ch/conferenceDisplay.py?confId=59378>
- **The CERN yellow report from the workshop**, including talks, transcripts from discussions and poster contributions, has a chance to become an important reference document.

## Report from the SPC panel

The SPC report (two white papers) was discussed at the SPC meeting during the CERN Council week in December (14-18), final report (two green papers) will be given to the Council during the Council week in March 2010.

*„Relations between CERN and the ongoing development work regarding future neutrino facilities. I. Summary „- answers to the Council questions and conclusions/recommendations.*

*„Relations between CERN and the ongoing development work regarding future neutrino facilities. II. Supporting document - extensive explanations.”*

Both the yellow report from the workshop and the SPC report will be input to establish the Future European Strategy for Neutrino Physics

# Possible synergy between the LHC injection chain and neutrino physics

**NOTICE:** the following slides illustrate the directions of work; in most cases decisions have not yet been taken

## Upgrade of the CERN accelerators:

The possible upgrade of the LHC injection chain (Linac 4, SPL, PS2) in view of the SLHC could open a door for the future neutrino facility at CERN and for other physics requiring high intensity proton driver

**BUT** LHC does not require a high power injection chain, so keeping necessary elements **upgradable** to high power is needed for future neutrino facility.

Even LHC requires reliability of the injection chain (PS is 50 years old!) and its better performance

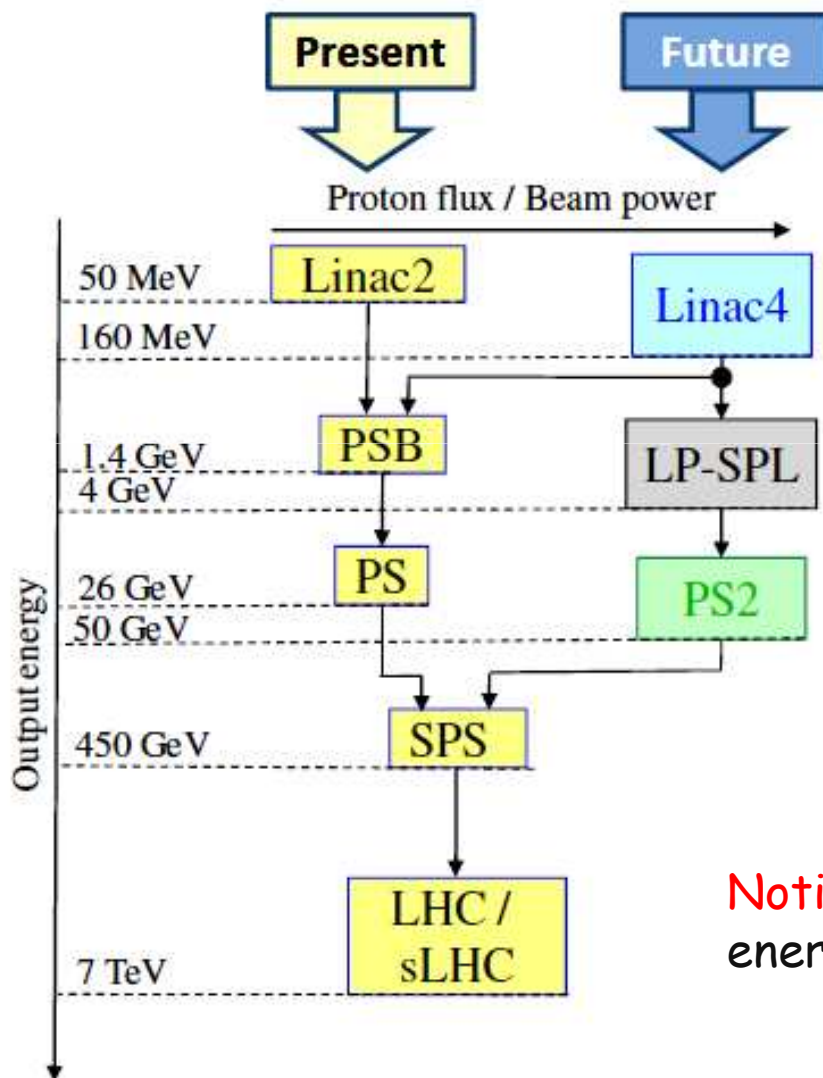
**SO** consolidation of the LHC injection chain is needed in a short time. Could it be sufficient for SLHC? The Chamonix workshop in January will start serious discussion on that.

From R.Garoby talk

## Description

**Notice** Linac4 is the only approved future accelerator !

Plans for future LHC injectors



**LP-SPL:**

Low Power-Superconducting  
Proton Linac (4 GeV)

**PS2:**

High Energy PS (~ 5 to 50 GeV  
– 0.3 Hz)

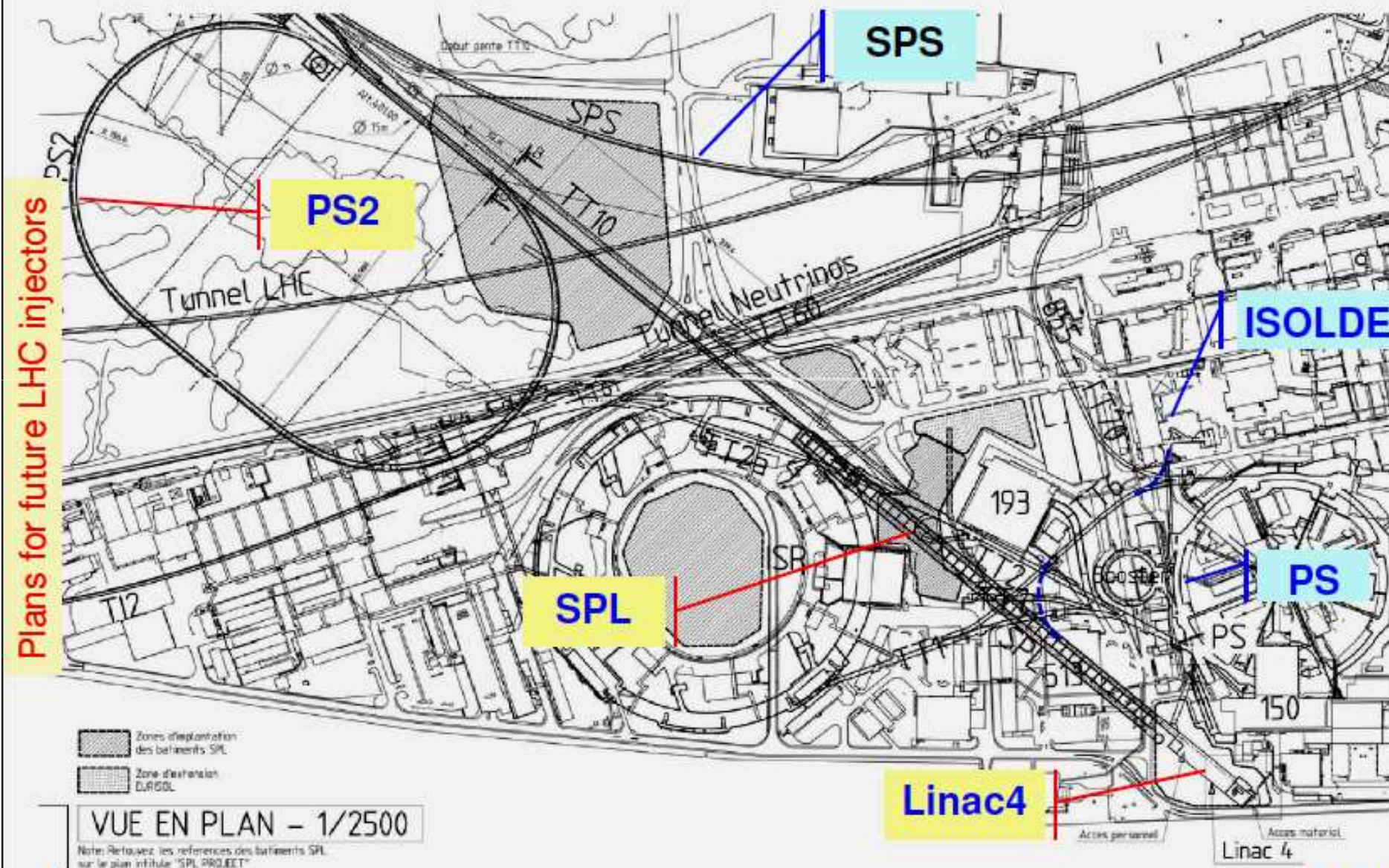
**sLHC:**

“Super-luminosity” LHC (up to  
 $10^{35} \text{ cm}^{-2}\text{s}^{-1}$ )

**Notice** increase of the injection  
energy of the synchrotrons

From R.Garoby talk

## Site layout



From R.Garoby talk

## Linac4 construction site - 5.5.2009

### Linac4 - implementation stage 1

from M. Vretenar

Plans for future LHC injectors



Linac4 tunnel (“cut and cover” excavation) seen from high-energy side.

Final concrete works starting at low-energy side, excavation proceeding at high energy side.

Tunnel level -12 m, length 100 m.

Delivery of tunnel and surface equipment building end of 2010.

Operation 1<sup>st</sup> April 2014

## Implementation stage 2:

## Planning

From R.Garoby talk

Plans for future LHC injectors



Construction of LP-SPL and PS2 will not interfere with the regular operation of Linac4 + PSB for physics.  
Similarly, beam commissioning of LP-SPL and PS2 will take place without interference with physics.

### PS2 baseline option

- $1 \cdot 10^{14}$  p/p at 50 GeV every 2.4 s (~330 kW)
- $\sim 4 \cdot 10^{20}$  pot/year ( $10^7$  s)
- Beam pulse duration: 4.2  $\mu$ s

R.G.

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## Recommendations

### *CERN future accelerators*

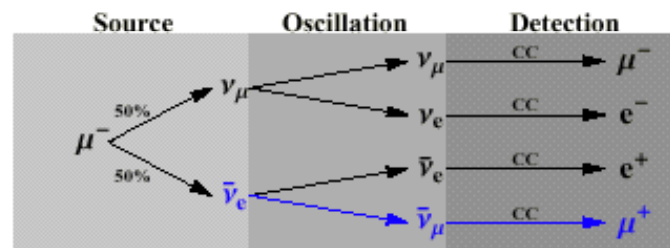
- Need for statement of interest in the study of the high power option.
- Prepare for the Council decision in 2012, where the cost of keeping the possibility of high beam power will be debated.
- It would be cheaper (and faster!) to build immediately for high beam power...

From R.Garoby talk

## Future neutrino facilities:

**Superbeams** -  $\nu_\mu$ 's from  $\pi$ , K decays, but based on proton beams of up to 4 MW power

**Neutrino factories** - neutrino-antineutrino pairs from decays of accelerated muons



**$\beta$  beams** - neutrinos (antineutrinos) from accelerated ions - beta emitters - first proposed were  $^{18}\text{Ne}$  ( $^6\text{He}$ )

## Future neutrino facilities:

- Superbeams - well defined roadmap in Japan, clear roadmap for FERMILAB, in Europe studies for SB from CERN to Frejus in EUROnu (HP-SPL) and also for other sites within LAGUNA (HP-PS2)
- Neutrino factory - work coordinated world-wide through the NUFACT workshops and IDS-NF, important European contributions into the NF R&D
- $\beta$  beams - specific for Europe, R&D led by CERN

The neutrino Design Studies basically financed through:

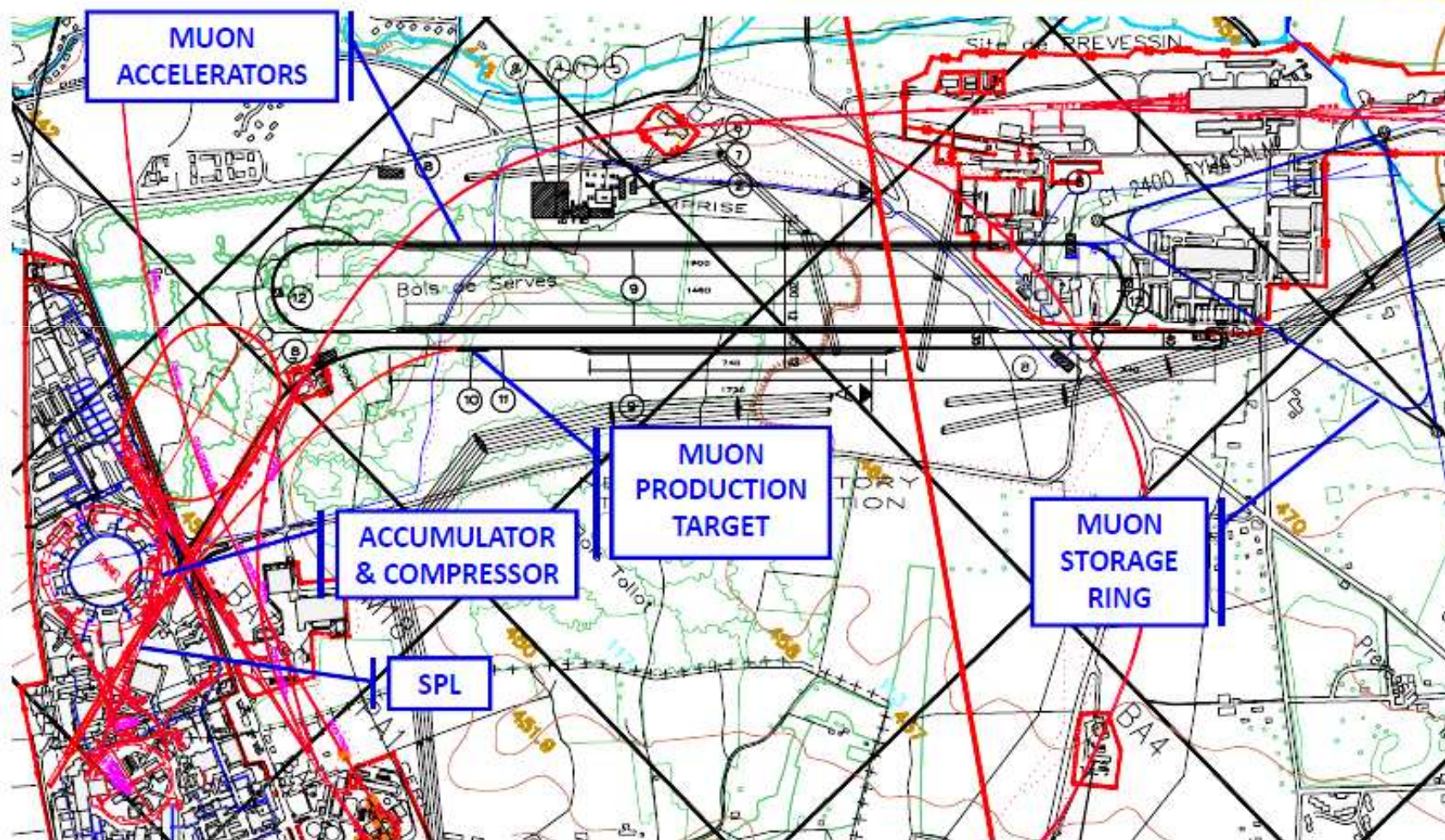
## European Commission programmes:

- **FP6:**
  - **BENE [Beams for European Neutrino Experiments]:**
    - **NA, part of CARE [Coordinated Accelerator R&D in Europe]**
  - **Beta-beam: conceptual design of 'CERN baseline scheme'**
    - **Part of EURISOL Design Study**
- **FP7:**
  - **EUROnu Design Study:**
    - **Super beam, Beta beam, and Neutrino Factory**
      - Conceptual design, cost, performance, risk, and schedule
  - **Neu2012 Networking Activity:**
    - **Part of EUCARD [European Coordinated Accelerator R&D]**
  - **Transnational Access to MICE:**
    - **Also part of EUCARD**
  - **LAGUNA Design Study**
    - **Water Cerenkov, Liquid Argon & Scintillator Detectors**

## Neutrino Factory at CERN

"Proof of principle" [obsolete v Factory design]

Neutrinos with the "High power" SPL



# Neutrino Factory Ingredients

## • Neutrino Factory comprises these sections

### – Proton Driver **HP-SPL, if at CERN**

- primary beam on production target

### – Target, Capture, and Decay **done at CERN**

- create  $\pi$ ; decay into  $\mu \Rightarrow$  **MERIT**

### – Bunching and Phase Rotation

- reduce  $\Delta E$  of bunch

### – Cooling

- reduce transverse emittance

$\Rightarrow$  **MICE Under construction at RAL**

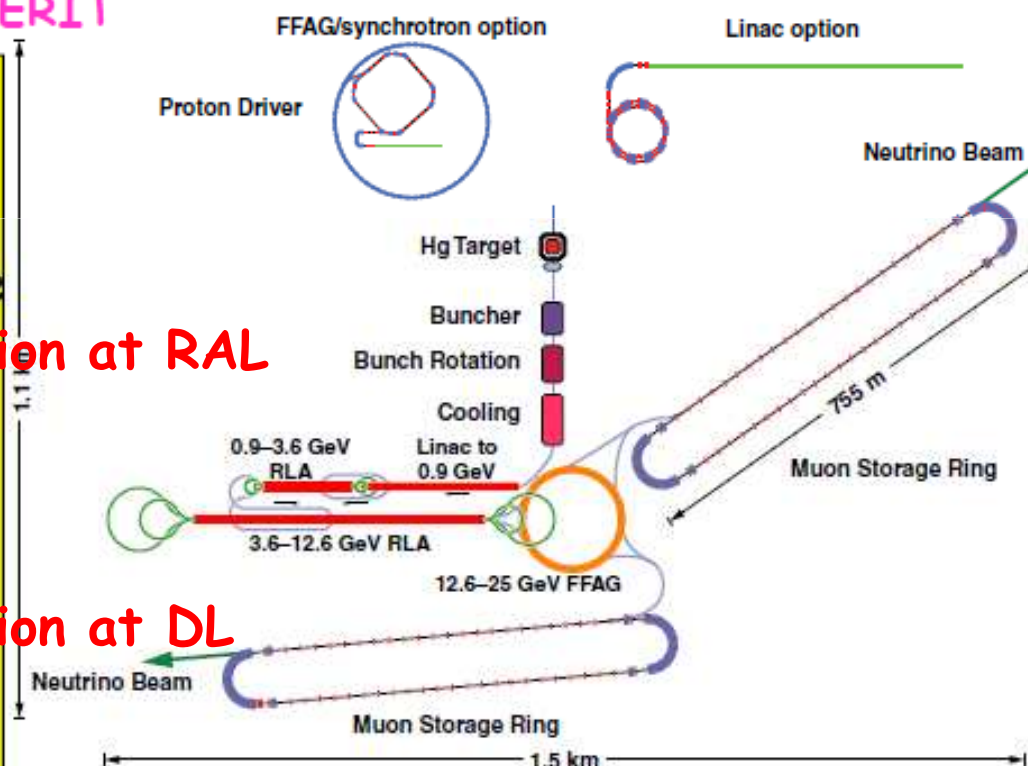
### – Acceleration

- 130 MeV  $\rightarrow$  25 GeV  
with RLAs+FFAGs  $\Rightarrow$  **EMMA**

### – Decay Ring **Under construction at DL**

- store for 500 turns;  
long straight sections

## IDS-NF Baseline Layout



# MERIT

from H.G.Kirk talk



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## Summary

- MERIT has successfully demonstrated the Neutrino Factory/Muon Collider target concept
- Target studies are continuing within IDS-NF framework
- The infrastructure for a 4MW target system needs to be designed/engineered (**this has generic value beyond a Neutrino Factory specific target station**)
- CERN participation in MERIT was crucial to its success. CERN participation in the development of a 4MW target system would be both welcome and beneficial to the entire accelerator physics community

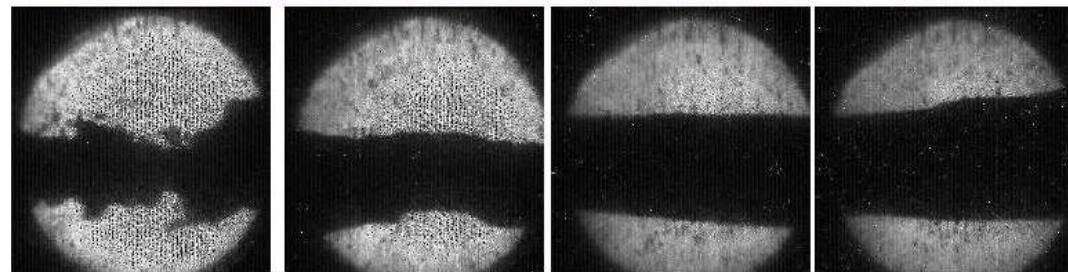
**BROOKHAVEN**  
NATIONAL LABORATORY

European Neutrino Physics Oct. 2-3, 2009

Harold G. Kirk



## Stabilization of Jet by High Magnet Field



0 T

5 T

10 T

15 T

Jet velocities: 15 m/s

Substantial surface perturbations mitigated by high-magnetic field.

# Beta beams - production of ions:

- ISOL method at 1-2 GeV (200 kW)

- $2 \cdot 10^{13}$   ${}^6\text{He}$  per second
- $< 8 \cdot 10^{11}$   ${}^{18}\text{Ne}$  per second
- Studied within EURISOL

Aimed:

He  $2.9 \cdot 10^{18}$  ( $2.0 \cdot 10^{13}/\text{s}$ )

Ne  $1.1 \cdot 10^{18}$  ( $2.0 \cdot 10^{13}/\text{s}$ )

- Direct production

- $> 1 \cdot 10^{13}$  (?)  ${}^6\text{He}$  per second
- $1 \cdot 10^{13}$   ${}^{18}\text{Ne}$  per second
- Studied at LLN, Soreq, WI and GANIL

- Production ring

See talks by T. Stora and S. Mitrofanov

- $10^{14}$  (?)  ${}^8\text{Li}$  per second
- $> 10^{13}$  (?)  ${}^8\text{B}$  per second
- Studied Within EUROv



Difficult Chemistry

**N.B. Nuclear Physics has limited interest in those elements => Production rates not pushed!**  
**Try to get resources to pursue ideas how to produce Ne!**

# Request from EUROnu:

R.Edgecock et al: Proposal for increased contributions from CERN to future neutrino facilities via the EUROnu FP7 Design Study

- This document was prepared in response to a request from the panel
- It has two annexes: from the IDS-NF Steering Group and from the Beta Beam Study Group.

	2010	2011	2012	2013
Accelerator physicist	2	3	3	3
Engineer/technical support	3	4	5	5
 Safety expertise	0.5	1	1	1
 Costing expertise	0.5	0.5	1	1
<b>Total</b>	<b>6</b>	<b>8.5</b>	<b>10</b>	<b>10</b>

## Detectors:

- (1) detectors of a total mass  $10^5 - 10^6$  tons, filled with liquids (water, liquid argon and scintillator) for neutrinos from astrophysical sources, proton decay and accelerator neutrinos,
- (2) magnetized detectors for NF
- (3) various detector technologies for neutrinoless double beta decay and dark matter searches

From the detector  
session summary by

**Dario Autiero**  
IPNL, Lyon

**Anselmo Cervera**  
IFIC, Valencia

## The role of CERN

- EU FP projects and networks are very useful...
- But more support from CERN would be very welcomed:
  - Technical R&D: electronics, PD, scintillators, LAr, ...
  - Test beams
  - R&D followup

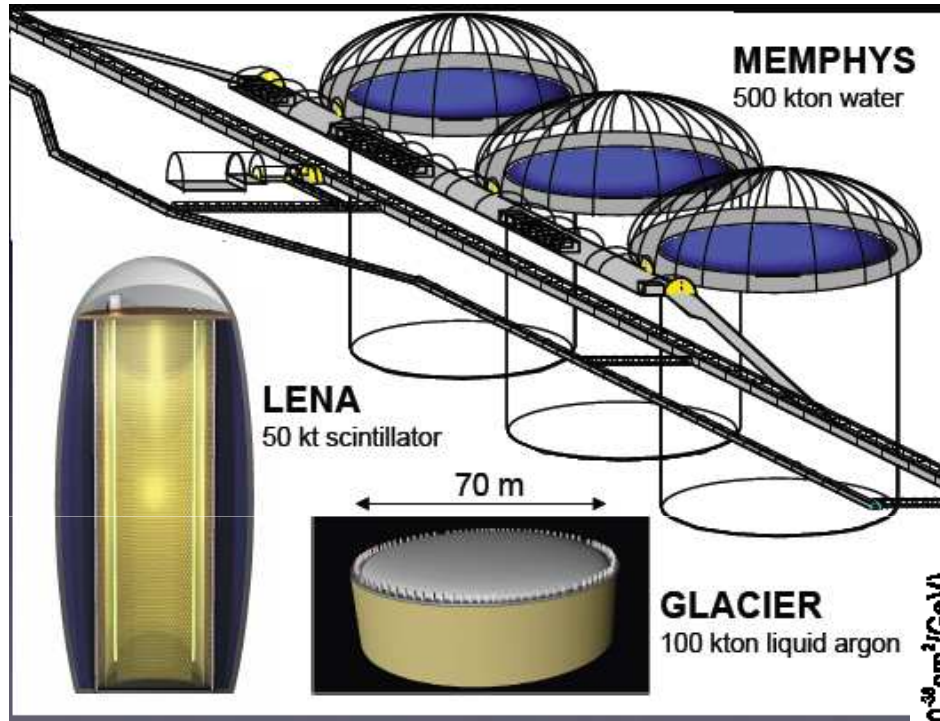
Table 1: Potential sites being studied with the LAGUNA design study.

Location	Type	Envisaged depth m.w.e.	Distance from CERN [km]	Energy 1 <sup>st</sup> Osc. Max. [GeV]	
Fréjus (F)	Road tunnel	$\simeq 4800$	130	0.26	HP-SPL
Canfranc (ES)	Road tunnel	$\simeq 2100$	630	1.27	
Umbria(IT) <sup>a</sup>	Green field	$\simeq 1500$	665	1.34	HP-PS2
Sierozsowice(PL)	Mine	$\simeq 2400$	950	1.92	
Boulby (UK)	Mine	$\simeq 2800$	1050	2.12	
Slanic(RO)	Salt Mine	$\simeq 600$	1570	3.18	
Pyhäsalmi (FI)	Mine	up to $\simeq 4000$	2300	4.65	

<sup>a</sup>  $\simeq 1.0^\circ$  CNGS off axis.

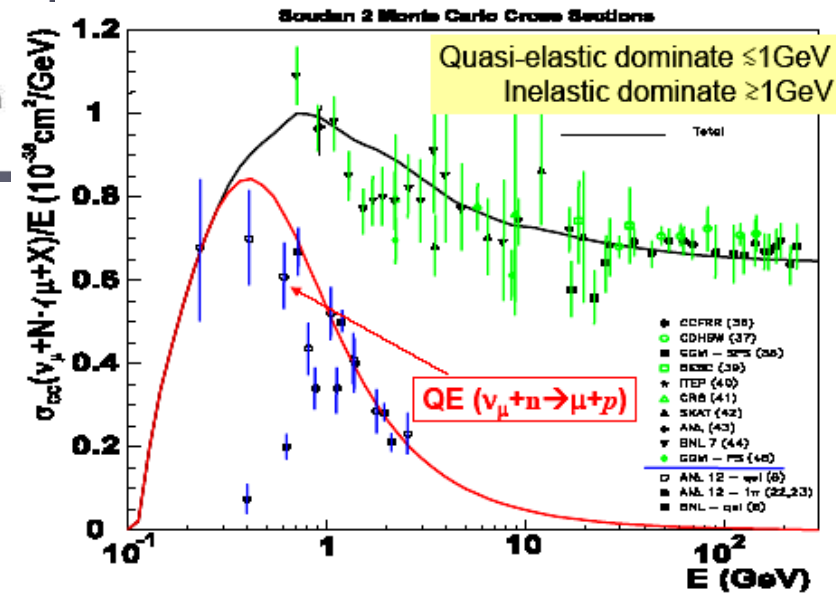
from A.Rubbia

# LAGUNA detectors:



Water Cherenkov detectors  
-ideal for QE neutrino  
interactions

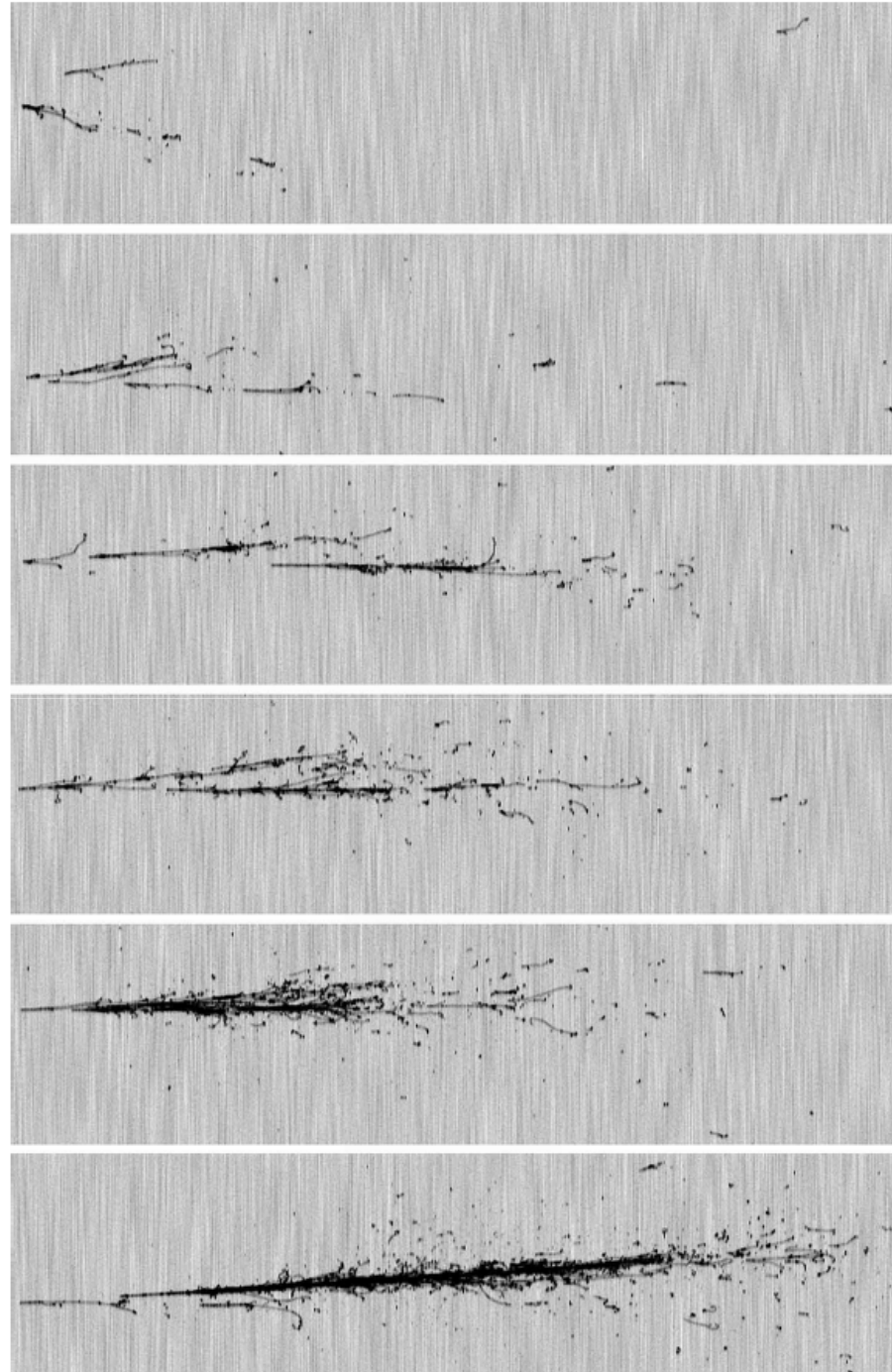
Liquid Argon - better at higher  
Energies (DIS)



But how the detection  
efficiency for liquid argon  
changes with energy?

just for illustration simulated  
 $\pi^0$ 's of 0.5, 1, 2, 3, 5, 10 GeV  
in the ICARUS detector  
(from the diploma work of  
P.Karbowniczek )

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## In conclusion:

-> It is unrealistic to expect to have a high intensity neutrino source of any kind in Europe before early 2020's.

-> Extracts from the workshop summary by S.Bertolucci, the CERN Research Director

### 2009-2013: deciding years

Experimental data will take the floor to drive the field to the next steps:

- LHC and Tevatron results
- $\Theta_{13}$  hierarchy (T2K, DChooz, NOvA etc..)
- $\nu$  masses and nature (KATRIN, Cuore, Gerda, Nemo...)
- Dark Matter searches
- .....



European Strategy for Future  $\nu$  Physics

2

### $\nu$ specific (@CERN)

- Specify the LHC injector consolidation/upgrade and its coupling to  $\nu$  roadmap.
  - **Strategy retreat end November**
- Increase support for coordinated R&D, within reality
- An oscillation experiment/R&D at PS?
  - LOI being submitted shortly to the SPSC
  - A possible way to attract local physicists?
- Keep working on accelerator R&D, contributing to the world effort.



European Strategy for Future  $\nu$  Physics

7

## The last word at the workshop

# Choices

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