Harp

A hadron production experiment for the neutrino factory

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European R&D program towards the neutrino factory

- The **HARP** experiment at CERN PS (approved feb. 2000)
- Measurement of the large-angle scattering of low-momentum muon in liquid hydrogen
- Study of high-power (MW) targets
- Study of RF cavities in strong magnetic fields and under strong irradiation
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Main deliverables of Harp will be:

- **Input** to Neutrino factory/muon colliders design
- **Input** to Atmospheric neutrino fluxes calculation
- **Precise predictions** of the neutrino fluxes for the k2k and MiniBooNE experiments
- **Increase** of reliability of hadron generators in MonteCarlo simulation packages
Aim: hadronic $d\sigma/dP_t/dP_l$ - various beams and targets

- High statistics $O(10^6)/"settings"$ & Low systematics errors

**Goal**: 2% accuracy over all phase space

**Stage I**: proton/$\pi$ beam in the range 2-15 GeV/c, multiple solid + cryo targets
**Stage II**: Additional (cryogenics) targets and additional Deuterium/Helium beam
**Stage III**: 15-100 GeV/c beams (SPS)
The experiment exploitation requires:

- Momentum evaluation over 2 decades (100 MeV-10 GeV)
- Large acceptance (even backward)
- \( p/\pi \) separation
- \( K/\pi \) separation
- Electron/\( \pi \) separation

Pt vs. Pl. of secondaries for protons@15GeV on Be
The detector: **Acceptance, PID, Redundancy**

- Threshold gas Cherenkov: \( \pi \) identification at large \( P_t \)
- Drift Chambers: Tracking and low \( P_t \) spectrometer
- Target-Trigger
- TPC, momentum and PID (dE/dX) at large \( P_t \)
- 0.7T solenoidal coil
- 1.5 T dipole spectrometer
- TOF: \( \pi \) identification in the low \( P_t \) and low \( P_t \) region
- EM filter (beam muon ID and normalization)
An example of PID redundancy in the Pt-Pl plane

p/π separation at 4σ level, "conservative" simplification

Pt-Pl box plot of π distribution from 15 GeV p on Be thin target
pion distribution for 2 GeV protons on beryllium target (GFLUKA)
proton distribution for 1.5 GeV protons on beryllium target (GFLUKA)
Infrastructures

PS East Hall

- Experimental Hall available until end of 2001
- Subdetector assembling space defined
Beam Line

- We will use the T9 beam line @ PS

- The energy range \(1.0 \text{ GeV} \) \(15.0 \text{ GeV}\) with a momentum resolution of 0.24% is good

- The flux of protons and pions of \(~10^5\) per spill is adequate

- Beam optics design (PS/CA/99-027): \(~5\times5~\text{mm}^2\) beam

- Beam instrumentation checked and upgraded (XMWC+TOF+C for beam purity/normalization)
**TARGETS**

*General*: covering a range of elements

<table>
<thead>
<tr>
<th>Solid Material</th>
<th>Thin Target (cm)</th>
<th>Thick Target (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be</td>
<td>0.81</td>
<td>40.70</td>
</tr>
<tr>
<td>C</td>
<td>0.76</td>
<td>38.00</td>
</tr>
<tr>
<td>Al</td>
<td>0.79</td>
<td>39.44</td>
</tr>
<tr>
<td>Ni</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>0.30</td>
<td>15.00</td>
</tr>
<tr>
<td>Sn</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>Ta</td>
<td>0.22</td>
<td>11.14</td>
</tr>
<tr>
<td>W</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>0.34</td>
<td>17.05</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Criogenic (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$</td>
</tr>
<tr>
<td>D$_2$</td>
</tr>
<tr>
<td>N$_2$</td>
</tr>
<tr>
<td>O$_2$</td>
</tr>
</tbody>
</table>
Specific Targets
(only for certain projects)

<table>
<thead>
<tr>
<th>Neutrino Factory</th>
<th>Li, Ni, Ta, Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>K2K</td>
<td>60cm Al rod</td>
</tr>
<tr>
<td>MiniBooNe</td>
<td>65cm Be rod</td>
</tr>
<tr>
<td>(Minos)</td>
<td>76cm C or Be rod</td>
</tr>
</tbody>
</table>

The design and prototyping for the support plate + internal support for trigger fibres was realised.

In particular two support plates are required:
- thin and thick targets
- K2K and MiniBooNe targets
Trigger

- Trigger: internal (sci-fibs) AND external. TOF AND Cherenkov.

...and far TOF plane (10 m distance) for small angle particles!
Magnetic/Electrostatic Field studies
Yoke opened on one side and longer
New Internal cage, all along the TPC
New pad plane/HV membrane
New pad geometry

The TPC project status

Upgrades of ALEPH TPC90 based on existing experience.

dE/dx Res~6%
HARP TPC magnet 5 May 2000
HARP TPC magnet 5 May 2000
R&D "The TPCino"

Our TPC should work in a high rate $\sim 10^3$ Hz
(ex Aleph few Hz)

To test a full chain of the electronics: preamplifier +
Front-End Digitizer Card (FEDC: 10MHz ADC +
programmable 0-suppression + memory) developed
for the ALICE TPC a small prototype (~5x10 cm)
equipped with the a full electronic chain (24 channels)
was made

→ Results available soon !!
"Orsay" magnet (change of orientation) ready for test
Nomad Drift Chambers ready to be re-operated

Field = 1.5 T
Spectrometer magnet HARP
5 May 2000

To be finished:
Coil fixation, connections, controls.

Will be mapped in the East Hall
during the summer
C4F10 threshold mode

34 Chooz PMs EMI 9356KA

Electron background occupancy simulation vs. granularity

PM shielding requirements

Mirrors/focusing design scheme (and technology)

mechanical structure designs
Prototype mirror element
Upper half

Volume=9 m³
The TOF wall will be made using the scintillators of a previous experiment (~ 300 ps)
A new geometry was designed
A new Laser calibration system is under development

The eID will be made reusing some chorus pb/scintillating fiber modules
From the **Software** point of view, an experiment crossing the FORTRAN/OOP centuries is a **DIFFICULT** experiment!

**but we decided to look at the future**:  

- **Single-Platform**: **LINUX** (Online & Offline)  
- **C++** for Online/Offline  
- **OBJECTIVITY** as DB  
- **GEANT4** as simulation tool  
- **ROOT** as analysis frame  

**Comment**: **non negligible data rate!! ~ 30 Gb/ Hour**
Prototype of the TPC simulation in the GEANT4 framework

TPC Hits,
ArCO2
Mixture,
0.7T Field,
10 cm
C Target
Cherenkov Simulation

C4F10 Gas Volume

Polarized photon generation

Rayleigh Scattering

Optical Absorption Length

Aberrations (spectral n)

5mm Plastic Walls

Fresnel refraction (polarization included)

Alu Mirrors spectral efficiency

Multi-Hits:
- InGoing particles
- Mirror Hit
- Outgoing Optical Photon
Technical Run in Oct 2000:

- Hardware operational except TPC and Cherenkov;
- Beam operational;
- DAQ skeleton operational;

to achieve:

- commissioning of the beam over the full momentum range, with intensities and particle compositions understood;
- straight track data for alignment purposes and detector calibration;

PS Operation  
Period 3A 2000  Sep 25 to Oct 25

Schedule issue date: 14 Dec 1999  VERSION 1.0  (colours convention: red(dark) = scheduling meeting, green(light) = weekend or holiday)
Harp design and construction is advancing rapidly for all the subdetector and projects

Our schedule is very ambitious!
Technical run 25 september / 25 october 2000
Data taking 2001
Plans for a Phase II with D and He beams in the first half of 2002