Neutrino Factory R&D in Europe

Rob Edgecock/RAL
• Introduction  
  i.e. what has happened since last year
• European feasibility study
• Proton driver  
  superbeam developments
• Target
• Pion collection
• Muon front-end
• Muon acceleration

........with thanks to many people from whom I’ve stolen transparencies!
Last year: “…..or the art of [talking] for half an hour about nothing!”

- cut backs at CERN due to LHC
- largely not replaced by other labs
- general lack of funding

This year: some signs of improvement:

- funding from EC FP6 + ISTC
- uplift in (at least) one country
- more positive noises from CERN management
- future proposals to FP6/7
- work still being done..........
European Commission 6th Framework Programme:

• EC has defined various **actions to fund**

• many only for specific **thematic priorities**

• made substantial funds available – 17.5B€!

• some actions possible for PP
  ⇒ **ESGARD**

• **Coordinated a proposal against Integrating Activities**
  ⇒ **Coordinated Accelerator Research in Europe**

• **Exploited two activities:**
  - **Networking Activities** → **BENE**
  - **Joint Research Activities** → **HIPPI**
Superconducting RF (SRF)

CARE

management
Network

Joint
Research
Activities

30% ~0.3M€

30% ~0.7M€

30% ~0.45M€

90% 3.6M€

Joint Research Activities

Networking Activities

6th Framework Program Integrating Activities CARE project

linear colliders (ELAN)

proton accelerators (HEI-IHB)

neutrino beams (BENE)

65% ~5M€

90% 3.6M€

High Field Magnets R&D (NED)

High Intensity Proton Pulsed Injector (HIPPI)

Multipurpose Virtual Laboratory (GANIL)

Photo Injectors (PHIN)

Governance Structure

Networking Activities

Superconducting RF (SRF)
Other Possible FP6 Actions

Design Studies:
- 1\textsuperscript{st} round (March 2004): EUROTeV EURISOL
- 2\textsuperscript{nd} round: NuFactDS

New JRAs under CARE

New and Emerging Science and Technology

→ both discussed later
UK Funding Uplift

From UK Gov, mainly due to initiative started by Ken Peach

Good news: £21M from PPARC

Bad news:

- LC beam delivery: £9M
- Cockcroft Institute: £7M
- Oxford/RH Centre: £2M
- UKNF: £2M
- MICE: £1M £7.5M

→ Discussed later & WG3
A possible layout of a neutrino factory

H' linac 2.2 GeV, 4 MW
Accumulator ring + bunch compressor
Ionization cooling
Drift
Phase rotation
Target

Linac → 2 GeV
Recirculating Linacs 2 → 60 GeV

Decay ring = 60 GeV
= 2000 m circumference

ν beam to far detector
ν beam to near detector
European Feasibility Study

H-Source
0.18 GeV linac
3 GeV RCS
15 GeV RCS
Target and capture
Drift
Phase rotation
Cooling
2 GeV muon linac
2 - 8 GeV
8 - 50 GeV recirc. linac

Muon Accelerators
Muon Storage Ring

Neutrino Factory at RAL
CERN proton driver: SPL

Number of changes: politically technically

See Haseroth WG3
CERN proton complex

- linac upgrade for LHC
- driver for EURISOL/BB
- driver for NF
Collaboration/funding:

- **HIPPI: CARE JRA**
  - R&D of the technology for high intensity pulsed proton linear accelerators up to an energy of 200 MeV
  - 9 labs
  - 11.1M€ + 3.6M€ (EC) for 5 years (2004-2008)

- **IPHI collaboration:**
  - 3 MeV RFQ

- **ISTC:**
  - DTL with magnetic focusing (3-40 MeV)
  - DTL with focusing by RF quadrupoles (DTL-RFQ) (3-40 MeV)
  - Coupled Cavity DTL (40-100 MeV)
  - $1550 total
  - all prototypes delivered by summer 2006
3 MeV test stand

- 3 MeV test stand to be installed in the PS South Hall (in place for linac 4)
- Purpose: test essential front-end issues (hardware & beam dynamics)
- Made of IPHI RFQ + CERN chopper line + IN2P3 diagnostics line + 2 LEP klystrons (1 for the RFQ + 1 for testing other RF structures).
- Initial use of a standard CERN proton source, to be replaced by an H- source.
- The elements will be placed in the exact position foreseen for Linac4.
- Operation with beam: 2007

Chopper line (CERN)

IPHI RFQ (CEA/IN2P3)
RAL Test Stand

• "5MW" test stand also planned at RAL
• Builds on existing test stand for current ISIS upgrade
• Work done for the ESS
• Main aim is a further ISIS upgrade
• Directly relevant to Neutrino Factory
• Complementary to CERN:
  - different chopper, frequency, etc
  - more generic
• Also participating in HIPPI
• Close collaboration with CERN developing

See Findlay WG3
Three programmes:

- Shock studies of solid targets
- TT2A experiment
- HARP

See Fabich/Catanesi Plenary
Kirk/Bennett WG3
Electron beam tests:

- **Electron beam welding machine**
- **Only realistic possibility for lifetime test**
- **Correct energy density**
- **Only surface effect**
- **First test done**
Shock Studies

- Second test under consideration
- Improved experimental setup & diagnostics
- Results also relevant to T2K

Spectrometer output

- Simple numerical model

- Summed $\lambda$ Intensity
- Simple Theory

(Time in ms)
Shock Studies

Proton beam tests:

• Correct energy density available from PS & at ISOLDE
• Lifetime tests difficult
• PS will be used for mercury
• Solid target tests already done at ISOLDE
• Further tests planned, upgraded instrumentation
• Also relevant to T2K and CNGS
Data taking in 2001 and 2002
420M physics triggers, 1.5 to 15 GeV/c, many targets
Since then: understanding detector
First physics distributions: winter conferences 2004
Latest results: this week............
• Baseline collector in CERN layout: horn
• Standard for conventional neutrino beams

Two horns required to achieve focusing needed for the Neutrino Factory

See Fabich WG3
Three main issues being studied:
- lifetime due to pulsing: 300/600kA at 50Hz
- heating/lifetime due to beam
- optimisation of parameters for physics
• CERN “baseline”: all 88MHz linear channel

<table>
<thead>
<tr>
<th>80 MHz</th>
<th>Decay [m]</th>
<th>Rotation [cm]</th>
<th>Cooling I [m]</th>
<th>Acceleration I [MV/m]</th>
<th>Acceleration II [MV/m]</th>
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<tbody>
<tr>
<td>Length [m]</td>
<td>15</td>
<td>8</td>
<td>90</td>
<td>≈ 10</td>
<td>≈ 450</td>
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<tr>
<td>Diameter [cm]</td>
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<td>40</td>
<td>40</td>
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<tr>
<td>B-field [T]</td>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>quads</td>
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<tr>
<td>Frequency [MHz]</td>
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<td>80</td>
<td>80</td>
<td>80</td>
<td>80-200</td>
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<tr>
<td>Gradient [MV/m]</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4-10</td>
</tr>
</tbody>
</table>

Basically unchanged for 2 years
RAL Front-end Studies

- Two front-ends being studied at RAL:
  - inverse phase rotation chicane
  - cooling ring

S = solenoid, A = absorber, 36 cavities in blocks of 3

- Both currently being optimised (pre-GRID!)
• Split proton beam on to “4” targets + horns
• “Funnel” pions into same decay channel
• FODO focussing using quads, rather solenoid focussing

Table 1. Acceptances and transmissions.

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Cooling</th>
<th>$\epsilon_{\pi}$ [cm]</th>
<th>$\epsilon_{\mu}$ [eV·s]</th>
<th>$Y_{\mu/\pi}$</th>
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</thead>
<tbody>
<tr>
<td>Single target and solenoid</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td>0.3</td>
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<td>Multiple targets and AG channel</td>
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<td>6</td>
<td>1</td>
<td>0.77</td>
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</table>
Front-end R&D

- **Contributions to three projects:**
  - MuScat
  - MuCool
  - MICE

- **Two others in Europe:**
  - Frictional cooling
  - Laser ionisation of muonium
• Measurement of muon MCS as input to
  - cooling simulations
  - MICE
  - Geant

• Two data-taking runs at TRIUMF – 2000 & 2003

• Data analysis taken longer than expected(!):
  - high precision experiment
  - small fractions of a few people

• First results this week

See Murray Plenary
European contributions

- **Beamline and infrastructure:** UK, Switzerland
- **Tracking detectors:** Italy, Switzerland, UK
- **Particle-id detectors:** Belgium, Italy
- **Coils:** Italy, UK
- **RF-power:** Switzerland, UK
- **Magnetic field measurements:** Netherlands
- **Software:** Italy, Switzerland, UK
Some activity on RLAs:
- at CERN some time ago
- Saclay more recently

More recently, much activity on FFAGs:
- Saclay: beam dynamics studies
- CERN: development of FFAG simulations
- RAL: studies towards an isochronous, 16 turn, 8-20 GeV FFAG

150 MeV proton FFAG: horizontal & vertical beam envelopes
• Electron model of a non-scaling FFAG

• Much work done (by one person!)
  → parameters for 10-20 MeV machine
  15m in circumference

• Increasing EU participation:
  - high current p-driver
  - medical applications
  - ADS
  - ion acceleration
  - industry

• Have a candidate host lab: Daresbury
  - two possible injectors
  - some associated infrastructure

• Investigating funding, e.g. FP6
Conclusions

- Financial situation has improved
- Hopefully, this will continue!
- Focus on a number of projects to attract more people
- Proton driver:
  - very healthy
  - two test stands under development
- Target and collection:
  - TT2A
  - solid target shock studies
  - tests/simulations of horns
  - First HARP results soon
- Front-end:
  - First MuScat results
  - MICE progressing well
- Acceleration:
  - Focus on e-model FFAG