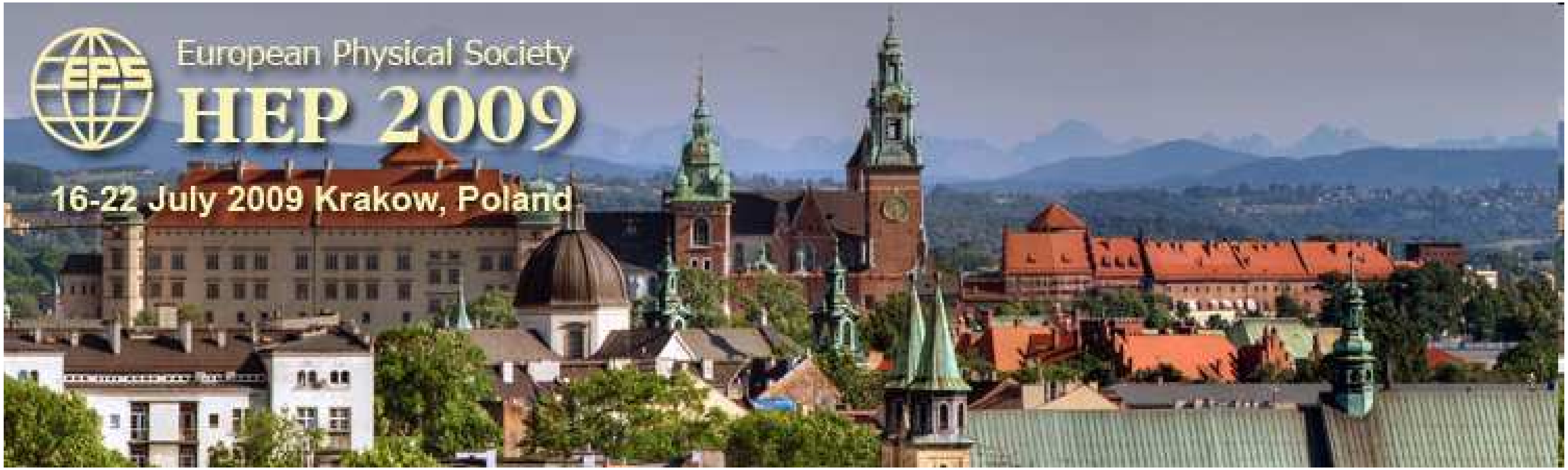
Neutrino Factory development

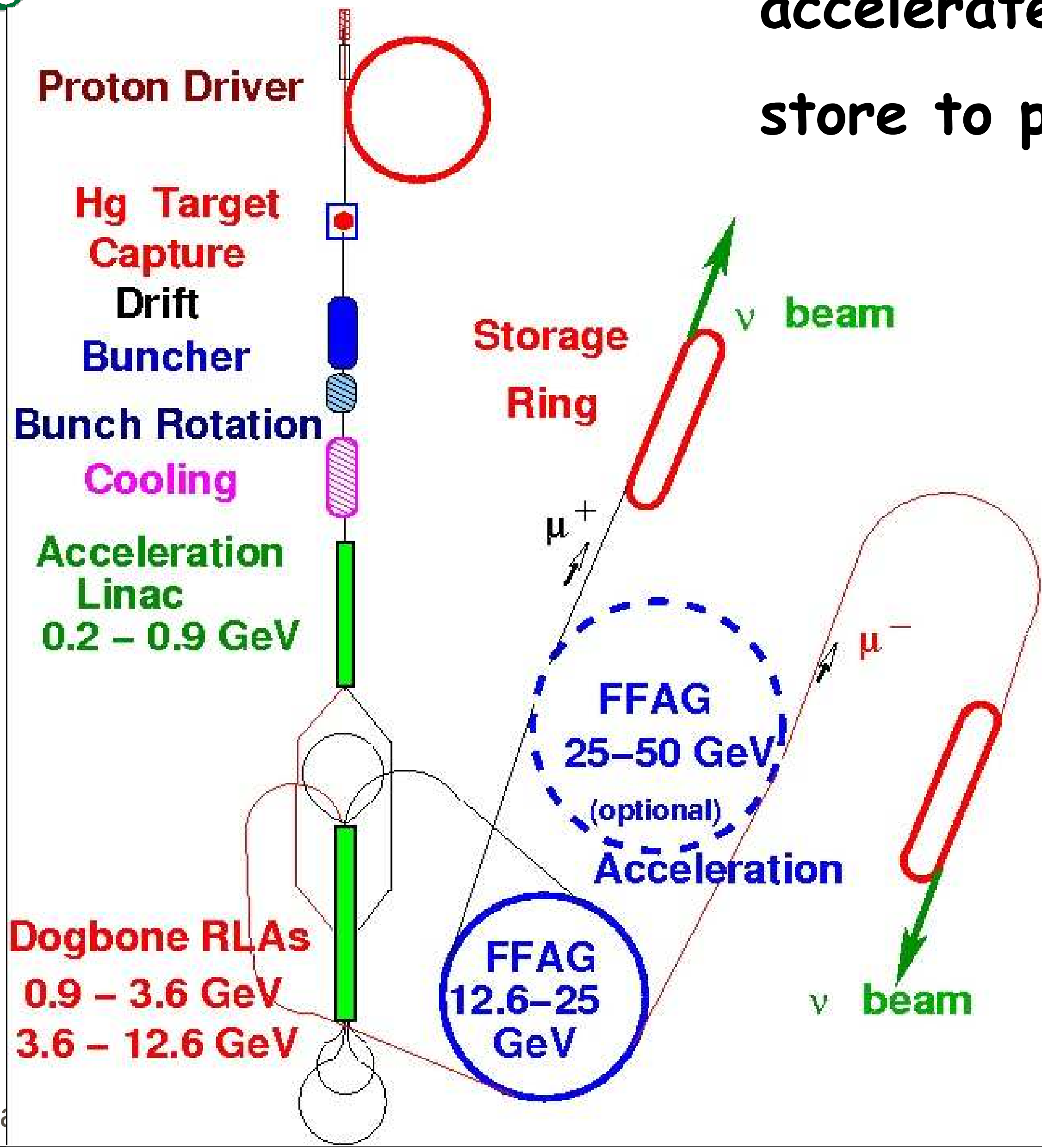
And the International Design Study



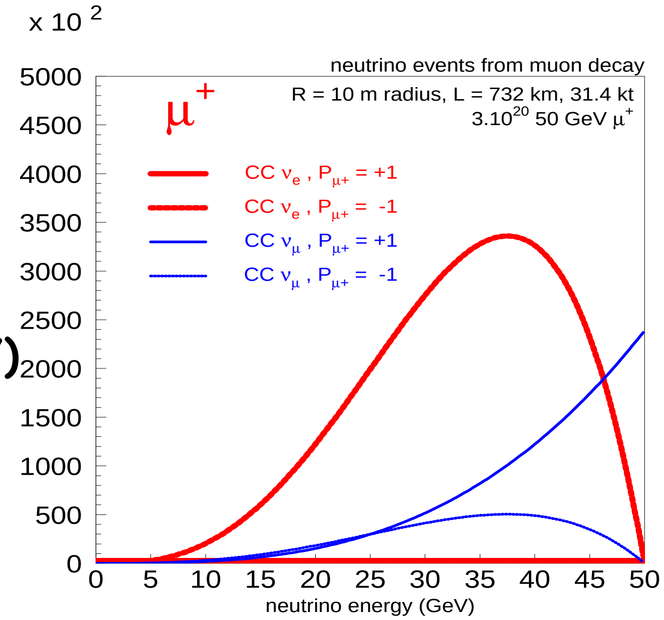
neutrino factory:

accelerate muons and

store to produce neutrinos



$$\mu^+ \to e^+ \nu_e \overline{\nu}_\mu$$



Unique: High energy electron neutrinos, spectrum extends up to ~muon energyabove tau production threshold (3.5 GeV) and matter resonance (~12 GeV)

Flux well known (10^{-3})

Appearance oscillation signal: wrong sign muons:

Golden channel:

$$\nu_e \to \nu_\mu ; \nu_\mu + N \to \mu^- + X$$

vs

$$\overline{\nu}_\mu \to \overline{\nu}_\mu ; \overline{\nu}_\mu + N \to \mu^+ + X$$

Detection « easy » : LARGE (100kton) magnetized iron neutrino detector (MIND) baseline detector.

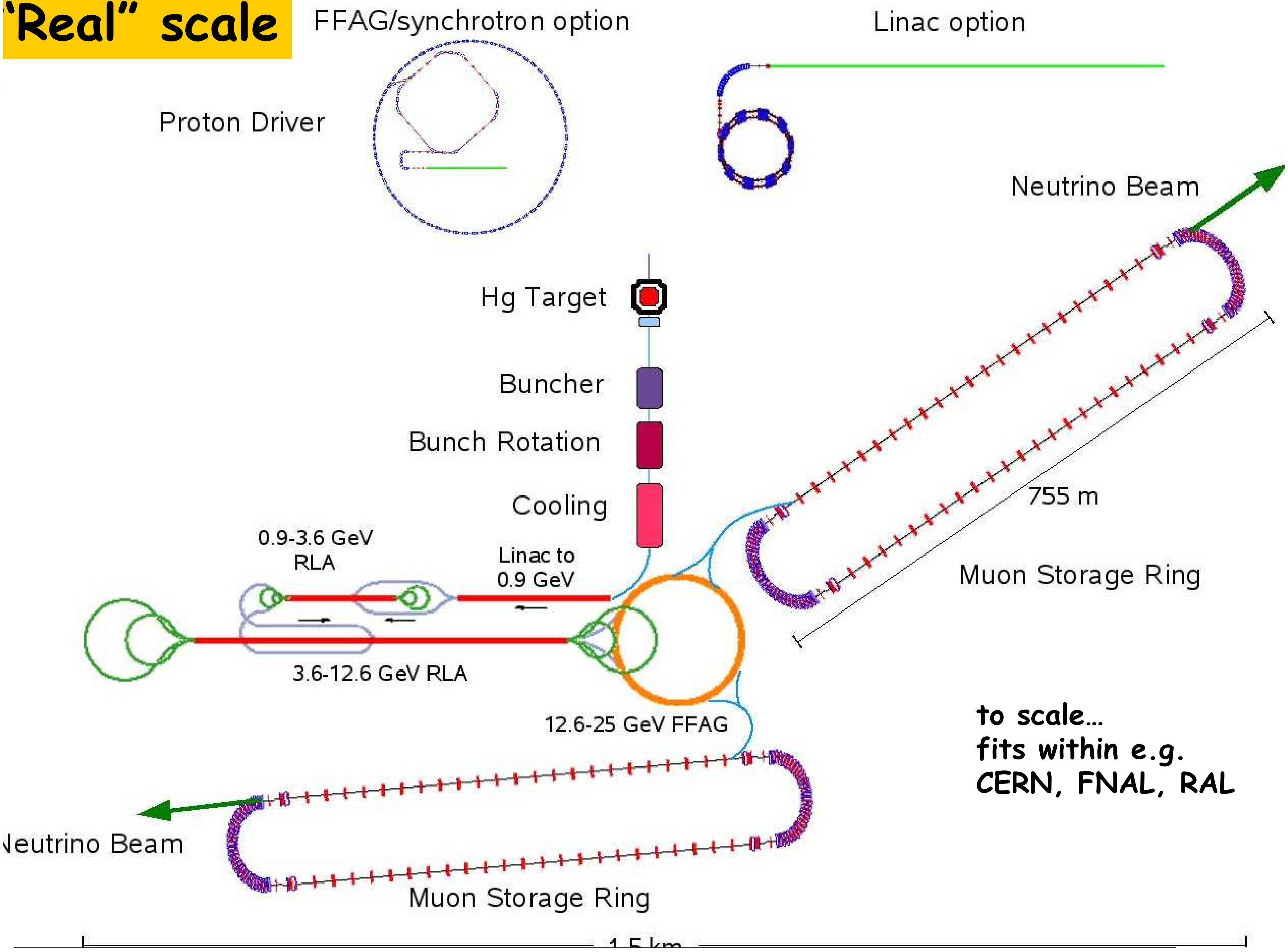
More difficult:

Silver channel: $\nu_e \to \nu_\tau ; \nu_\tau + N \to \tau^- + X$ wrong sign taus:

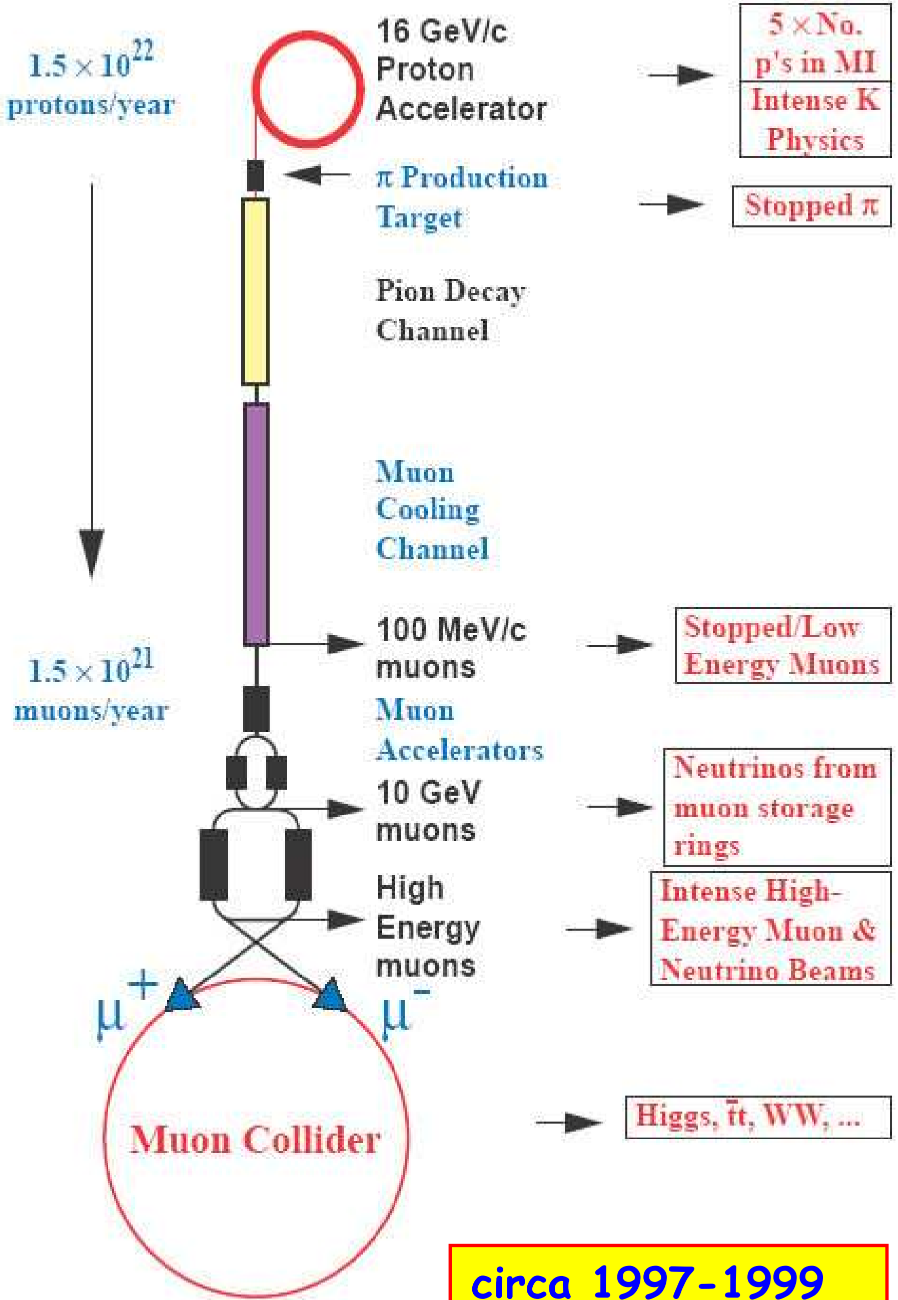
Platinum channel: $\overline{\nu}_\mu \to \overline{\nu}_e ; \overline{\nu}_e + N \to e^+ + X$ wrong sign electrons:

require emulsion or fine grain (Larg or TASD) detector in magnetic field – a challenge!

‘Real” scale

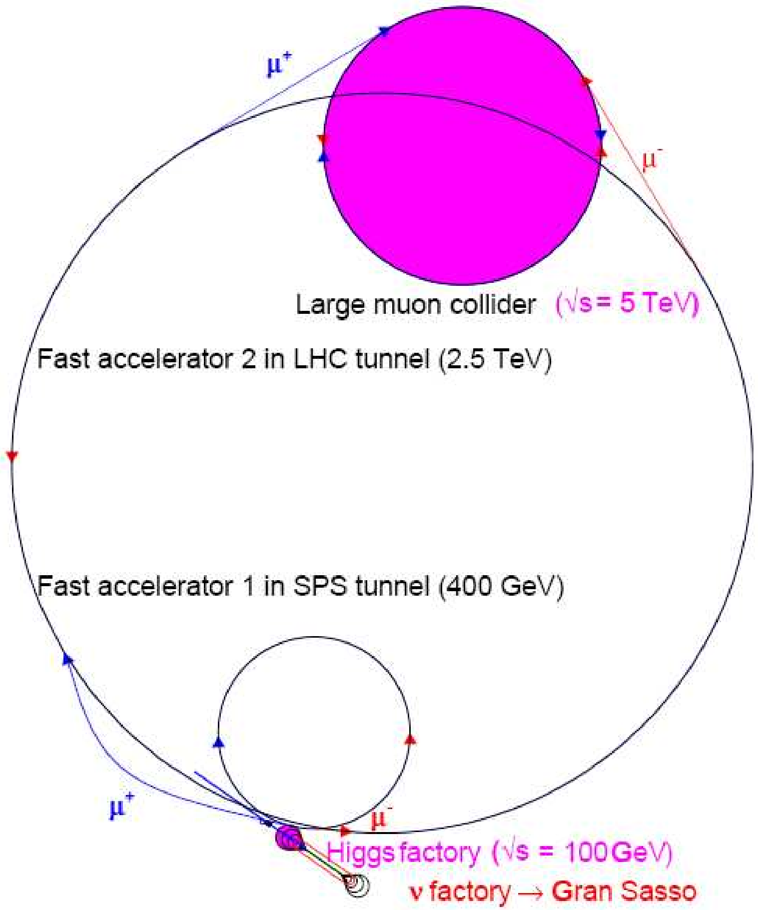


to scale…
fits within e.g.
CERN, FNAL, RAL



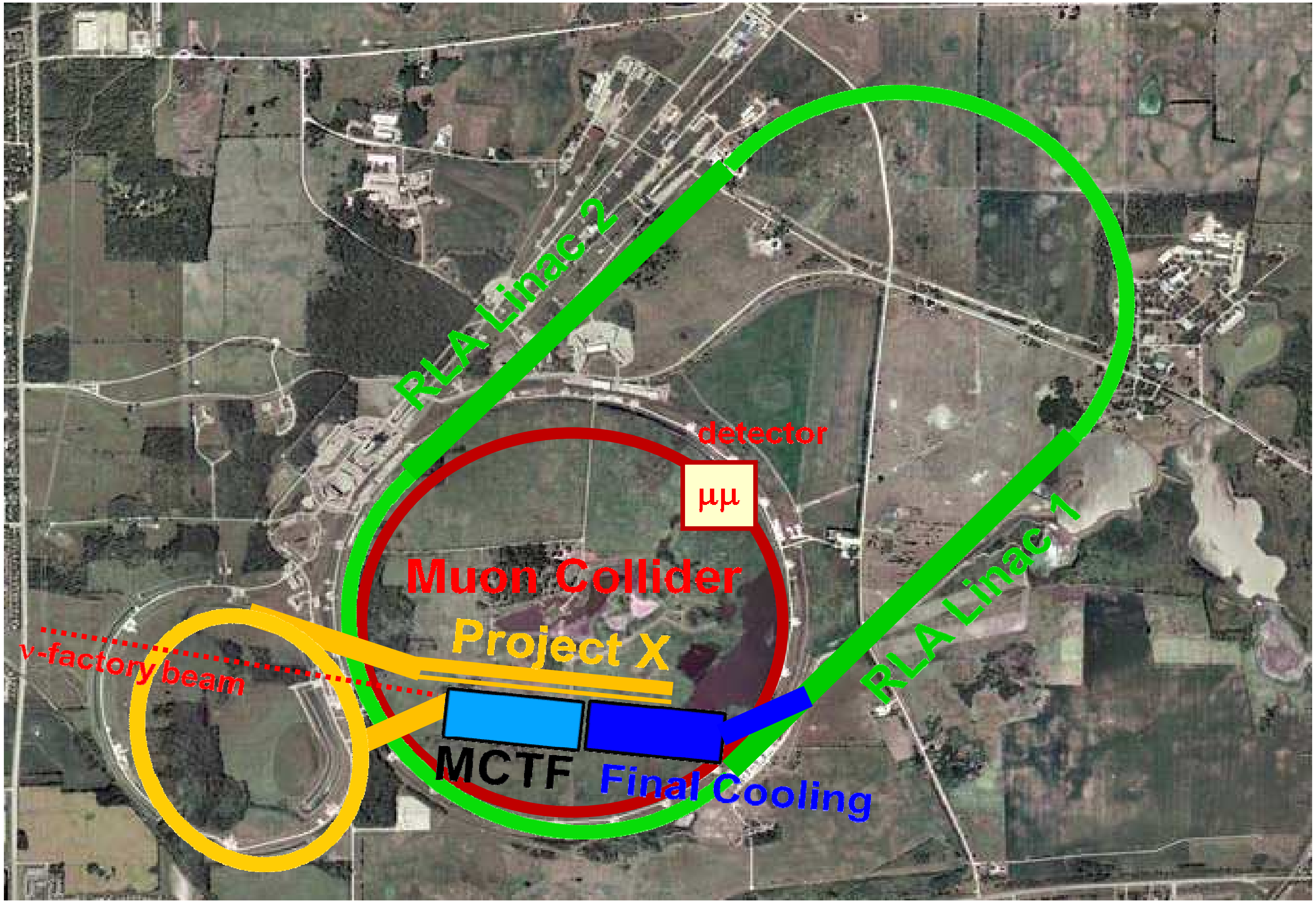
circa 1997-1999
US, Europe, Japan

Intense nucl. and hadr. physics
Intense Low-E muons
Neutrino Factory
Higgs(es) Factory(ies)
Energy Frontier -> 5 TeV



Possible layout of a muon complex on the CERN site.

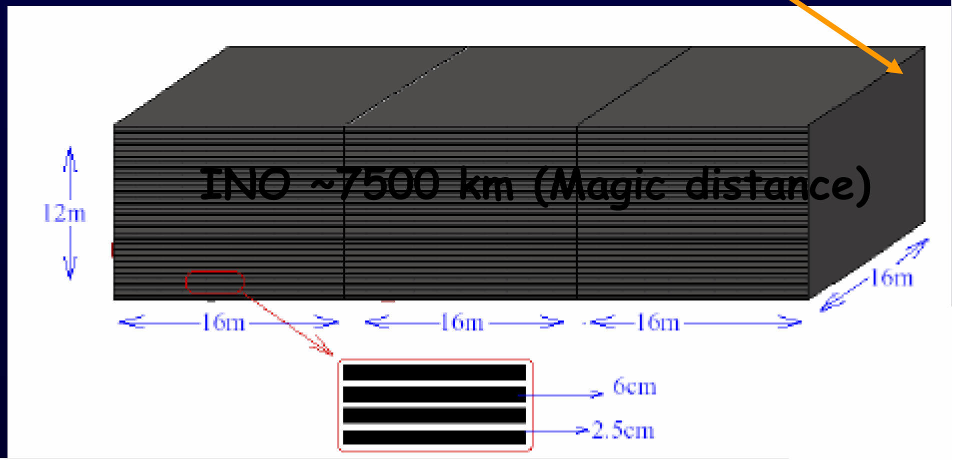
Fermilab Muon Complex - *Vision*



Laguna site!

Explore neutrino factory
or muon collider
as an option for the future.
Feasibility, cost

Long baseline detectors: Magnetized Iron, emulsions, liquid argon
Good baselines are: ~3000-5000 depending on muon threshold + 7500 km



References and Links

Original ideas in 1970's (Amaldi, Budker)

Neutrino Beams From Muon Storage Rings: Characteristics And Physics Potential
S. Geer Phys.Rev.D57:6989-6997,1998, Erratum-ibid.D59:039903,1999]

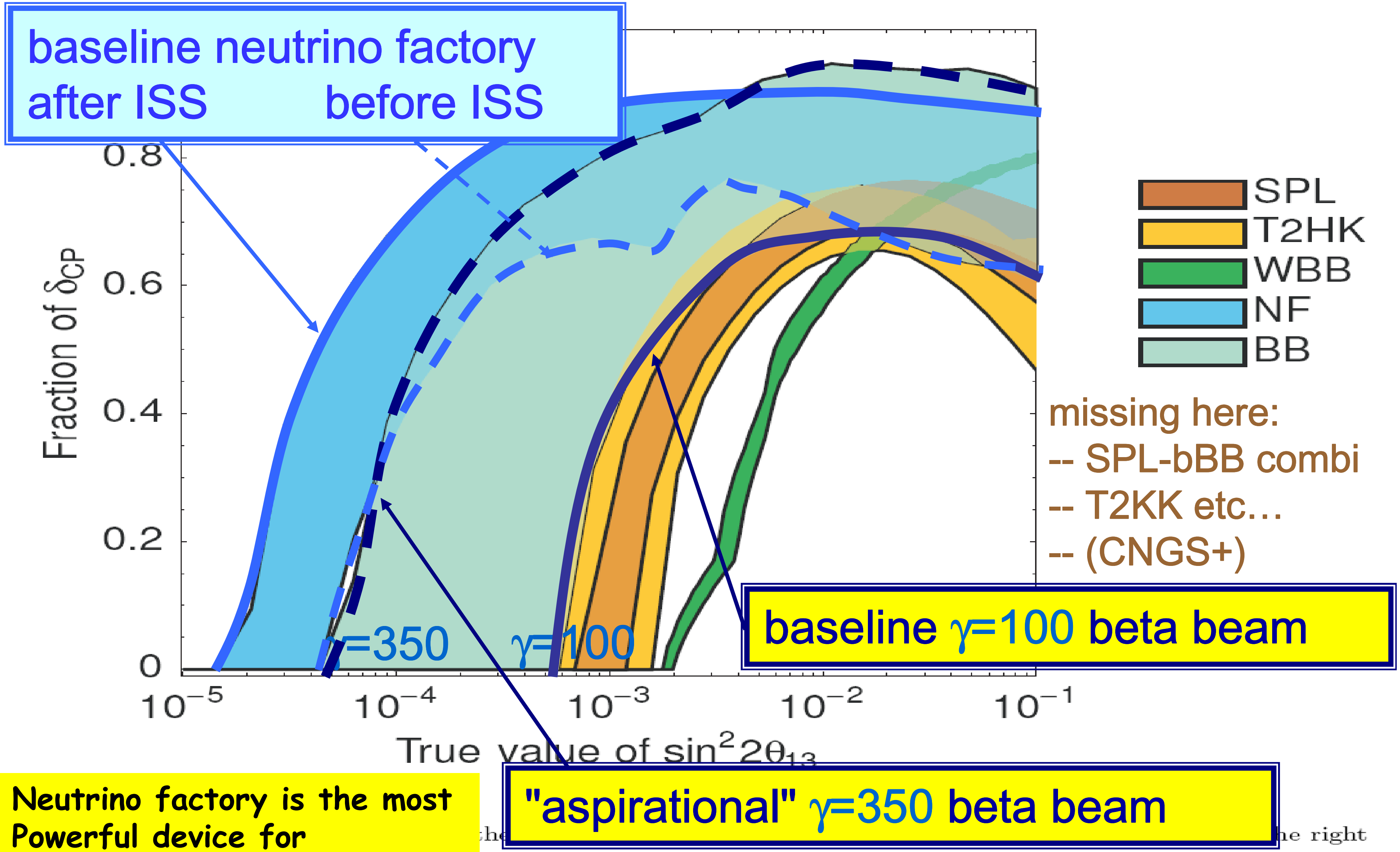
Prospective study of muon storage rings at CERN, ECFA-CERN CERN 99-02 (1999)

Study IIA Neutrino Factory and Beta Beam Experiments and Development,
C. Albright et al, BNL-72369-2004, FNAL-TM-2259, LBNL-55478,

ECFA-CERN study of a Neutrino Factory Complex
A. Blondel et al., eds. CERN-2004-002.- ECFA-04-230 March 2004.

ISS reports
Accelerator design concept for future neutrino facilities. arXiv:0802.4023
Detectors and flux instrumentation for future neutrino facilities. JINST 4:T05001,2009.
Physics at a future Neutrino Factory and super-beam facility. arXiv:0710.4947 [hep-ph]

ISS study
-- Performed comparison between proposed facilities
-- defined the baseline parameters.
to be followed-up quantitatively (R&D, feasibility, cost) ➔ International Design Study

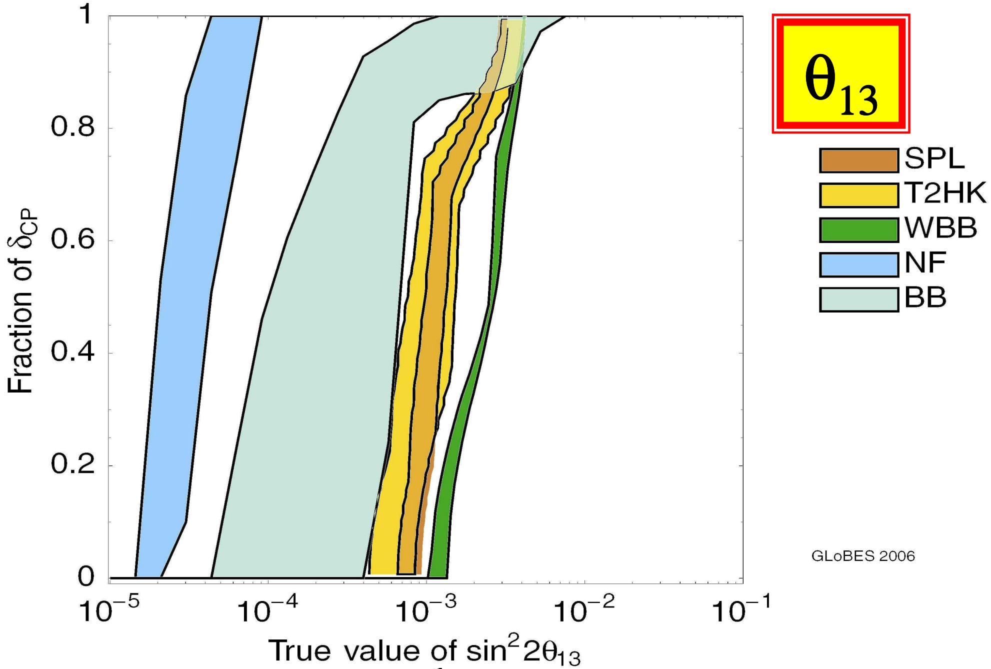


Neutrino factory is the most
Powerful device for
neutrino CP violation,
matter effects,
universality,
precise measurements of
Neutrino mixing parameters

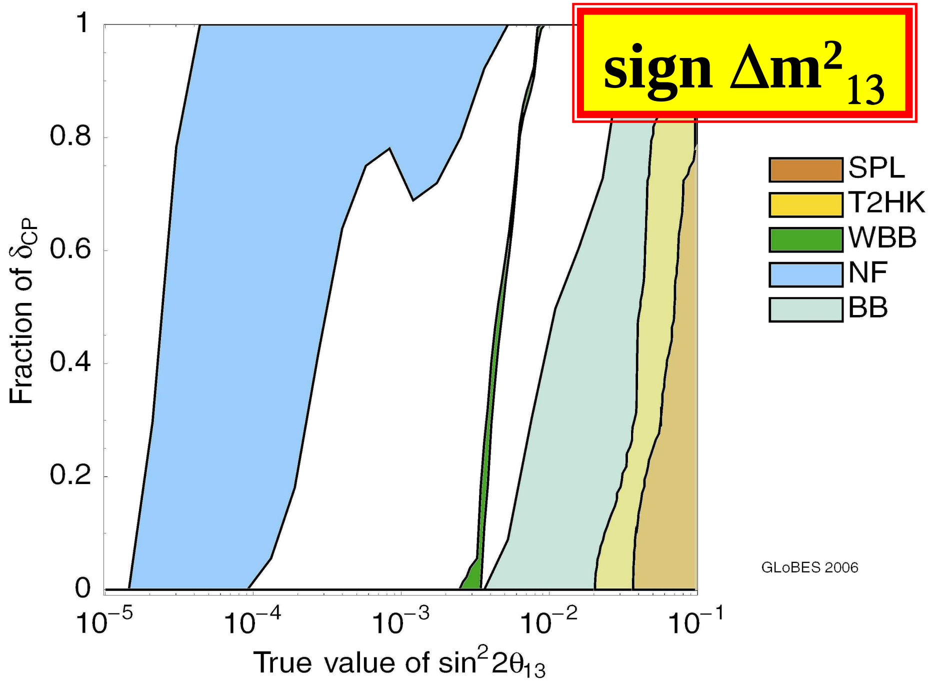
he ... he right
e excluded at the 3σ confidence level. The discovery limits are shown as a
values of the true value of the CP phase δ ('Fraction of δ_{CP}') and the true
ges of the bands correspond to the conservative set-ups while the left-hand
-ups, as described in the text. The discovery reach of the SPL super-beam
T2HK as the yellow band, and that of the wide-band beam experiment as
f the beta-beam is shown as the light green band and the Neutrino Factory
band.

Overall comparisons from ISS

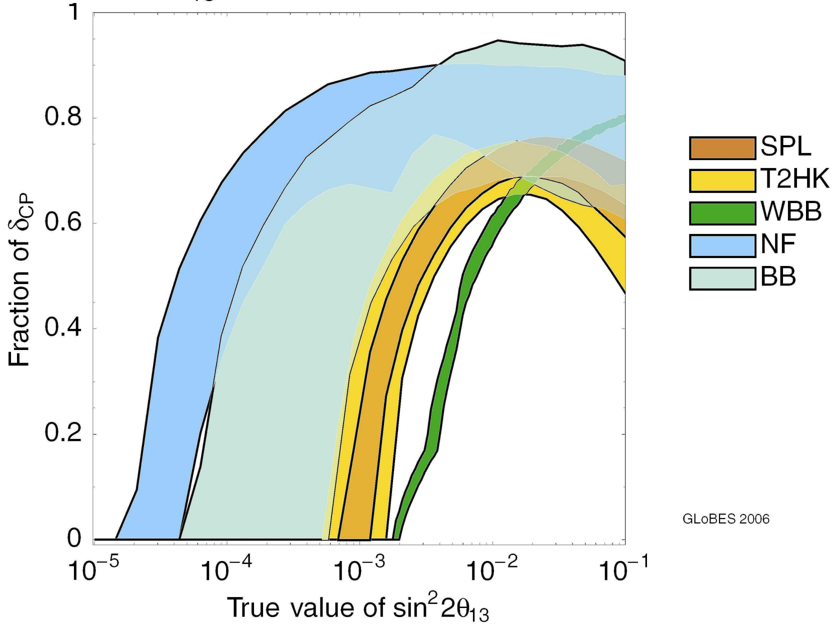
θ_{13}



sign Δm^2_{13}

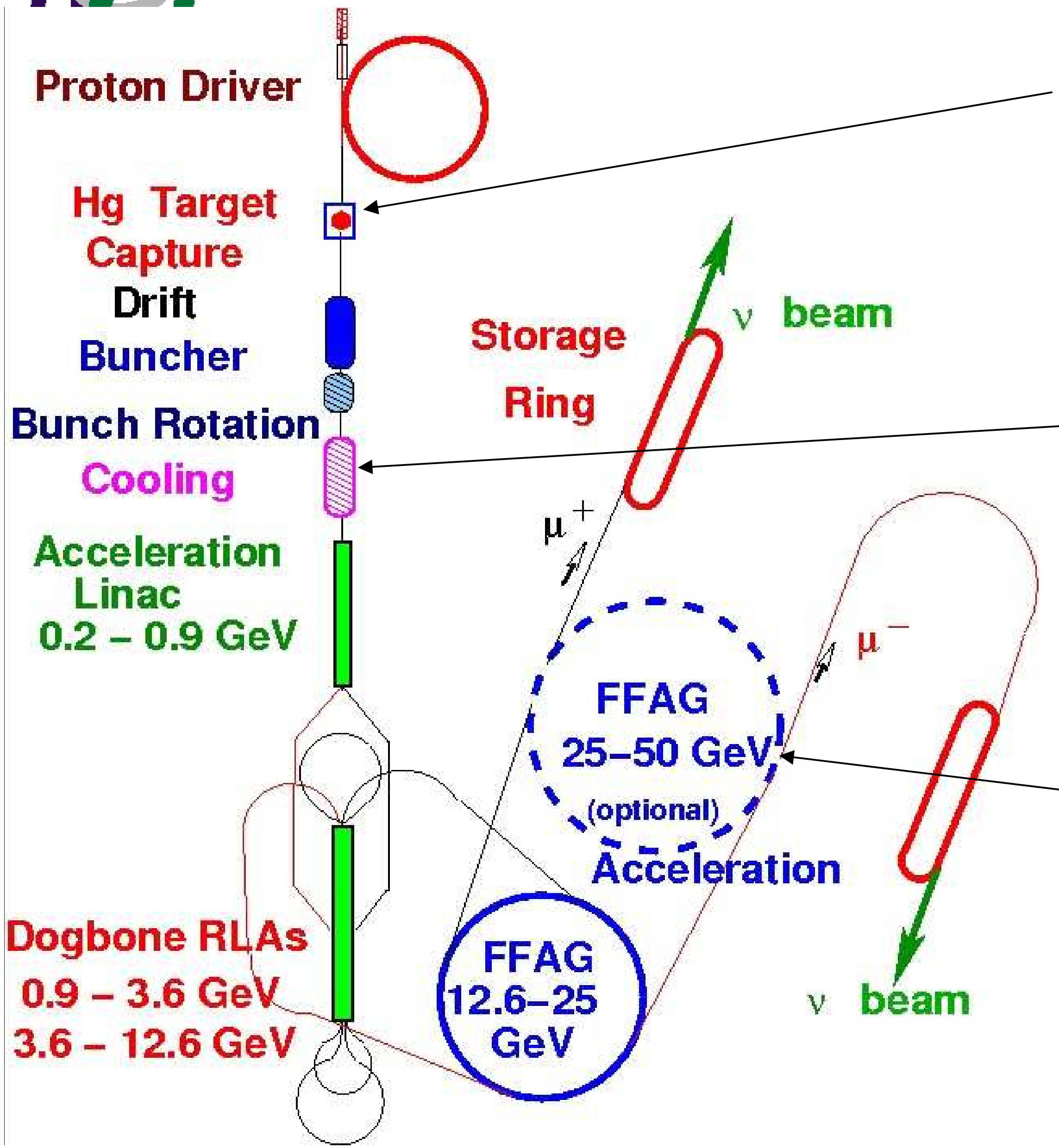


CP phase δ



NuFACT does it all…
(+ univ. test etc…)
but when can it do it
and at what cost?

Major challenges tackled by R&D expts



High-power target
- 4MW
- good transmission

MERIT experiment (CERN)

Fast muon cooling
MICE experiment (RAL)

Fast, large aperture accelerator (FFAG)
EMMA (Daresbury)

ISS baseline

Neutrino Factory Assets and Challenges

-- 'new accelerator' (never built) but studied since 1996.

-- 'small' collaboration (~100-200) but strongly international

-- particle production from target well known (e.g. HARP)

-- target technology (Hg jet) established to >= 4MW (MERIT!)
but target station issues (radiation and safety) need to be addressed locally!

-- principles of ionization cooling and phase rotation well understood
but achievable gradient for ~200 MHz cavities in 2-4 T mag. field not well known
never done, need demonstration (→ MUCOOL, MICE)

-- acceleration schemes for muons well developped
but experience with non scaling FFAG is missing (→ EMMA)

-- detector issues: (will require test beam exposure of proto to 0.5-10 GeV particles)
threshold for muon detection in MIND
tau detection in calorimetric detector
electron detection with charge assignement
near detector design and storage ring instrumentation (polarization meast etc…)

-- cost estimate and optimization of facility

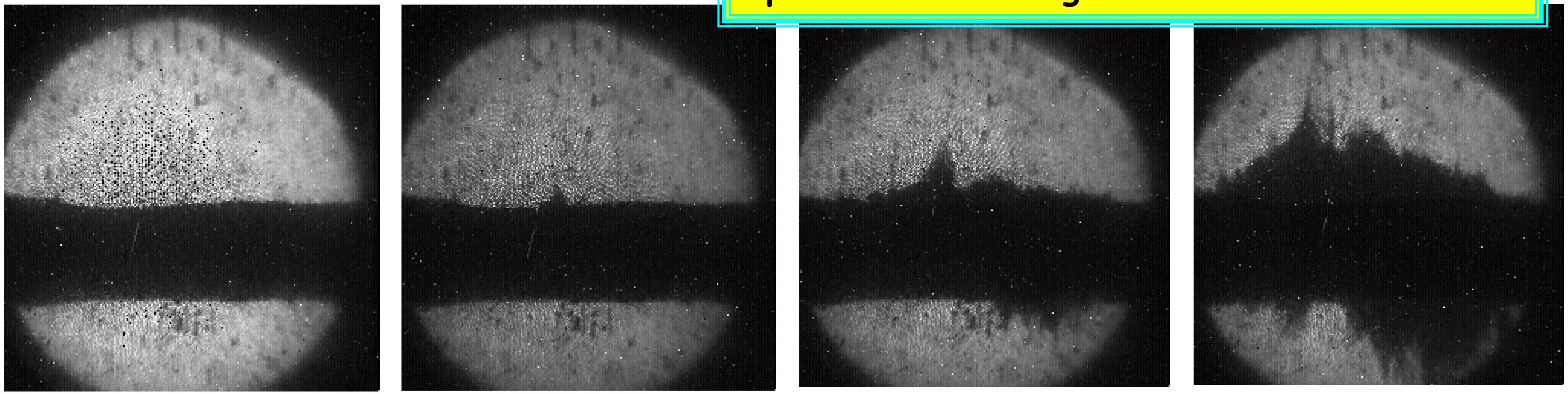
MERIT EXPERIMENT at CERN

BNL, MIT, ORNL, Princeton University CERN, RAL

Splash velocity – 24 GeV beam

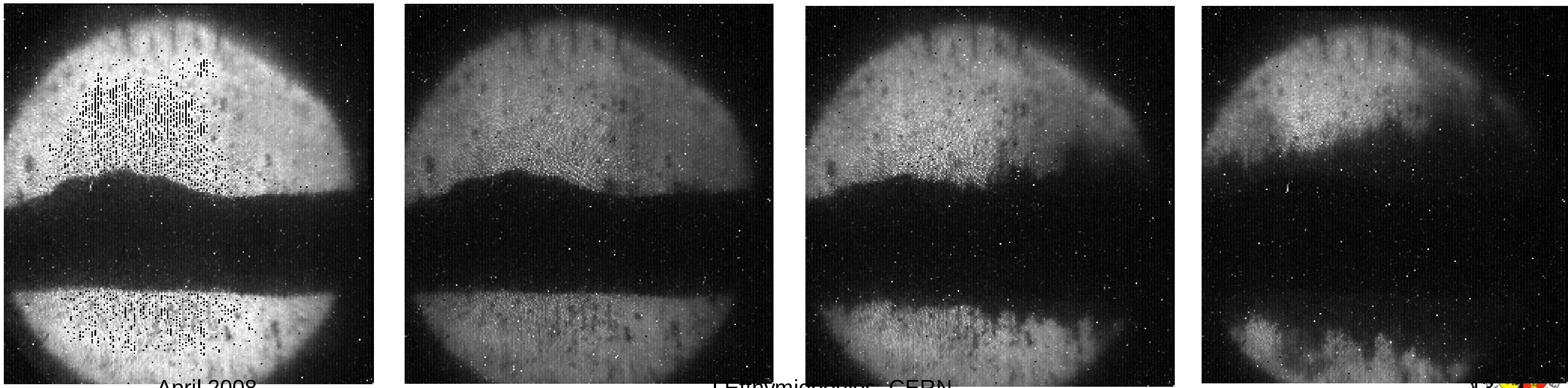
Demonstrated liquid mercury jet technology for neutrino factory and muon collider up to 8MW on target *Oct22-Nov12 2007*

10TP, 10T ***V = 54 m/s***



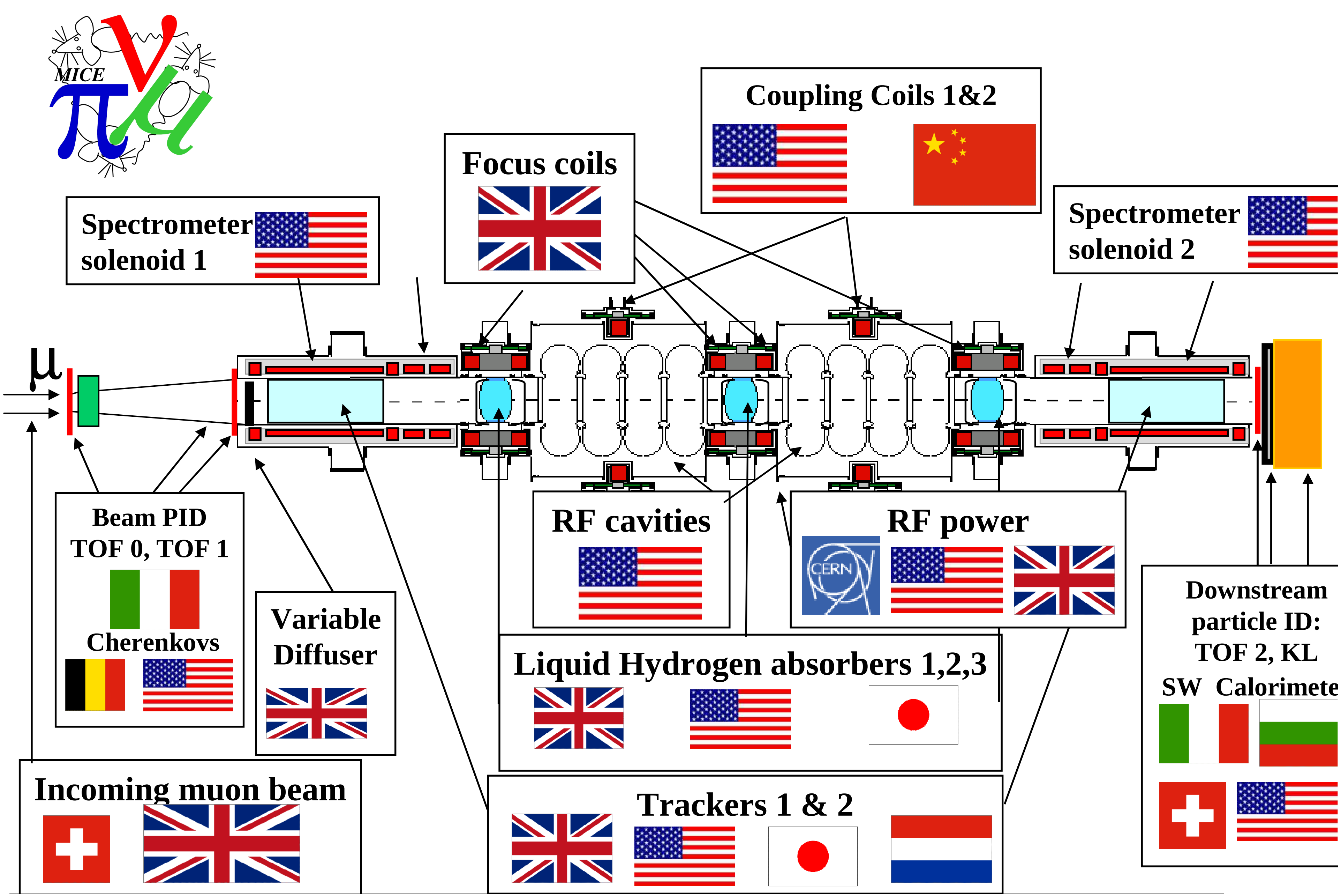
t=0 *t=0.075 ms* *t=0.175 ms* *t=0.375 ms*

20TP, 15T ***V = 65 m/s***

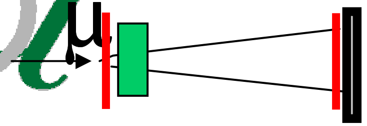


t=0 *t=0.050 ms* *t=0.175 ms* *t=0.375 ms*

Muon Ionization Cooling Eexperiment (MICE) Collaboration

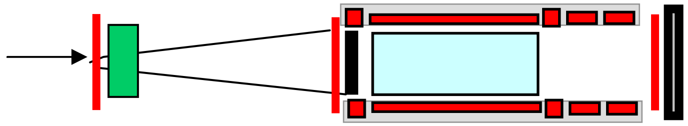


MICE Schedule as of April 2009



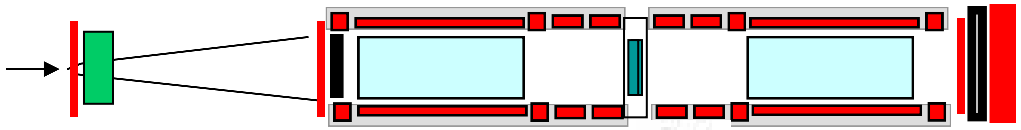
STEP I

Run: Sep09



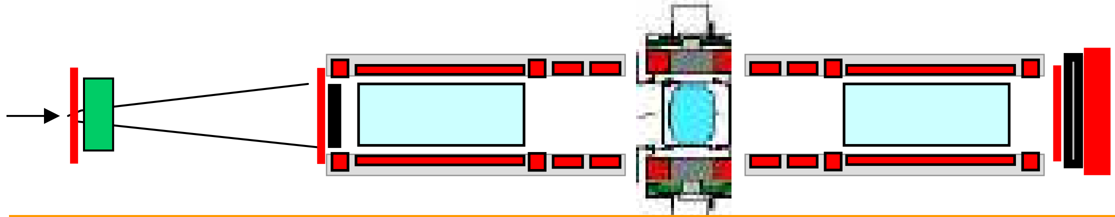
STEP II

Run: Q4 2009



STEP III/III.1

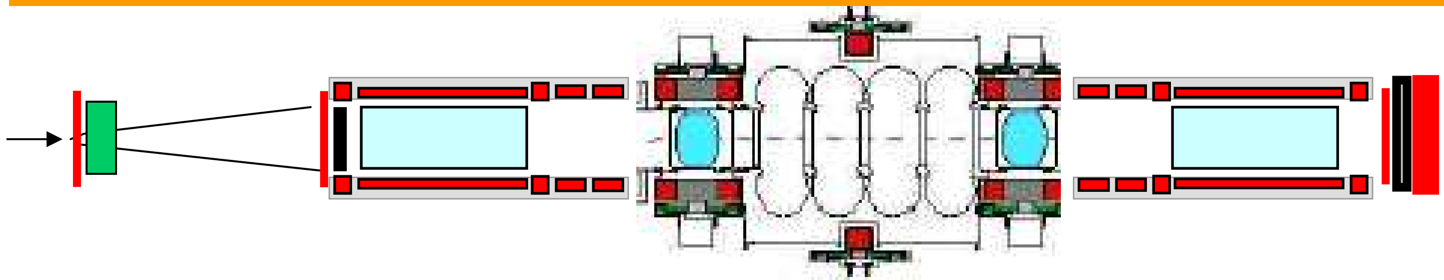
Run: Q1 2010



STEP IV

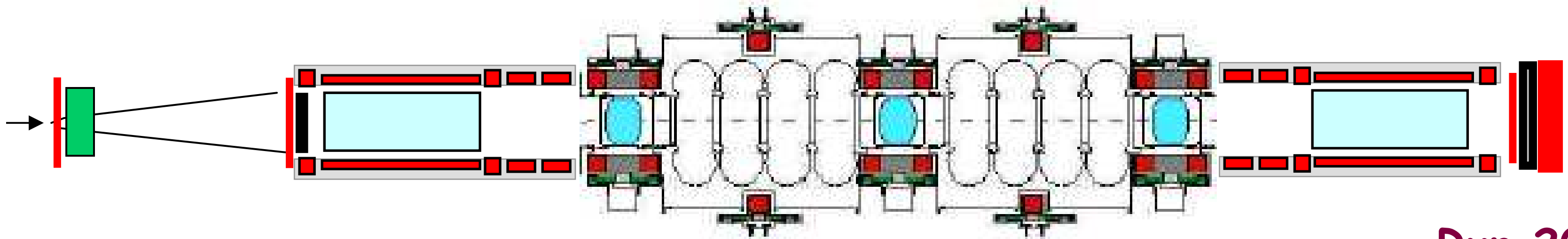
Run: Q2 2010

----------- ISIS shut-down (provisional) Aug 2010-Apr 2011 -----------



STEP V

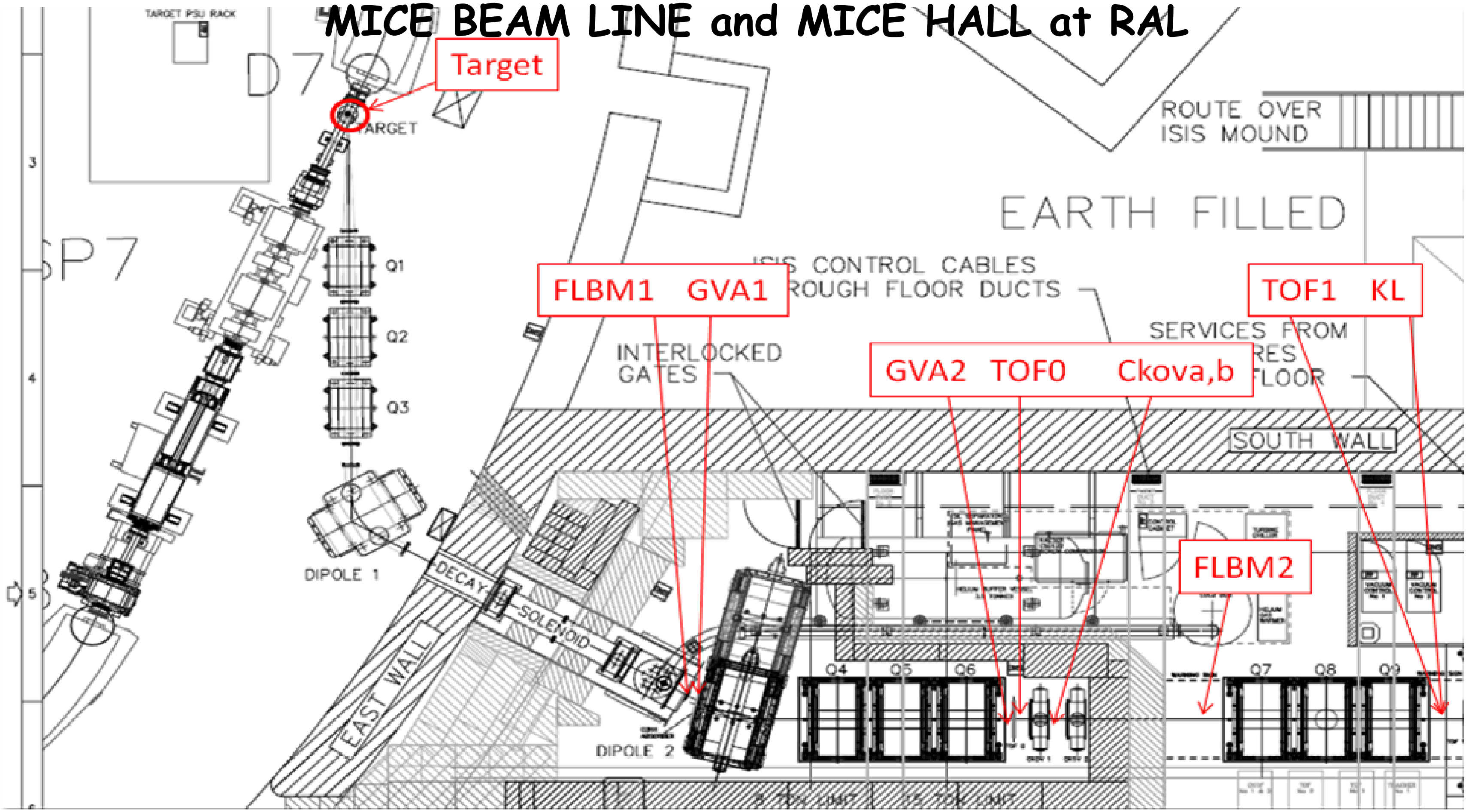
Run: 2011



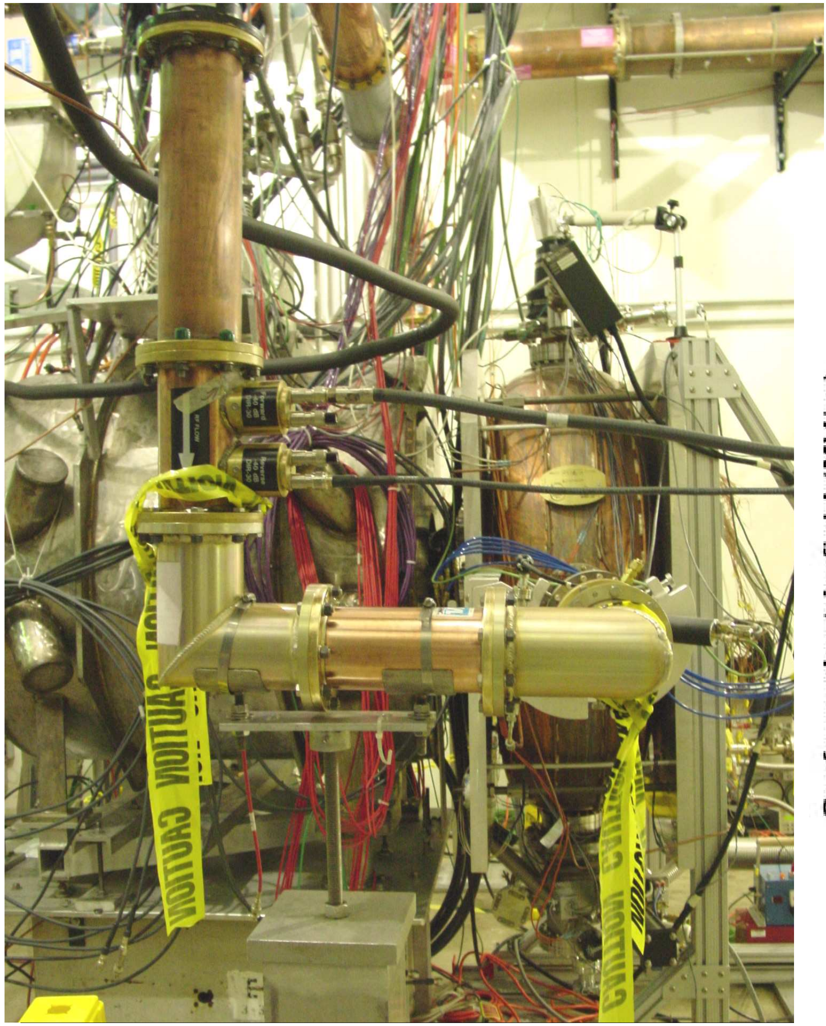
STEP VI

Run 2012

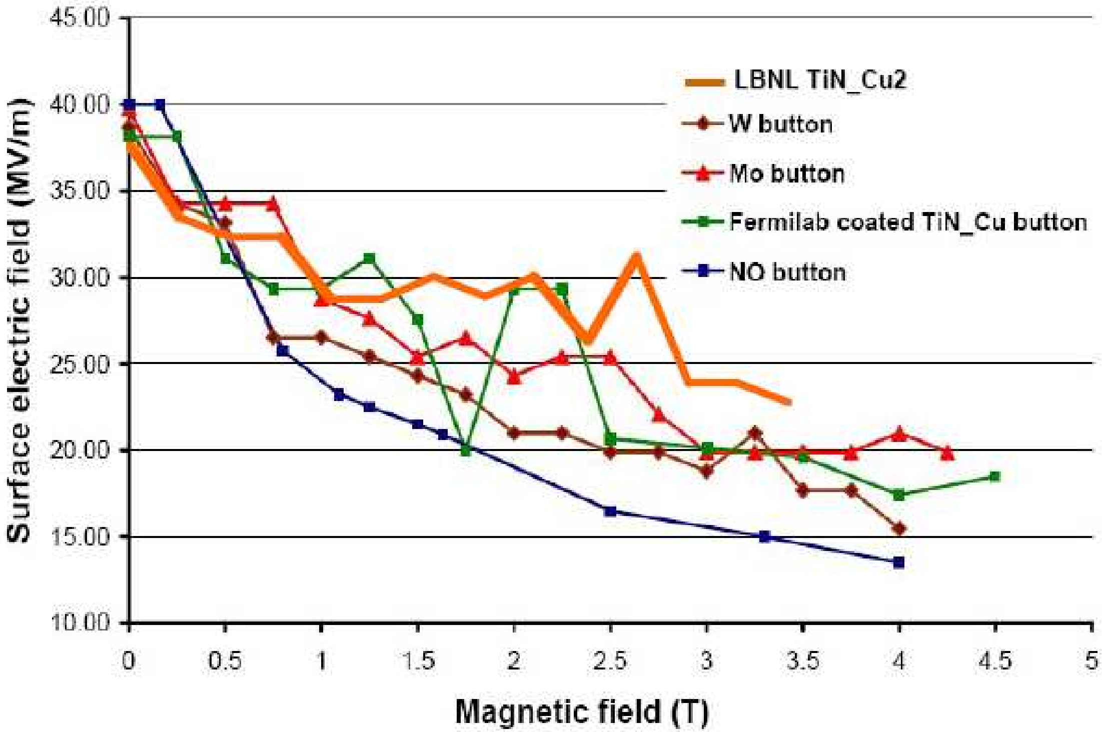
MICE BEAM LINE and MICE HALL at RAL



MUCOOL test area at FNAL.



Maximal achievable surface electric field



International Design Study IDS-NF

The collaboration

International Design Study of the
Steering Group Neutrino Factory

A.Blondel, K.Long (chair), M.Zisman, Y.Kuno

Physics and Performance Evaluation:
A.Donini, P.Huber, S.Pascoli, W.Winter

Accelerator:
S.Berg, Y.Mori, C.Prior, J.Pozimski

Detector:
A.Bross, A.Cervera, N.Mondal, P.Soler

https://www.ids-nf.org

EU component is part-funded via EUROnu

Aim: produce CDR for 2012

'CDR' implies:
Physics performance of *costed* scenario
Conceived as input to cost/performance comparison required at C.E.R.N.
Council Strategy Group 2012 decision point

Conclusions

The neutrino factory studies have demonstrated outstanding capabilities in reach and precision for θ_{13} , Δm^2_{13}, neutrino CP violation and unitarity.
Some features are unique.

The accelerator R&D is proceeding
MERIT has demonstrated the liquid target technology
MICE, MUCOOL and EMMA are underway.
Detector prototypes and tests are being planned.

An International Design Study has begun to establish cost and performance of a well-defined baseline setup by 2012/2013.

Opportunities exist in Europe in particular with the upgrade of the LHC injector chain (SPL)