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Rutherford Appleton Laboratory

Report of Activities in Europe

Ken Peach

For the MUTAC Review
April 25 - 26, 2005
LBNL
Berkeley, California

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Preliminary Remarks

- 1997
  - CERN DG (Chris Llewellyn Smith) set up a study group (John Ellis, Eberhard Keil & Gigi Rolandi) to look at options for the CERN programme after the LHC
    - Specifically the next "high energy frontier"
  - Various sub-groups looked at specific options
    - Linear e+e- colliders
    - Very Large Hadron Colliders
    - Muon Colliders
- 1998
  - Ellis, Keil & Rolandi report to Chris Llewellyn Smith
    - "Options for Future Colliders at CERN"
    - section 3.3 discusses two $\mu^+\mu^-$ colliders
      - 4 TeV & ~100GeV
    - In this context, it notes
      - *"the high-intensity neutrino beam produced by muon decays can be used for oscillation experiments in a range of mixing angles and Δm^2 not probed heretofore"*
      - This is the only mention of neutrino physics

J Ellis, E Keil, G Rolandi, "Options for Future Colliders at CERN", CERN/EP/9803

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Following European Steps

- **Mid-1998**
  - Meeting at CERN to discuss the muon collider
  - Rapidly turned attention to the neutrino factory
    - ECFA Neutrino Working Group
    - Prospective Study of Muon Storage rings at CERN (99-02)
      - Autin, Blondel, Ellis
    - NuFACT99 in Lyon
- **Comment**
  - US "Muon Collider" community
    - From Steve Geer's "Muon Collider History"
      - *"The muon collider concept is an idea dating back to Tinlot (1960), Tikhonin (1968), Budker (1969), Skrinsky (1971), and Neuffer (1979). The modern enthusiasm for the muon collider results from the realization that ionization cooling [Skrinsky and Parkhomchuk (1981)] offers the possibility of making very bright muon beams and hence a high luminosity muon collider. This realization surfaced at the Sausalito workshop in 1995, where it was also demonstrated that it may be possible to reduce to a reasonable level the backgrounds in the detector due to the prolific production of high energy electrons from muon decay all the way around the ring. Thus the muon collider might provide a unique facility for particle physics research.*

        As a result of the Sausalito meeting an informal muon collider collaboration was formed consisting of about 80 physicists, most of whom were accelerator physicists. The initial goal of this group was to write a "feasibility study" for the Snowmass 1996 workshop."
  - Without the US initiative (and work) on the muon collider, the European interest in the neutrino factory would not have been possible

NuFACT 99-05

- The NuFACT workshops have been and are very important in ensuring that the world-wide effort on neutrino factories is coordinated and collaborative
- European effort is not independent of the US or Japanese activity
- In particular, European effort depends upon, and supports, US activities
  - But
    - For *political* reasons, we need a "European dimension", mainly to attract EU funding
      - Needed while national particle physics funding is preoccupied by the LHC

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European Activities

- **Supported by ECFA and ESGARD**
  - European Steering Group on Accelerator R&D
  - CARE Coordinated Accelerator R&D in Europe
    - BENE Beams for European Neutrino Experiments
      - Input to CERN SPSC "Villars" meeting
        - » Chance for CERN to re-engage in NF accelerators R&D?
    - NED High field magnets
    - HIPPI High Intensity Pulsed Proton Injectors
  - EURISOL Beta Beams
  - *NF Design Study – call for proposals cancelled!*
  - MICE Ionisation Cooling
  - nToF11 Target Studies
  - High Power target studies
  - Beta Beams
  - CERN SPL and Superbeams
  - European Neutrino Factory Design
  - FFAG starting
  - T2K, Double Chooz θ_{13}
    - Also CNGS, MINOS…

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Comment

- Much of what is going on in Europe *has already been covered*
- The European activity is *not* independent of the US activity
  - but interdependent with it!

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MICE

Universite Catholique de Louvain Belgium

INFN: Bari, Frascati, Genova, Legnaro, Milano, Napoli, Padova, Trieste
Roma III; ROMA TRE university, Italy

KEK, Osaka University Japan

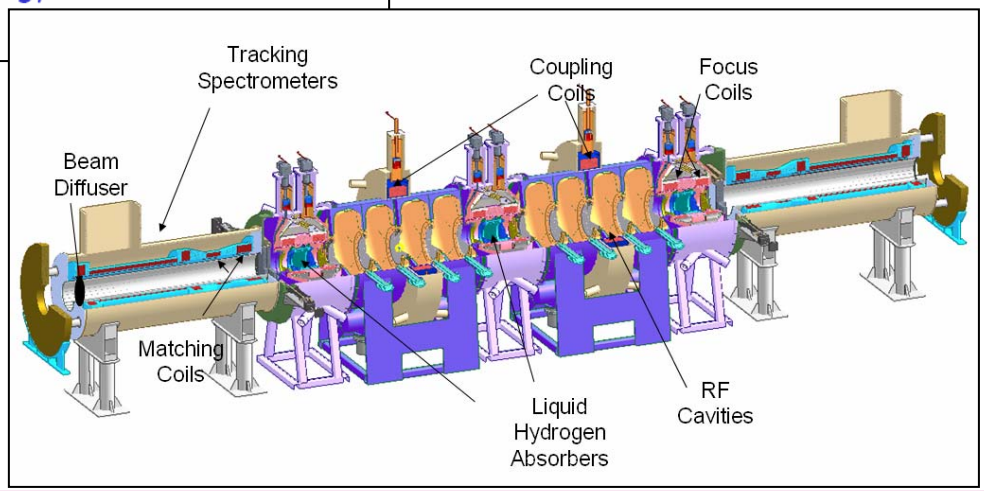
NIKHEF The Netherlands

CERN, Geneva, PSI Switzerland

Brunel, Edinburgh, Glasgow, Liverpool, Imperial, Oxford, RAL,
Sheffield UK

ANL, BNL, FNAL, JLab, LBNL,
Universities of Fairfield, Chicago, UCLA Physics, Northern Illinois,
Iowa,
Mississippi, UC Riverside, Illinois-UC
Enrico Fermi Institute, Illinois Institute of Technology
USA

THE MICE COLLABORATION
3 continents
7 countries
40 institute members
140 individual members
- Engineers & physicists (part. & accel.)

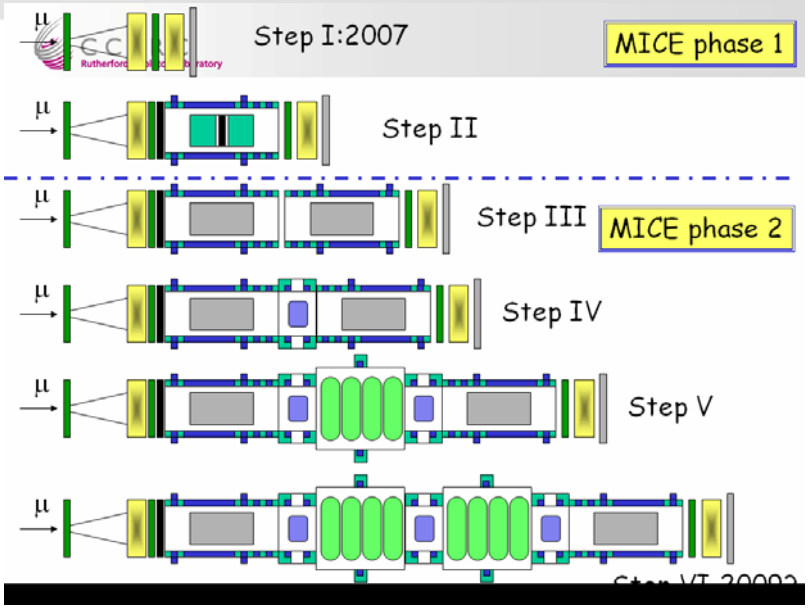


Some comments on MICE

- Very pleased MICE Phase 1 is approved
- @RAL
  - Important politically in the UK that this is an international project
- Confident Phase 2 to follow

Note

- Breaking MICE into 2 phases was essential to gain UK approval for £7.5M from the Large Scale Facilities Fund
- "Gateway" process required sensitive political management
- Could not have been achieved without international support
  - The "trick" was to find a way of meeting formal "Gateway" requirements without international "contracts"



Lesson:

We have to be politically athletic if we are to build a Neutrino Factory in the next 10-15 years

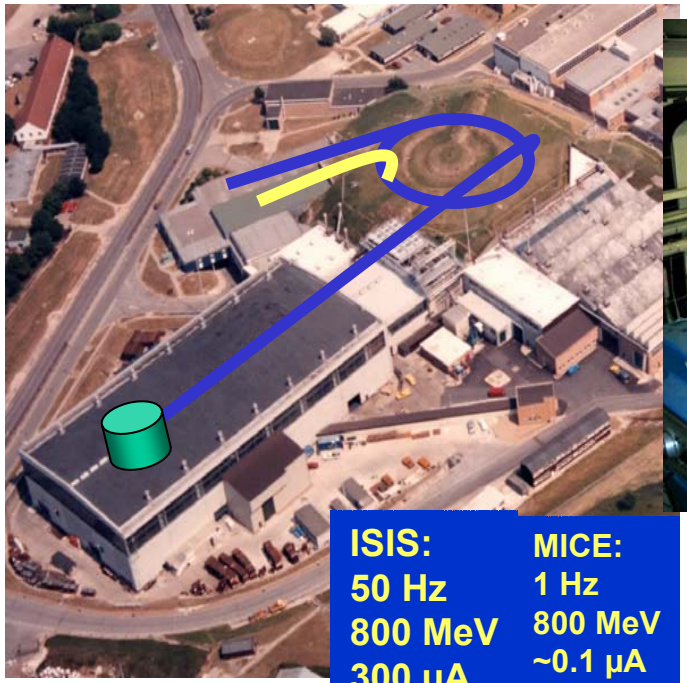
After Drumm

Some history

- 2000 NuFACT00 (Monterey)
  - Need for Ionisation Cooling Demonstration & searchs for a suitable beam
- 2001 NuFACT01 (Tsukuba)
  - birth of MICE
- 2002 LoI to PSI & RAL
  - PSI: +ve but no,
  - RAL: yes ⇨ requested a full proposal
    - NUFACT02 (London) – UK Science Minister (Lord Sainsbury) at Workshop dinner!
- 2003 Proposal to RAL (January) to Gateway 1 (December)
  - IPR (Astbury) panel
  - MICE-UK: PPRP
  - CCLRC scientific approval dependent on funding
  - MICE went to "Gateway" (G1) in December
- 2004 Gateway 1 (January) to Gateway 3 (December)
  - Gateway Review: Business case Green, but funding "deep Amber"…
  - Defines MICE Phase 1 and 2
  - Project costs & schedule reviewed (recommended by Astbury & GW1)
  - Phase 1 of project submitted to the "Gateway" (G2&3)
  - Passed by PPARC science committee (⇨ aware of Phase 2)
- 2005 Approval (March)
  - Approved by PPARC
  - Approved by CCLRC
  - Noted by RCUK
  - Announced by the Minister (Lord Sainsbury)
  - MoU for PSI Solenoid signed

After Drumm

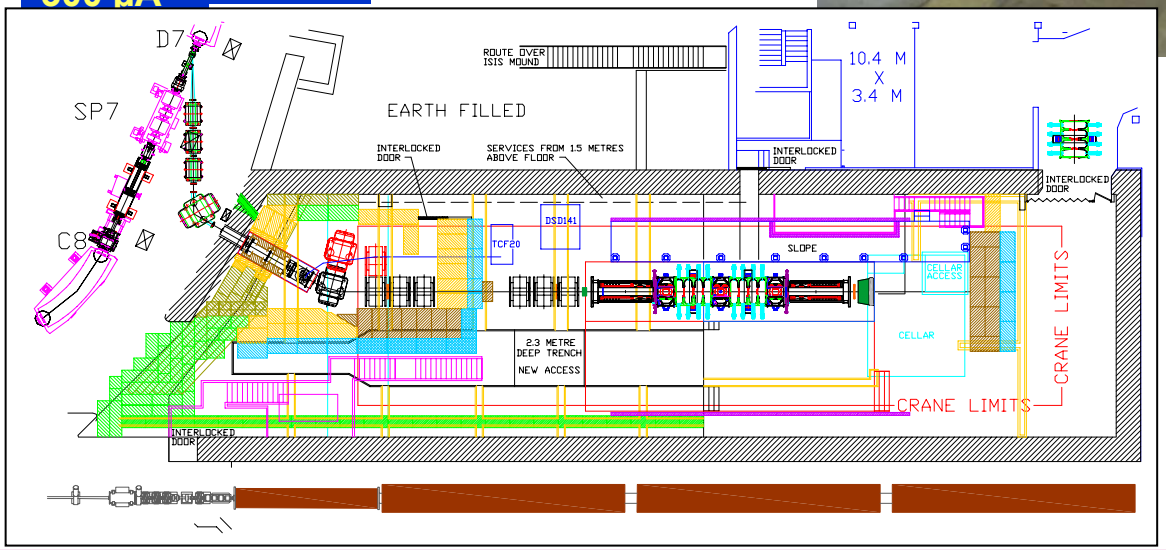
Implementing MICE on ISIS



Nimrod linac hall HEP test beam → MICE

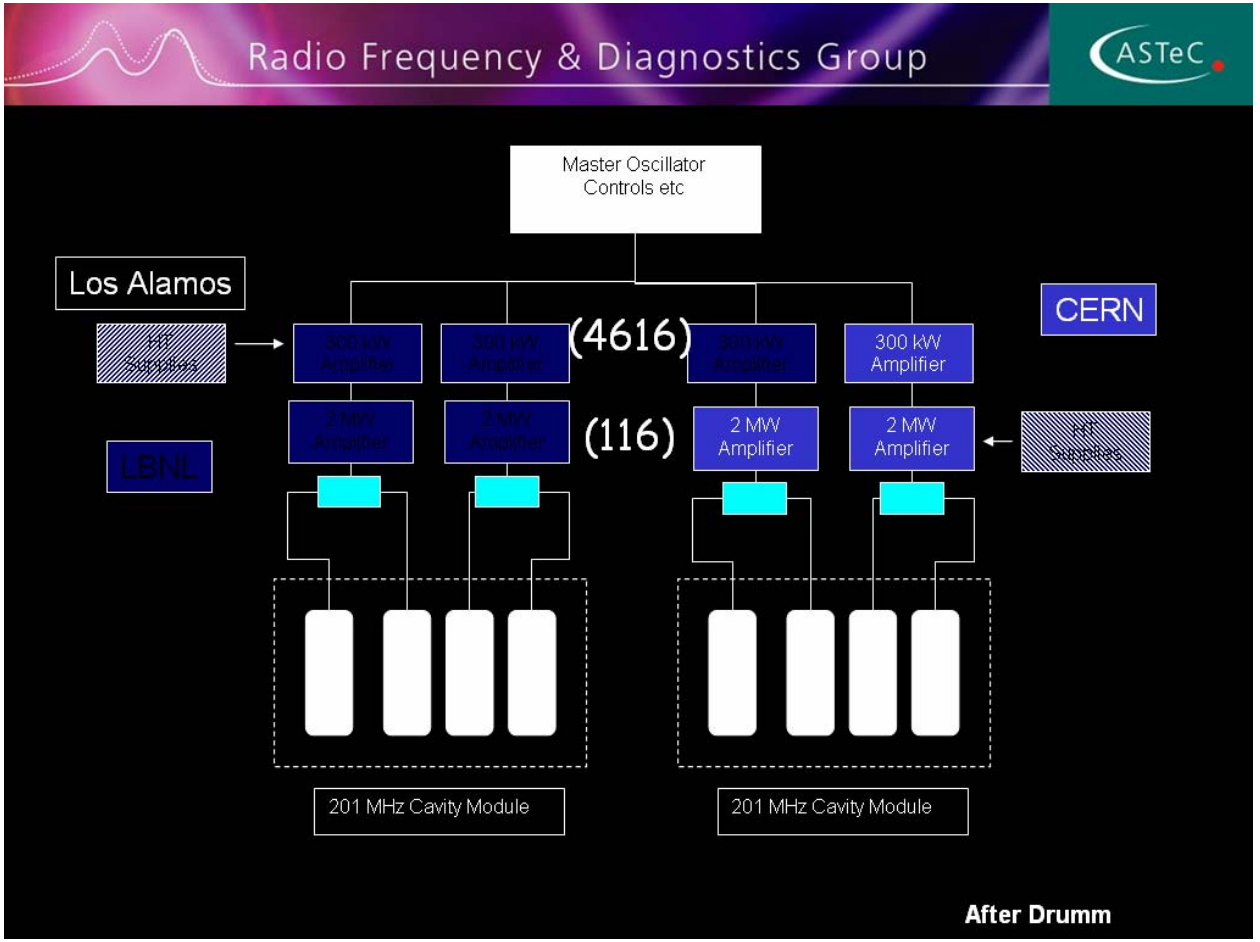
ISIS:
50 Hz
800 MeV
300 μA

MICE:
1 Hz
800 MeV
~0.1 μA



RF

Curved Be window for the 805-MHz pillbox cavity



After Drumm

CARE/BENE in 2004

- CARE/BENE
  - Coordinated Accelerator Research in Europe
  - Beams for European Neutrino Experiments

1. Presentation of the scientific case for high intensity neutrino beams
   - Superbeams, beta beams, neutrino factory
   - Fostering of ongoing development of accelerator technology to make them possible
   - Opportunities to plan, fund and realise on a realistic timescale a much enhanced European accelerator neutrino programme

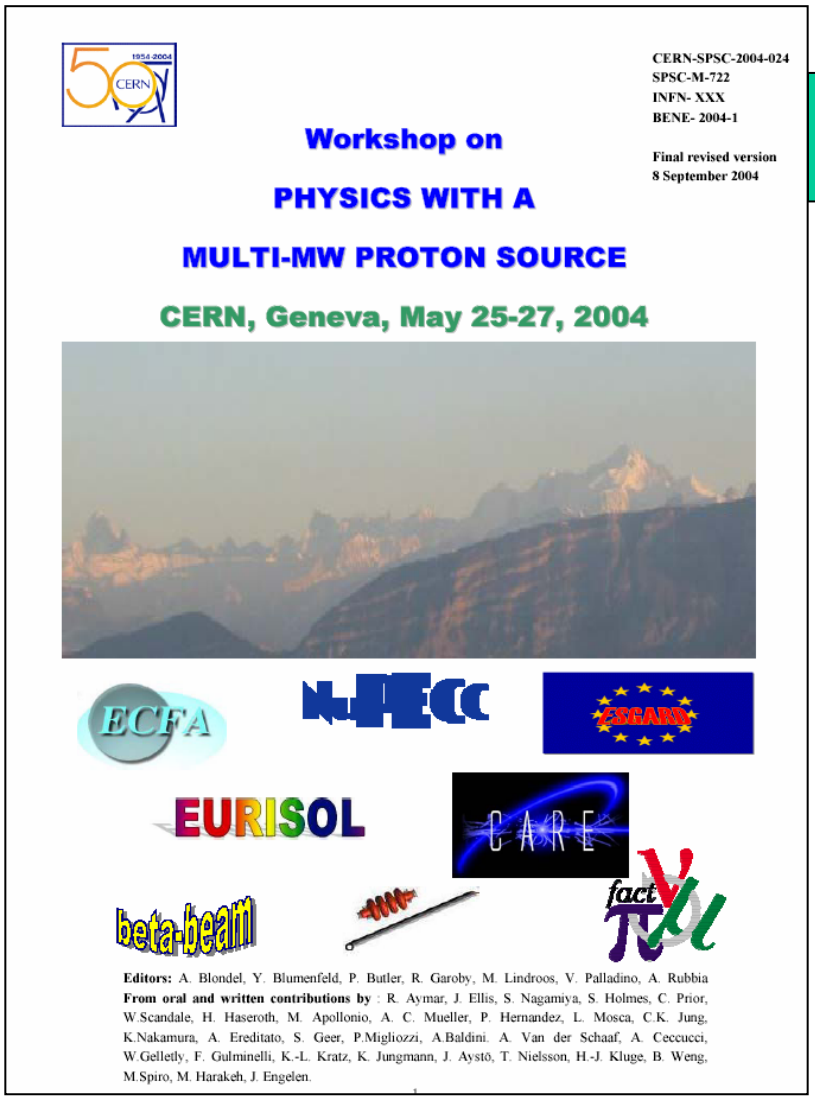
2. Approval of a Beta Beam Conceptual Design Study
   - Funded by the EU within the EURISOL Design Study
     - Work Package 11 – 1MEuro + matching funds fromnational agencies
     - Started January 2005, due December 2008

3. Progress towards a proposal for a Neutrino factory and superbeam design study
   - Framework 7 Eu programme for funding
   - Proposal for “scoping study” in preparation
   - Hope to launch at NuFACT05

See http://bene.na.infn.it/

After Palladino

CERN SPSC "Villars" meeting



CERN-SPSC-2004-024
SPSC-M-722
INFN- XXX
BENE- 2004-1

Final revised version
8 September 2004

Workshop on

PHYSICS WITH A

MULTI-MW PROTON SOURCE

CERN, Geneva, May 25-27, 2004

Editors: A. Blondel, Y. Blumenfeld, P. Butler, R. Garoby, M. Lindroos, V. Palladino, A. Rubbia
From oral and written contributions by : R. Aymar, J. Ellis, S. Nagamiya, S. Holmes, C. Prior, W.Scandale, H. Haseroth, M. Apollonio, A. C. Mueller, P. Hernandez, L. Mosca, C.K. Jung, K.Nakamura, A. Ereditato, S. Geer, P.Migliozzi, A.Baldini. A. Van der Schaaf, A. Ceccucci, W.Gelletly, F. Gulminelli, K.-L. Kratz, K. Jungmann, J. Aystö, T. Nielsson, H.-J. Kluge, B. Weng, M.Spiro, M. Harakeh, J. Engelen.

A 140 page Summary Report of the MMW Workshop and 9 talks by BENE in Villars

ohn Dainton
/illars 2004
ober 7th 2004
ERN seminar

Villars 2004

After Palladino

Villars "output"

CERN SPS and PS Committee

Fixed-Target Physics at CERN beyond 2005
Summary and Conclusions of an Evaluation by the SPSC
(Villars meeting 22-28 September 2004)

February 2005

1. Identified a *construction window* (2010-2020) for a neutrino project at CERN
   - after the LHC, before CLIC
2. Endorsed the *strategic importance of a MMW proton driver* for CERN
   - for all of CERN's programmes
3. Recommended CERN and other agencies to *reinforce the necessary R&D*

Under discussion

After Palladino

Support from the CERN SPC

Recommendations

- CERN should make every reasonable effort to deliver the approved p.o.t. to CNGS.

- Future neutrino facilities offer great promise for fundamental discoveries. CERN should join the world effort in developing technologies for new facilities : Beta beams, Neutrino Factory…wherever they are sited.
- Focus now on enabling CERN to do the best choice by 2010 on future physics programme.
- Explore further synergies with EURISOL

After Blondel

High Power Proton Sources

- Various studies in Europe
  - SPL@CERN
  - IPHI@SACLAY
  - UK Neutrino Factory R&D
  - RAL/ISIS study
    - MMW spallation sources
      - and other applications
- included as part of CARE
  - HIPPI

Letter from John Wood/RAL

BENE

3. Progress towards a proposal for a Neutrino factory and superbeam design study

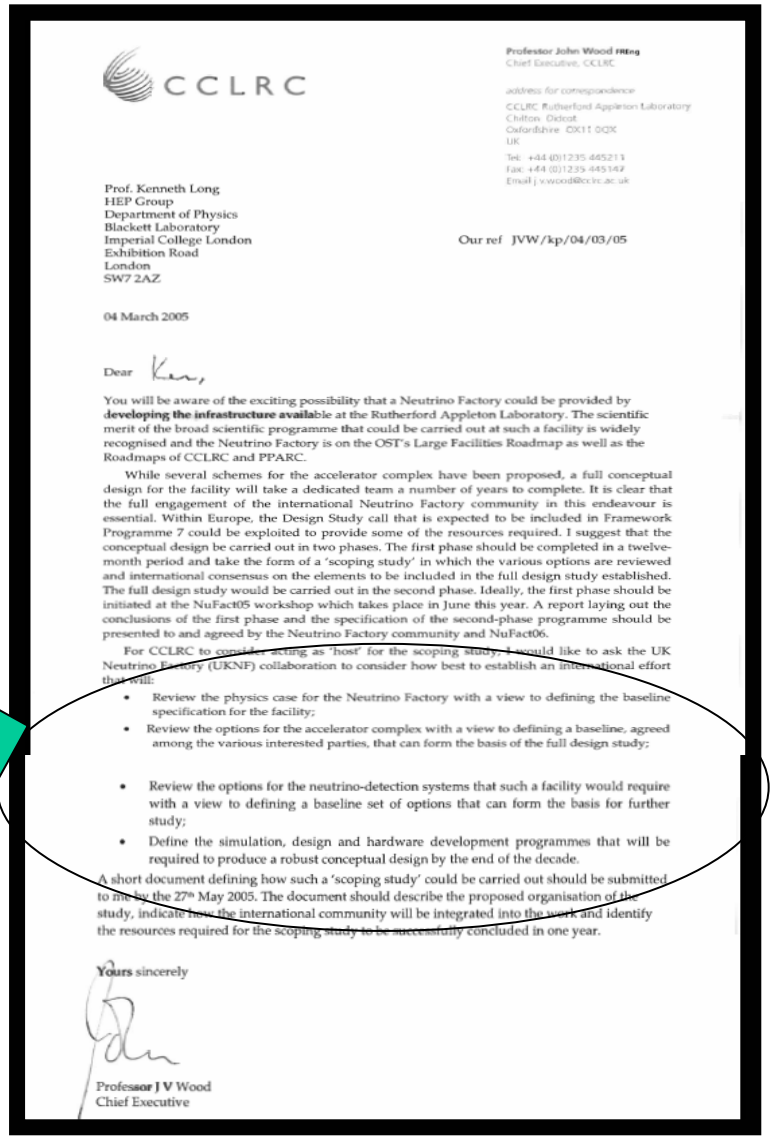
- **Framework 7 Eu programme for funding**
- **Request for a preliminary "scoping study" by 27th May, in preparation**
- **Hope to launch at NuFACT05**

For CCLRC to consider acting as 'host' for the scoping study, I would like to ask the UK Neutrino Factory (UKNF) collaboration to consider how best to establish an international effort that will:

- Review the physics case for the Neutrino Factory with a view to defining the baseline specification for the facility;
- Review the options for the accelerator complex with a view to defining a baseline, agreed among the various interested parties, that can form the basis of the full design study;
- Review the options for the neutrino-detection systems that such a facility would require with a view to defining a baseline set of options that can form the basis for further study;
- Define the simulation, design and hardware development programmes that will be required to produce a robust conceptual design by the end of the decade.

Meeting with Ken Long @ FNAL 15th April

Meeting in Imperial 6/7 May



CCLRC

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Chief Executive, CCLRC

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Prof. Kenneth Long
HEP Group
Department of Physics
Blackett Laboratory
Imperial College London
Exhibition Road
London
SW7 2AZ

Our ref JVW/kp/04/03/05

04 March 2005

Dear Ken,

You will be aware of the exciting possibility that a Neutrino Factory could be provided by developing the infrastructure available at the Rutherford Appleton Laboratory. The scientific merit of the broad scientific programme that could be carried out at such a facility is widely recognised and the Neutrino Factory is on the OST's Large Facilities Roadmap as well as the Roadmaps of CCLRC and PPARC.

While several schemes for the accelerator complex have been proposed, a full conceptual design for the facility will take a dedicated team a number of years to complete. It is clear that the full engagement of the international Neutrino Factory community in this endeavour is essential. Within Europe, the Design Study call that is expected to be included in Framework Programme 7 could be exploited to provide some of the resources required. I suggest that the conceptual design be carried out in two phases. The first phase should be completed in a twelve-month period and take the form of a 'scoping study' in which the various options are reviewed and international consensus on the elements to be included in the full design study established. The full design study would be carried out in the second phase. Ideally, the first phase should be initiated at the NuFact05 workshop which takes place in June this year. A report laying out the conclusions of the first phase and the specification of the second-phase programme should be presented to and agreed by the Neutrino Factory community and NuFact06.

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- Review the options for the neutrino-detection systems that such a facility would require with a view to defining a baseline set of options that can form the basis for further study;
- Define the simulation, design and hardware development programmes that will be required to produce a robust conceptual design by the end of the decade.

A short document defining how such a 'scoping study' could be carried out should be submitted to me by the 27th May 2005. The document should describe the proposed organisation of the study, indicate how the international community will be integrated into the work and identify the resources required for the scoping study to be successfully concluded in one year.

Yours sincerely

Professor J V Wood
Chief Executive

Target & collection (nToF11)

Proposal to test a 10m/s Hg Jet in a 15T Solenoid with an Intense Proton Beam

nToF-11

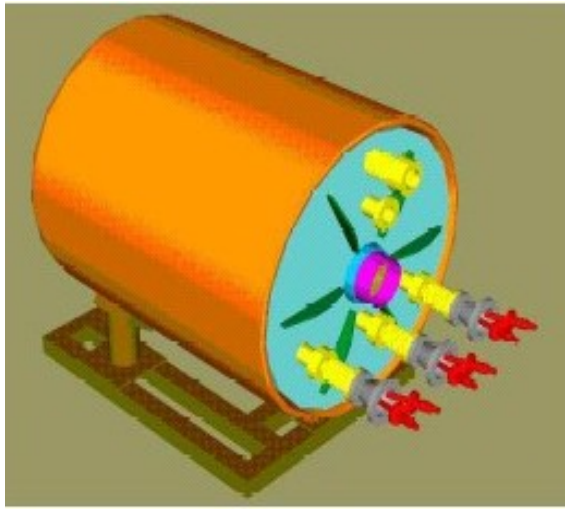
CERN-INTC-2003-033
INTC-I-049
26 April 2004

A Proposal to
the ISOLDE and Neutron Time-of-Flight Experiments Committee

Studies of a Target System for a 4-MW, 24-GeV Proton Beam

J. Roger J. Bennett[1], Luca Bruno[2], Chris J. Densham[1], Paul V. Drumm[1], T. Robert Edgecock[1], Tony A. Gabriel[3], John R. Haines[3], Helmut Haseroth[2], Yoshinari Hayato[4], Steven J. Kahn[5], Jacques Lettry[2], Changguo Lu[6], Hans Ludewig[5], Harold G. Kirk[5], Kirk T. McDonald[6], Robert B. Palmer[5], Yarema Prykarpatskyy[5], Nicholas Simos[5], Roman V. Samulyak[5], Peter H. Thieberger[5], Koji Yoshimura[4]

Spokespersons: H.G. Kirk, K.T. McDonald
Local Contact: H. Haseroth



Participating Institutions

1) RAL } EU
2) CERN
3) KEK } Japan
4) BNL
5) ORNL } US
6) Princeton

After Blondel

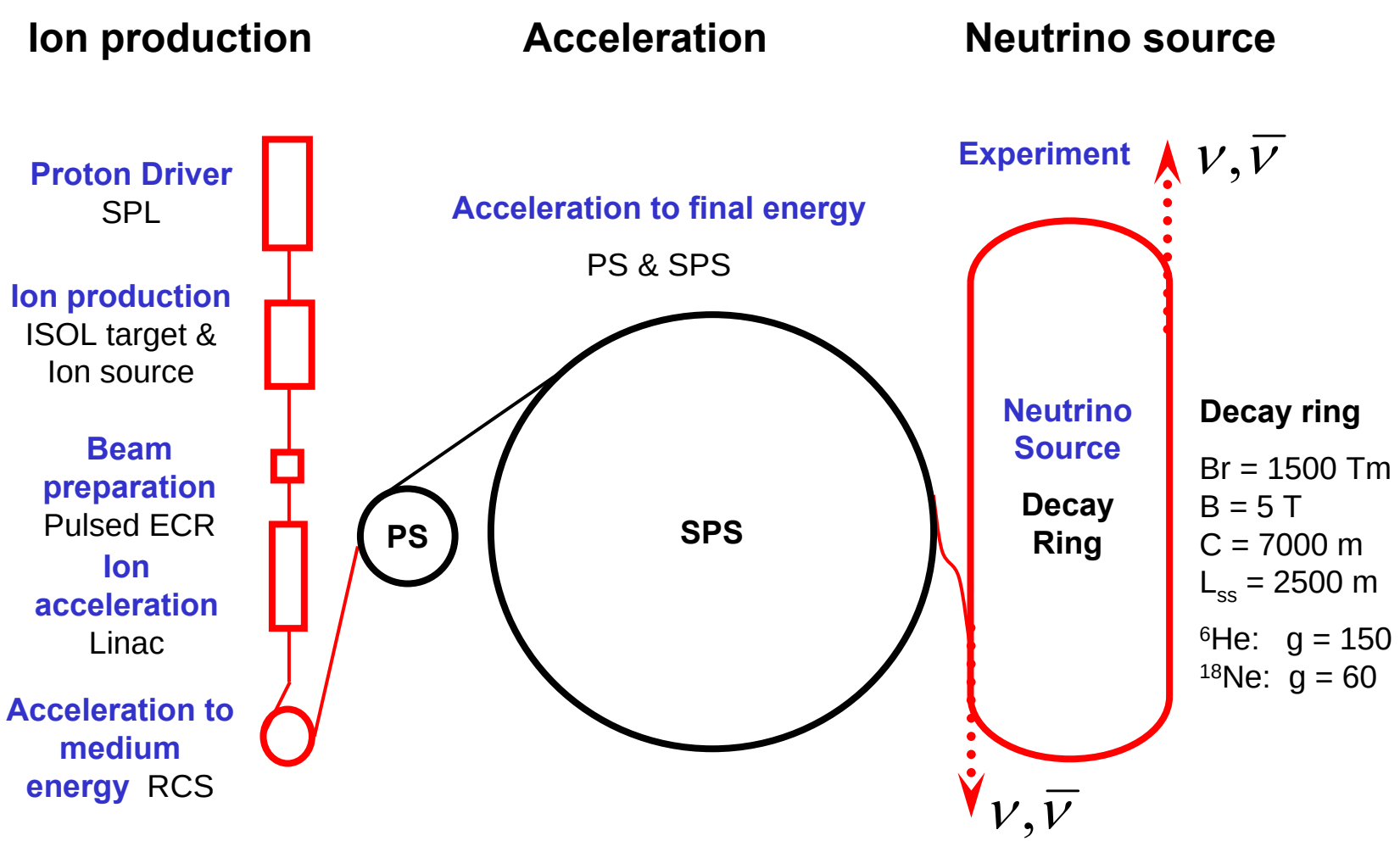
Introduction to Beta-beams

- Beta-beam proposal by Piero Zucchelli
  - *A novel concept for a neutrino factory: the beta-beam*,
    - Phys. Let. B, 532 (2002) 166-172.
- AIM: production of a pure beam of electron neutrinos (or antineutrinos) through the beta decay of radioactive ions circulating in a high-energy (γ~100) storage ring.
- Baseline scenario
  - Avoid anything that requires a “technology jump” which would cost time and money (and be risky).
  - Make maximum use of the existing infrastructure.

http://cern.ch/beta-beam/

After Lindroos

Beta-beam baseline design



After Lindroos

Main parameters

- Factors influencing ion choice
  - Need reasonable numbers of ions.
  - Noble gases preferred
    - simple diffusion out of target
    - gaseous at room temperature.
  - Not too short half-life to get reasonable intensities.
  - Not too long half-life as otherwise no decay at high energy.
  - Avoid potentially dangerous and long-lived decay products.
- Best compromise
  - Helium-6 to produce antineutrinos:

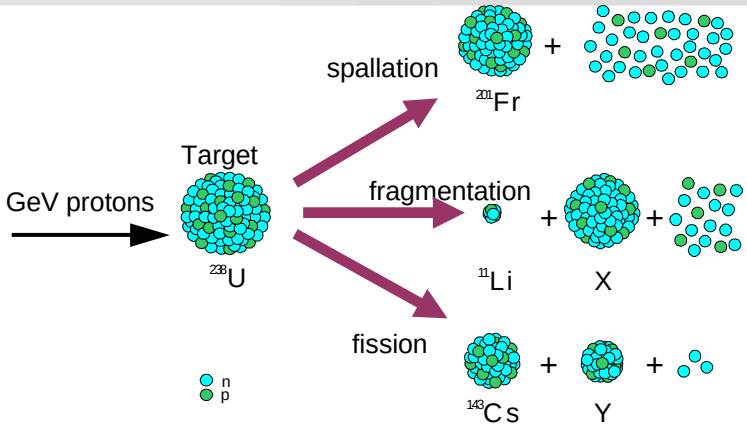
$$^{6}_{2}He \rightarrow ^{6}_{3}Li\ e^{-}\ \bar{\nu}$$

$$\text{Average } E_{cms} = 1.937 \text{ MeV}$$

  - Neon-18 to produce neutrinos:

$$^{18}_{10}Ne \rightarrow ^{18}_{9}F\ e^{+}\nu$$

$$\text{Average } E_{cms} = 1.86 \text{ MeV}$$



^{6}He via spallation n

^{18}Ne directly

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FLUX

- **The Design Study is aiming for:**
  - **A beta-beam facility that will run for a "normalized" year of 10^7 seconds**
  - **An integrated flux of 10 10^{18} anti-neutrinos (^{6}He) and 5 10^{18} neutrinos (^{18}Ne) in ten years running at γ=100**

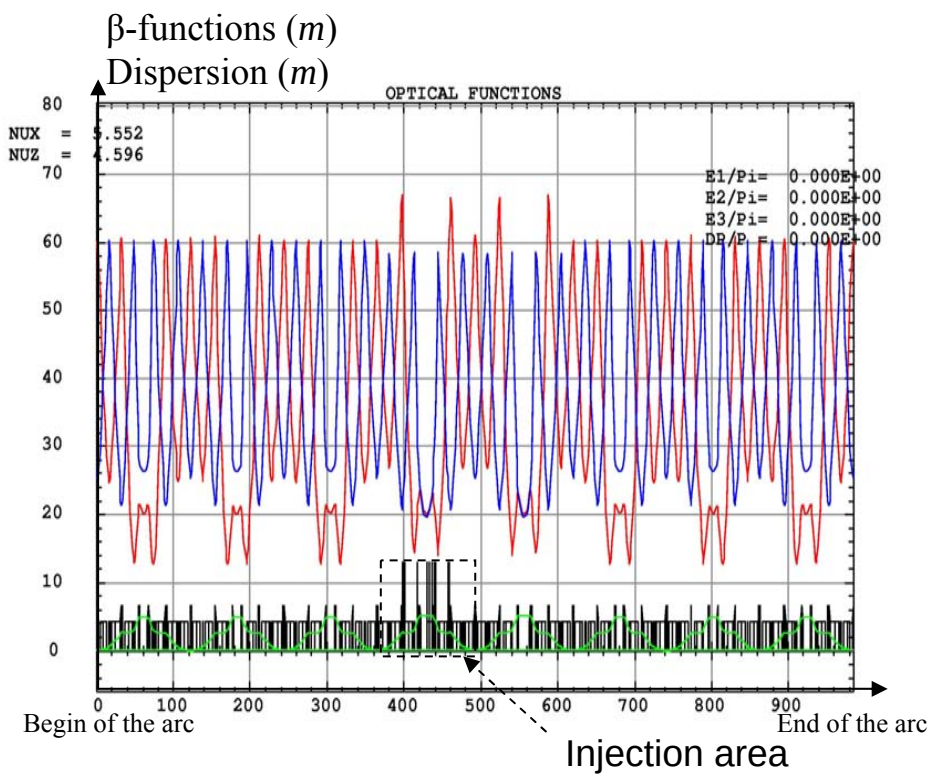
With an Ion production in the target to the ECR source:

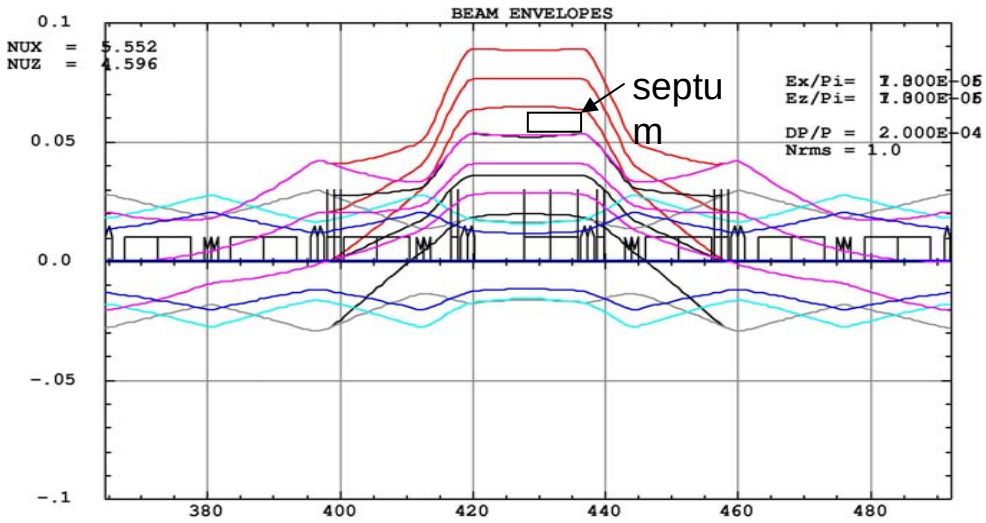
- **^{6}He= 2 10^{13} atoms per second**
- **^{18}Ne= 8 10^{11} atoms per second**

After Lindroos

Decay ring studies

A. Chance, CEA-Saclay (F)





FODO structure

Central cells detuned for injection

Arc length ~984m

Bending 3.9 T, ~480 m L_{eff}

5 quadrupole families

— Horizontal β_x

— Vertical β_y

— Horizontal Dispersion D_x

Horizontal envelopes :

— $\Delta p/p = 0$ bumps off

— $\Delta p/p = 0$ bumps on

— $\Delta p/p = 0.8\%$ bumps off

— $\Delta p/p = 0.8\%$ bumps on

Vertical envelopes :

— stored beam

— injected beam

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Future R&D

- Future beta-beam R&D together with EURISOL project
- Design Study in the 6th Framework Programme of the EU

- The EURISOL Project
  - Design of an ISOL type (nuclear physics) facility.
  - Performance three orders of magnitude above existing facilities.
  - A first feasibility / conceptual design study was done within FP5.
  - Strong synergies with the low-energy part of the beta-beam:
    - Ion production (proton driver, high power targets).
    - Beam preparation (cleaning, ionization, bunching).
    - First stage acceleration (post accelerator ~100 MeV/u).
    - Radiation protection and safety issues.

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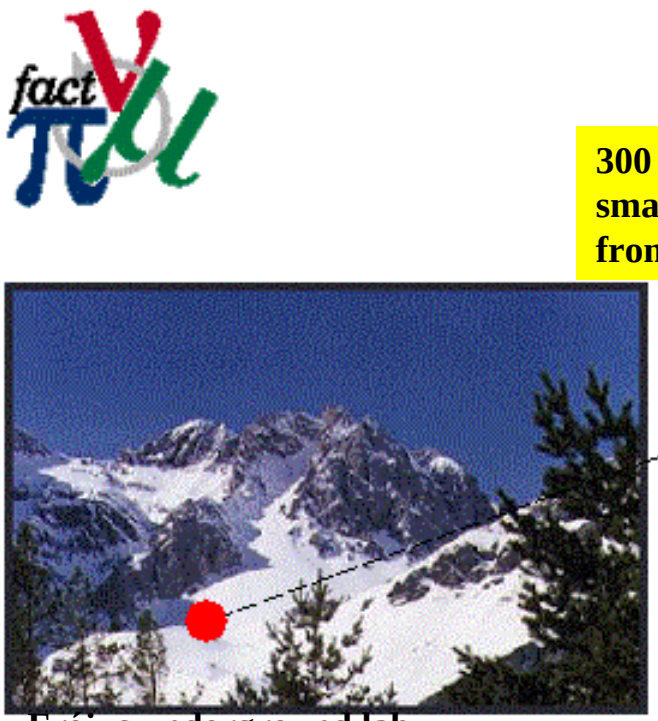
Beta Beam Conclusions

- Well-established beta-beam baseline scenario.
- Beta-Beam Task well integrated in the EURISOL DS.
  - Strong synergies between Beta-beam and EURISOL.
- Design study started for "base line" isotopes.
- Baseline study should result in a credible conceptual design report.
  - We need a "STUDY 1" for the beta-beam to be considered a credible alternative to super beams and neutrino factories
  - New ideas welcome but the design study cannot (and will not) deviate from the given flux target values and the chosen baseline
  - Parameter list to be frozen by end of 2005
- **Recent new ideas promise a fascinating continuation into further developments beyond (but based on) the ongoing EURISOL (beta-beam) DS**
  - **Low energy beta-beam, EC beta-beam, High gamma beta-beam, etc.**
- **And this is only the beginning…**

After Lindroos

CERN-SPL-based Neutrino SUPERBEAM



Fréjus underground lab.

300 MeV ν_μ Neutrinos small contamination from ν_e (no K at 2 GeV!)

target!

A large underground water Cerenkov (400 kton) UNO/HyperK or/and a large L.Arg detector. proton decay search, supernovae events solar and atmospheric neutrinos. Performance similar to J-PARC II
A window of opportunity for digging the cavern stating in 2008

A possible layout of a Low Energy Neutrino Super Beam

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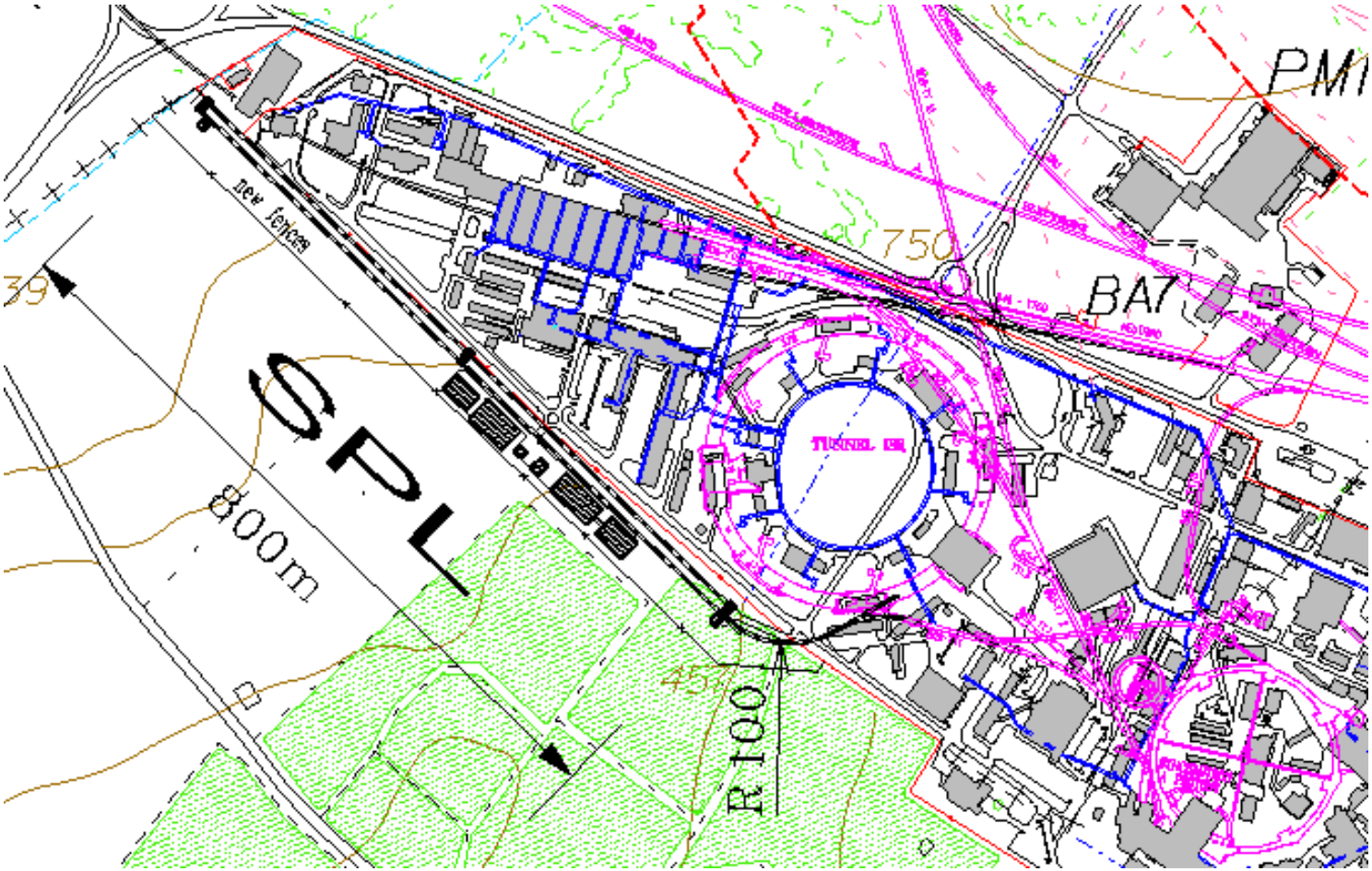
SPL layout



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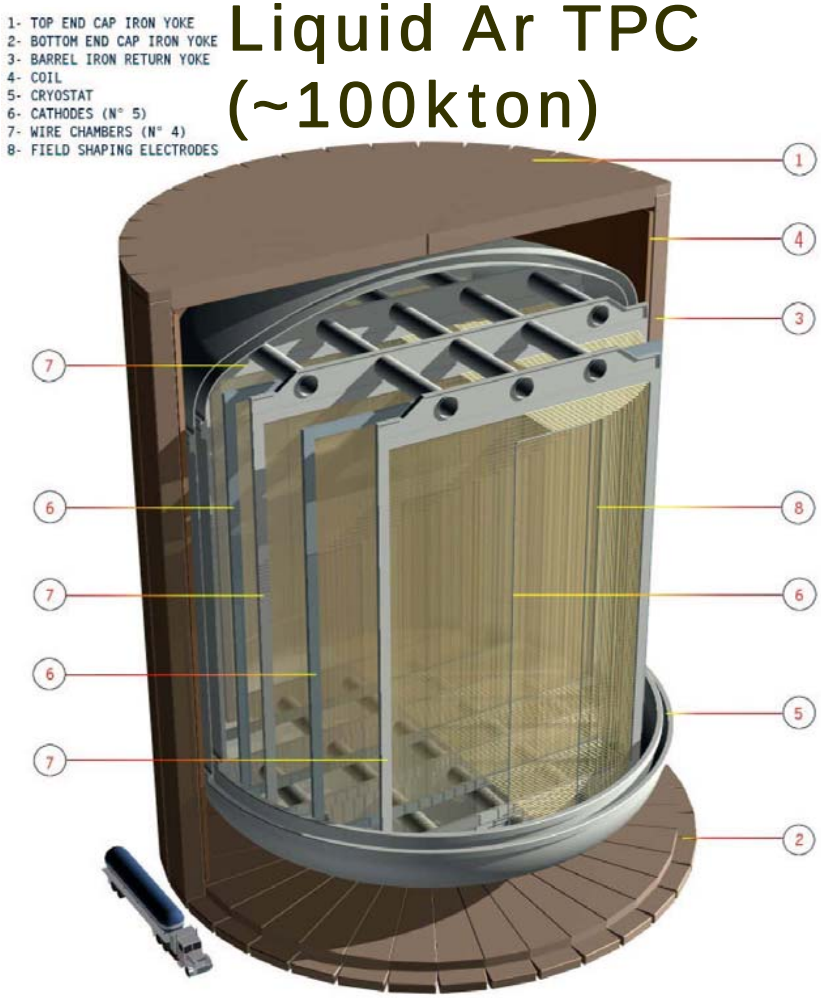
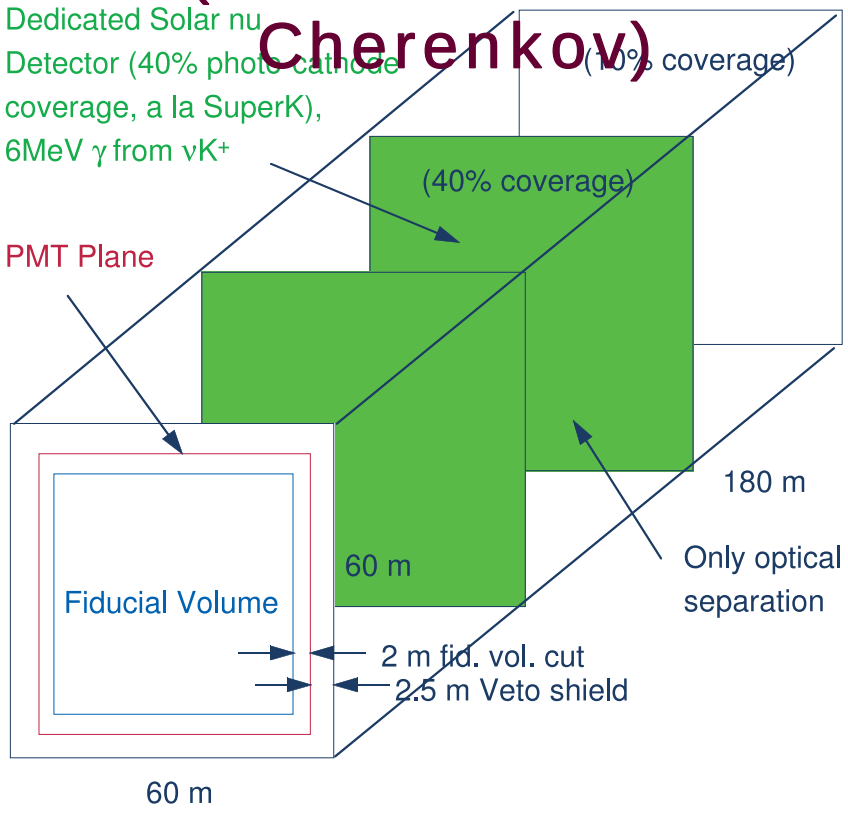
Detectors

Liquid Ar TPC (~100kton)

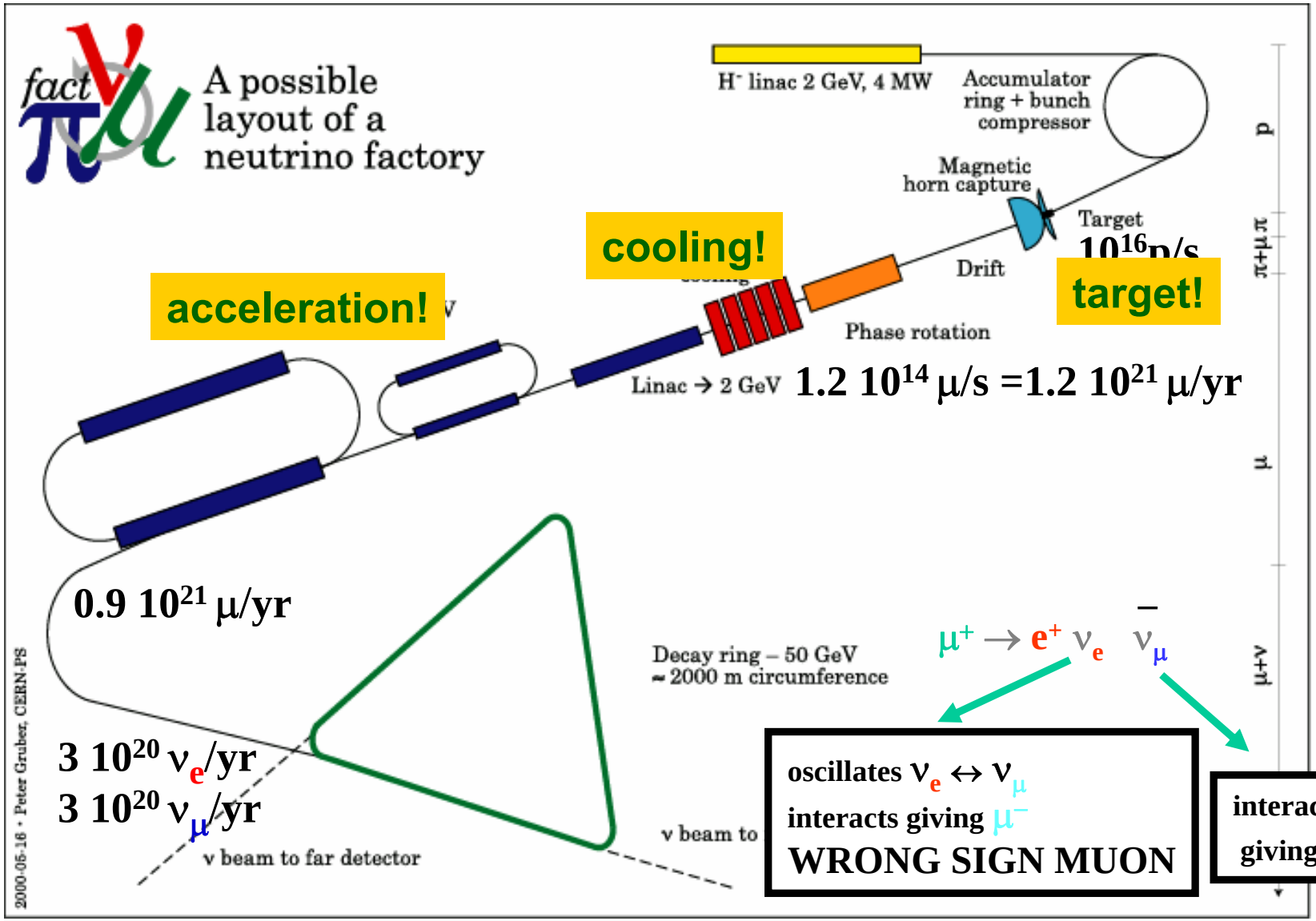


UNO (400kton Water Cherenkov)



After Blondel

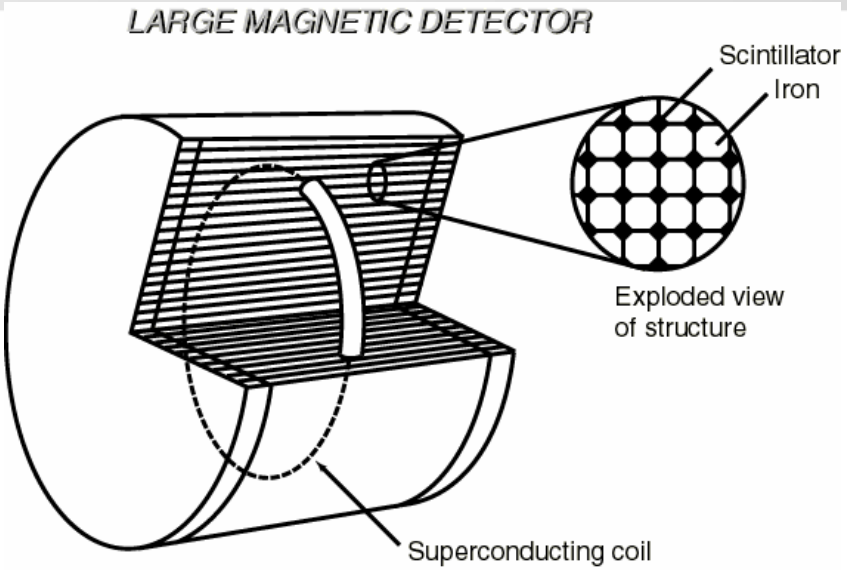
Neutrino Factory CERN layout



After Blondel

Detector

- Iron calorimeter
- Magnetized
  - Charge discrimination
  - B = 1 T
- R = 10 m, L = 20 m
- Fiducial mass = 40 kT



Also: L Arg detector: magnetized ICARUS
Wrong sign muons, electrons, taus and NC evts

Events for 1 year

Baseline	$\bar{\nu}_\mu$ CC	ν_e CC	ν_μ signal ($\sin^2 \theta_{13}=0.01$)	
732 Km	3.5×10^7	5.9×10^7	1.1×10^5	(J-PARC I /SK = 40)
3500 Km	1.2×10^6	2.4×10^6	1.0×10^5	

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Non-scaling FFAG?

- Several scaling FFAGs exist or designed in Japan
- US/EU – look at "non-scaling" FFAGs
  - Smaller, simpler, cheaper?
- Non-scaling FFAGs have three unique features:
  - multi-resonance crossings
  - huge momentum compaction
  - asynchronous acceleration
- Proof-of-Principle electron machine planned
- Collaboration of 14 institutes [EU, US, Canada, Japan]
- Location: Daresbury Laboratory, using ERLP
- Two correlated proposals submitted:
  - UK Basic Technology programme (hardware)
  - EU FP6: opportunity to gain experience

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Electron Model at Daresbury

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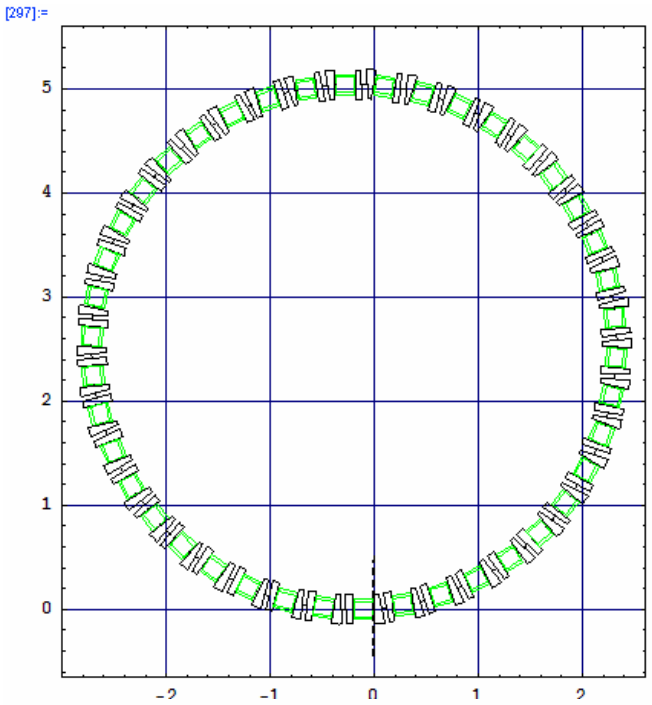

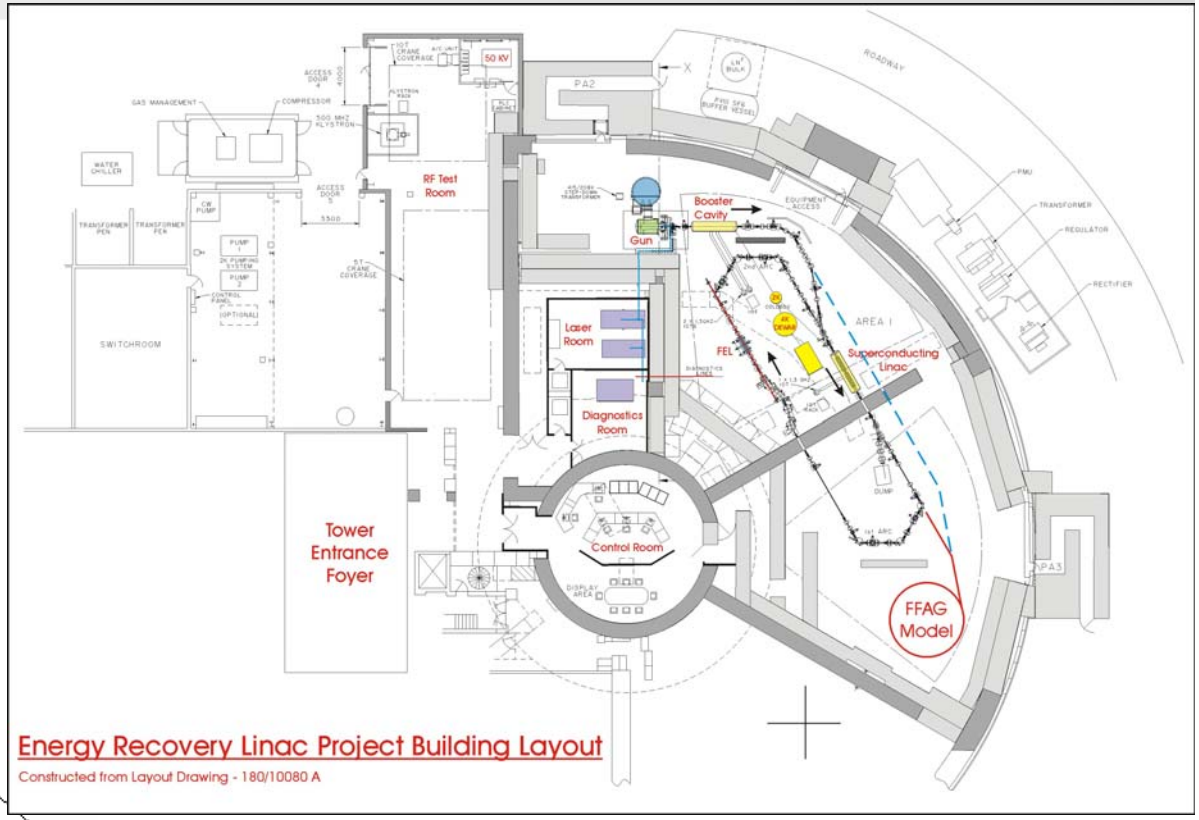

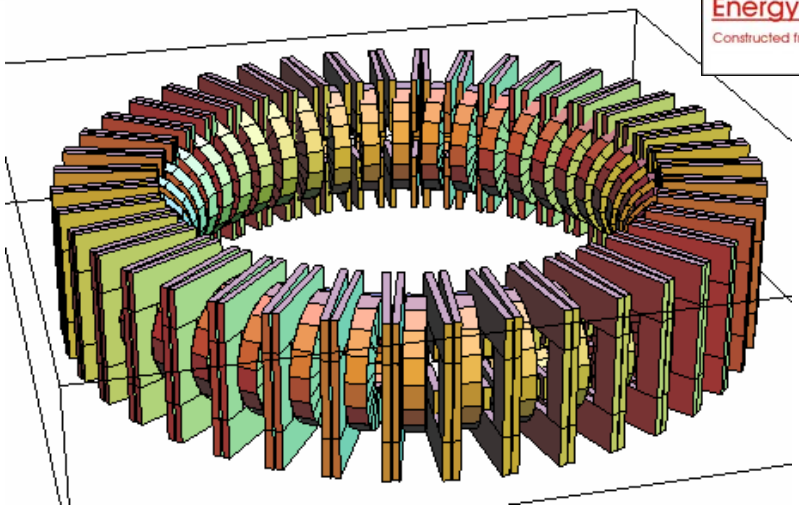

42 Cells / 0.2T Poletip Field

15.9m Circumference

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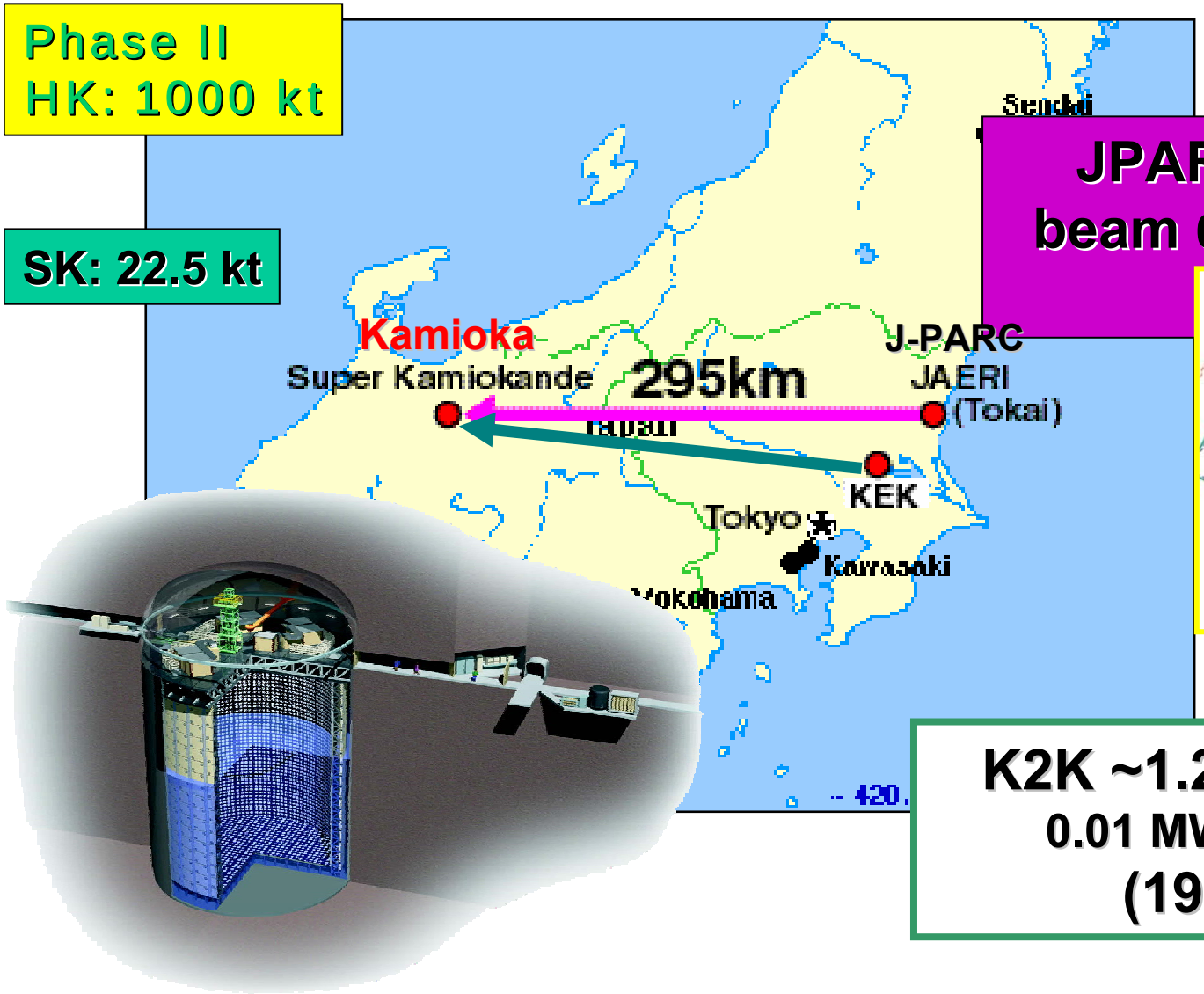
T2K

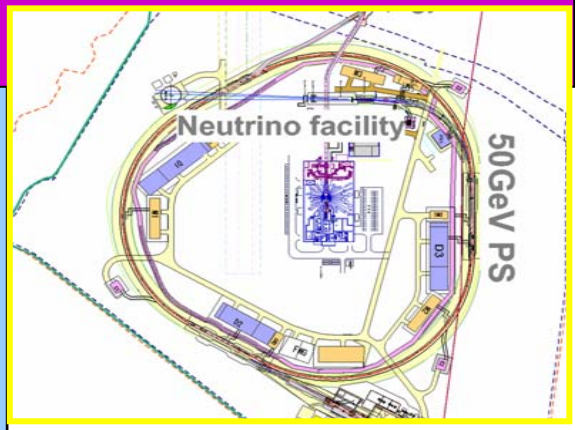
Phase II
HK: 1000 kt

SK: 22.5 kt



Phase II:
4 MW upgrade

JPARC-ν ~0.6GeV ν
beam 0.75 MW 50 GeV PS



K2K ~1.2 GeV ν beam
0.01 MW 12 GeV PS
(1999-2005)

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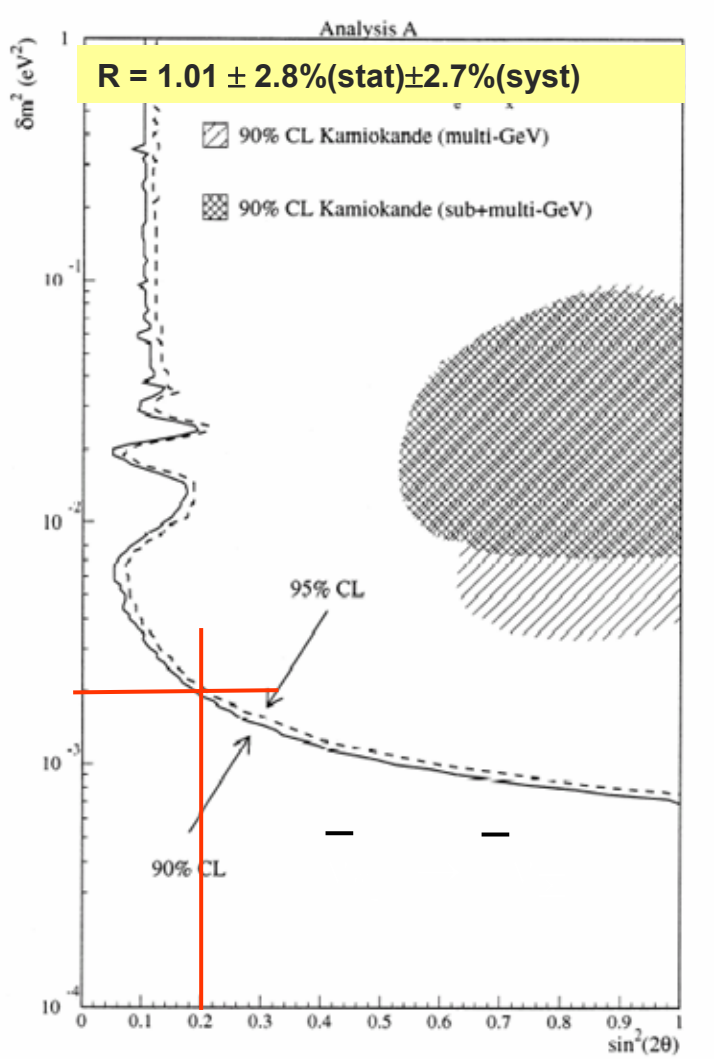
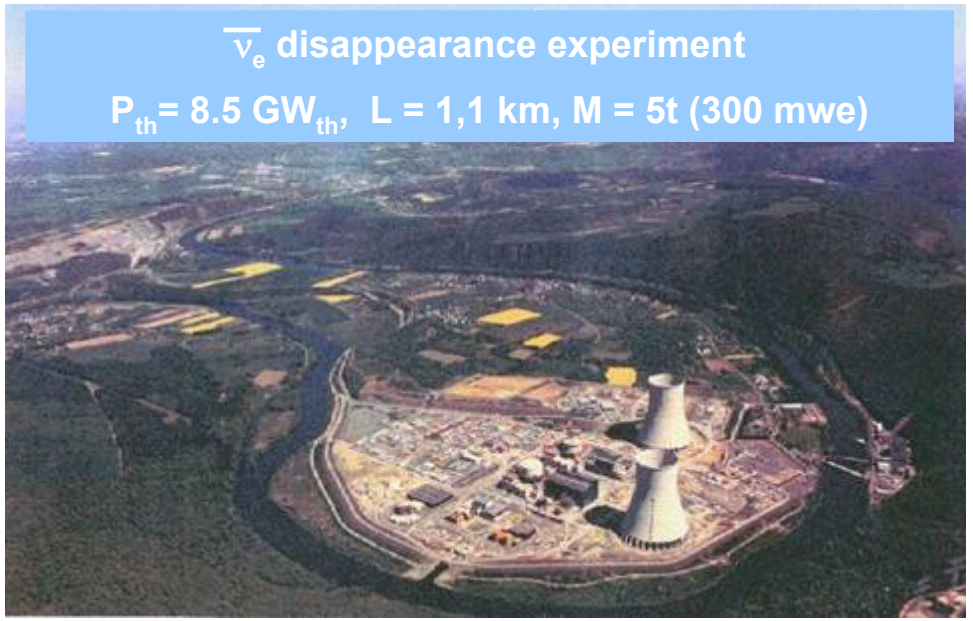
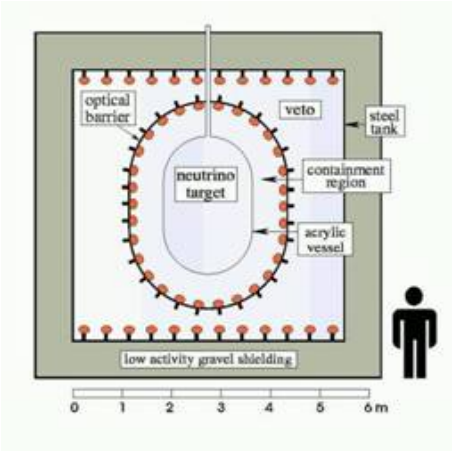
θ_{13} : Best current constraint: CHOOZ



M. Apollonio et. al., Eur.Phys.J. C27 (2003) 331-374





World best constraint !

@Δm^2_{atm}=2 10^{-3} eV^2

$\sin^2(2\theta_{13})$<0.2

(90% C.L)

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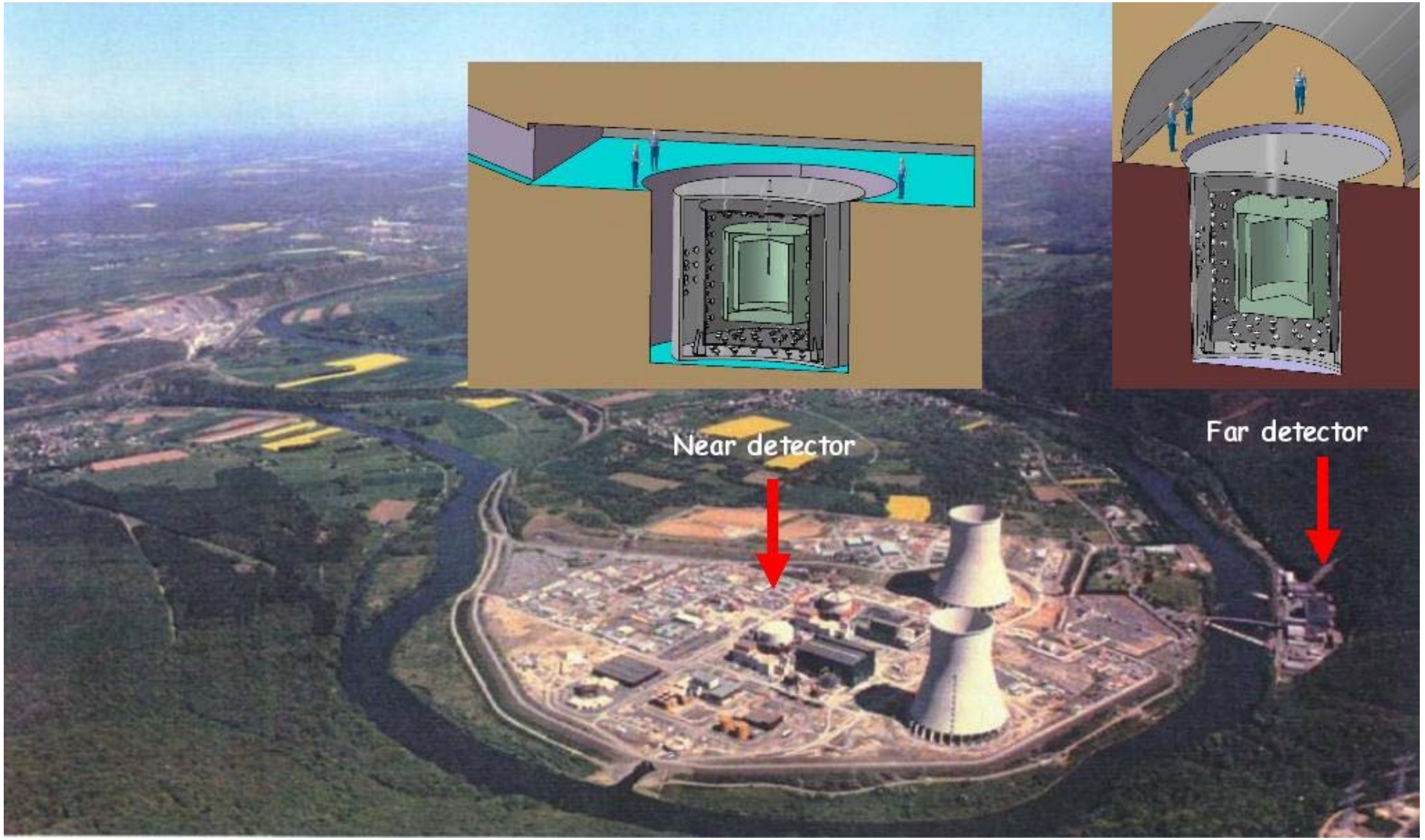
Double-Chooz (France)



After Blondel

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Summary

- **Several strong European activities *as part of the world-wide effort* are making steady progress**
- **Rising up the political agenda**
  - **squeezed by the LHC and the ILC**
- **Needs a strong US programme**
  - **Intellectually and financially**