Neutrino Factories and Muon colliders

Alessandra M. Lombardi

- **Machine specifications for Neutrino Factory and Muon Colliders**

- **Fundamental components proton driver,**
  pion production,
  muon capture and cooling (front end),
  muon acceleration and decay/collider ring.

- **Trade-offs, open questions, necessary and ongoing R&D**

- **Questions and feedback**

Emphasis on nufact

efforts going on world wide

list of the active groups NFWG, Feasibility study I , Feasibility study II, 6^{th} months multi tev collider , japan

copy of the agenda I will not speak about technical details of eachparticular choice but the physics motivation behind each choice; details in the talks that follow physics at a neutrino factory

- neutrino oscillation (ratio 1:1 of ν_e/ν_μ)
- CP violation (choice mu+ mu- at different time)
- matter effects

physics at a muon collider
low energy and high energy frontier

- no bremstrahlung
- Higgs factory
- precision studies of new particles
- good energy resolution and calibration

goals of a neutrino factory

- flux 10^{21} muons/year in the decay ring
- energy 50 GeV (minimum)
- both sign muons but not at the same time
- divergence less than $0.1/\beta\gamma$ (0.2 mrad at 50 GeV) i.e 6d normalised emittance $5\ 10^{-5}\ m^3$

rapid acceleration, reduction of the transverse phase space, good efficiency

goals of a muon collider

- flux 10^{21} muons/year in the collider
- high energy muon beam 400 GeV to 30 TeV
- 6d normalised emittance : $10^{-10}\ m^3$

rapid acceleration, reduction of the trans & long phase space, good efficiency

the general mechanism for a neutrino factory/muon collider

1) A proton beam bombards a target. Pions are produced isotropically and are collected in the forward direction.

2) pions decay into muons

3) muons are captured in a RF system, their energy spread reduced, their transverse phase space density increased (phase rotation and cooling) and then

4) the muons are accelerated to 20-50 GeV (neutrino factory) or more (100 GeV to several TeV) and then

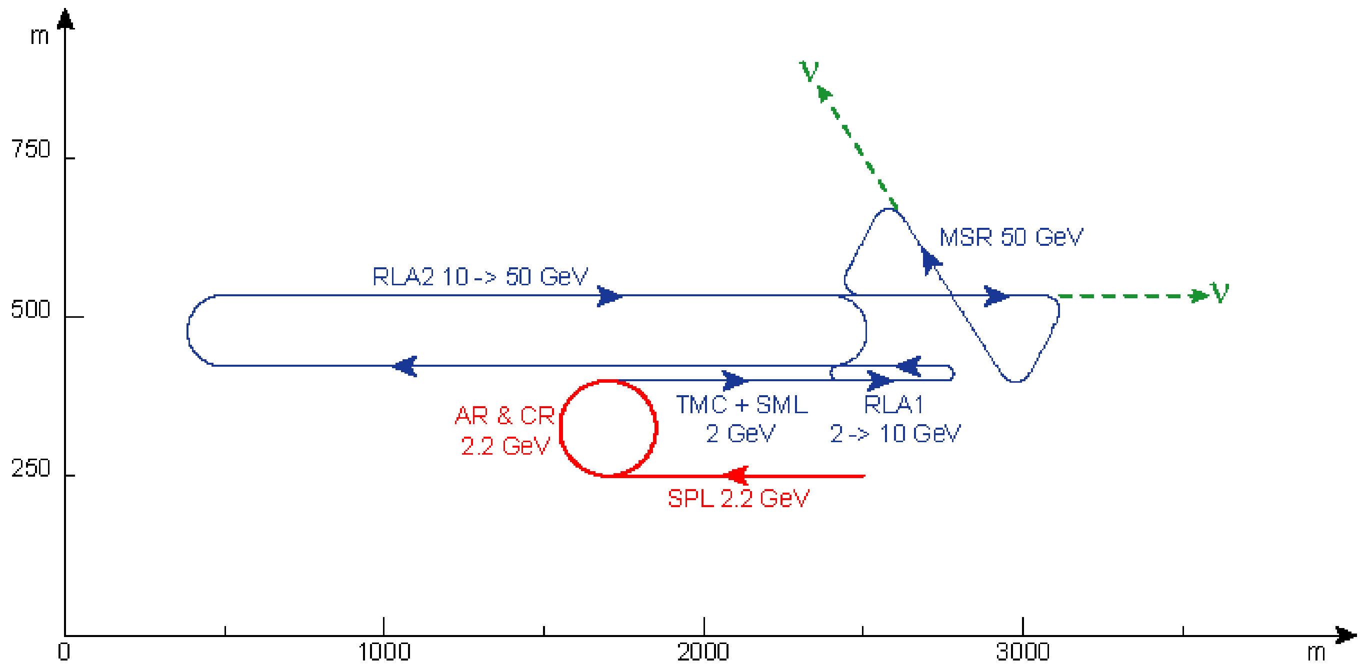
5a-neutrino factory) the muons are injected in a decay ring, with straight sections pointing towards the detectors, where they decay into neutrinos

5b-muon collider) the muons are injected in a collider ring

layout of a neutrino factory
CERN proposal

Layout of Neutrino Factory

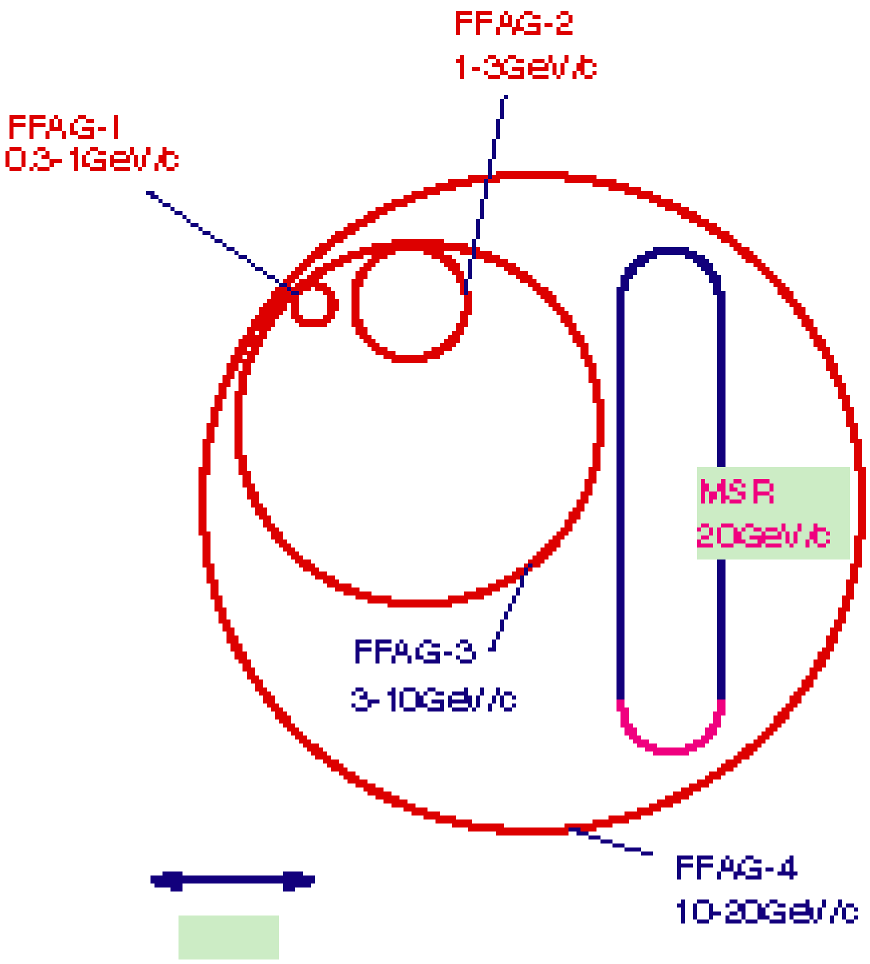
(preliminary) - E. Keil



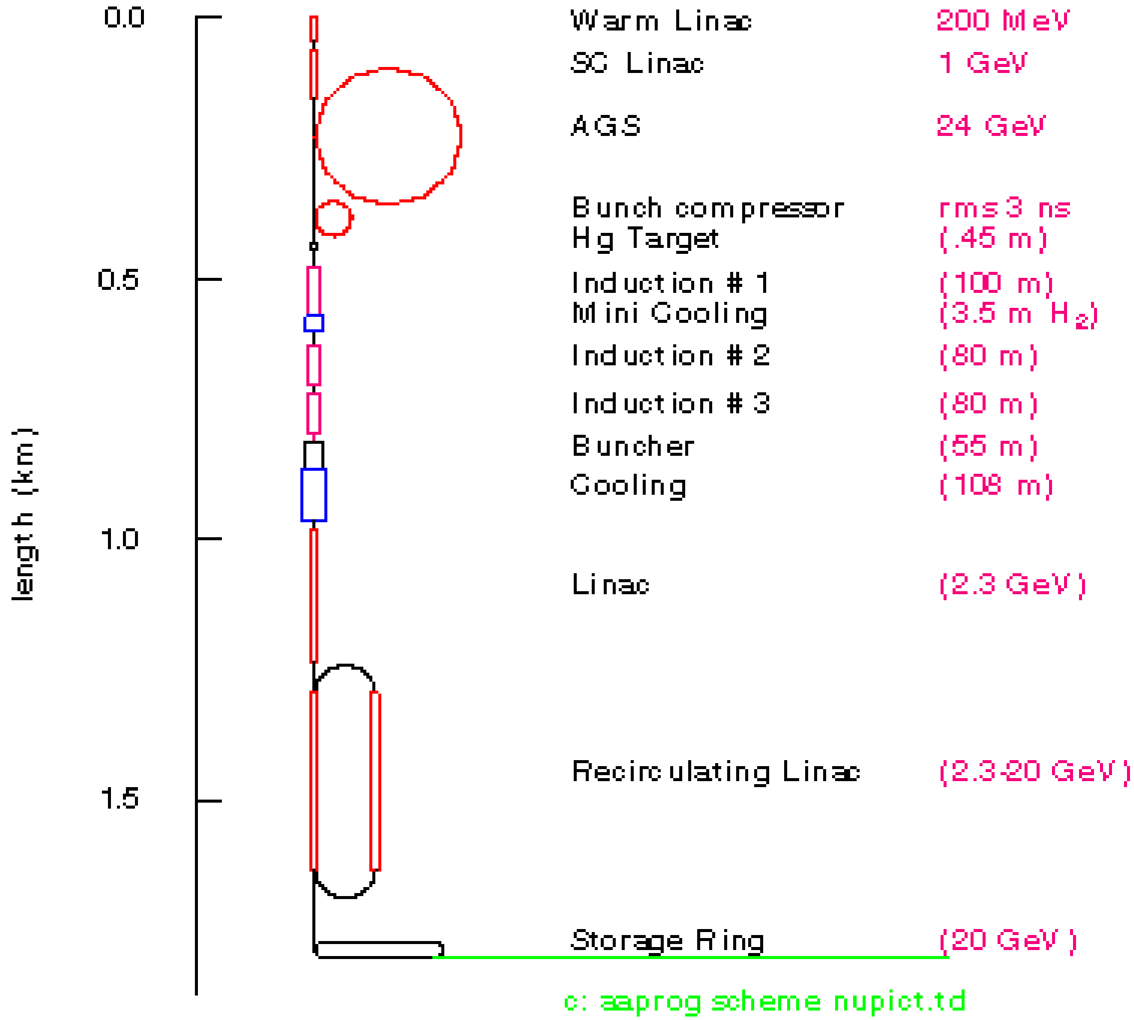
SPL: Superconducting Proton Linac
AR: Accumulator Ring
CR: Compressor Ring
TMC: Target + pion/Muon Collection

SML: Superconducting Muon Accelerator
RLA: Recirculating Linear muon Accelerator
MSR: Muon Storage Ring

layout of a neutrino factory
KEK proposal



layout of a neutrino factory
STUDY II proposal



layout of a neutrino factory
STUDY I proposal

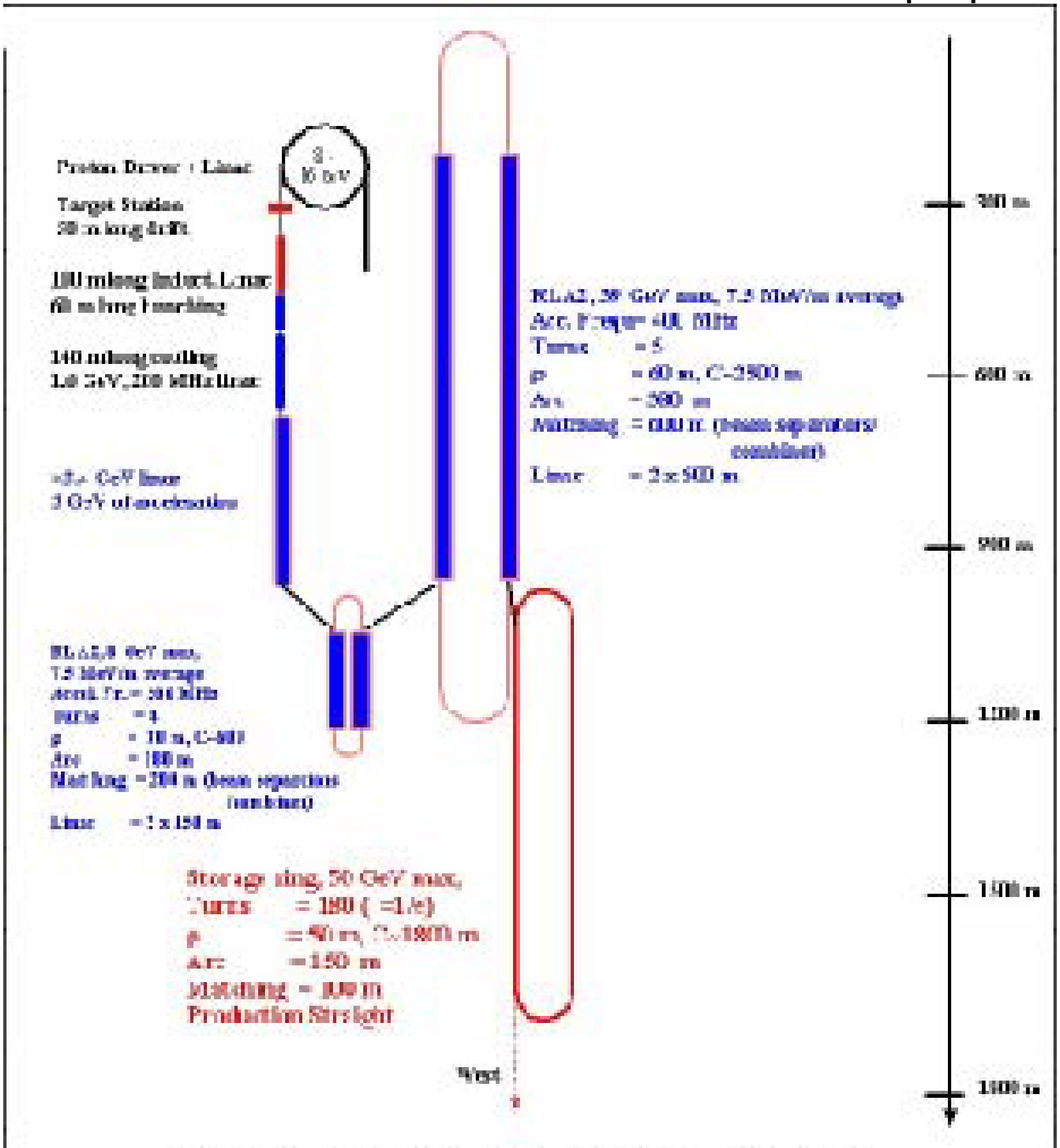
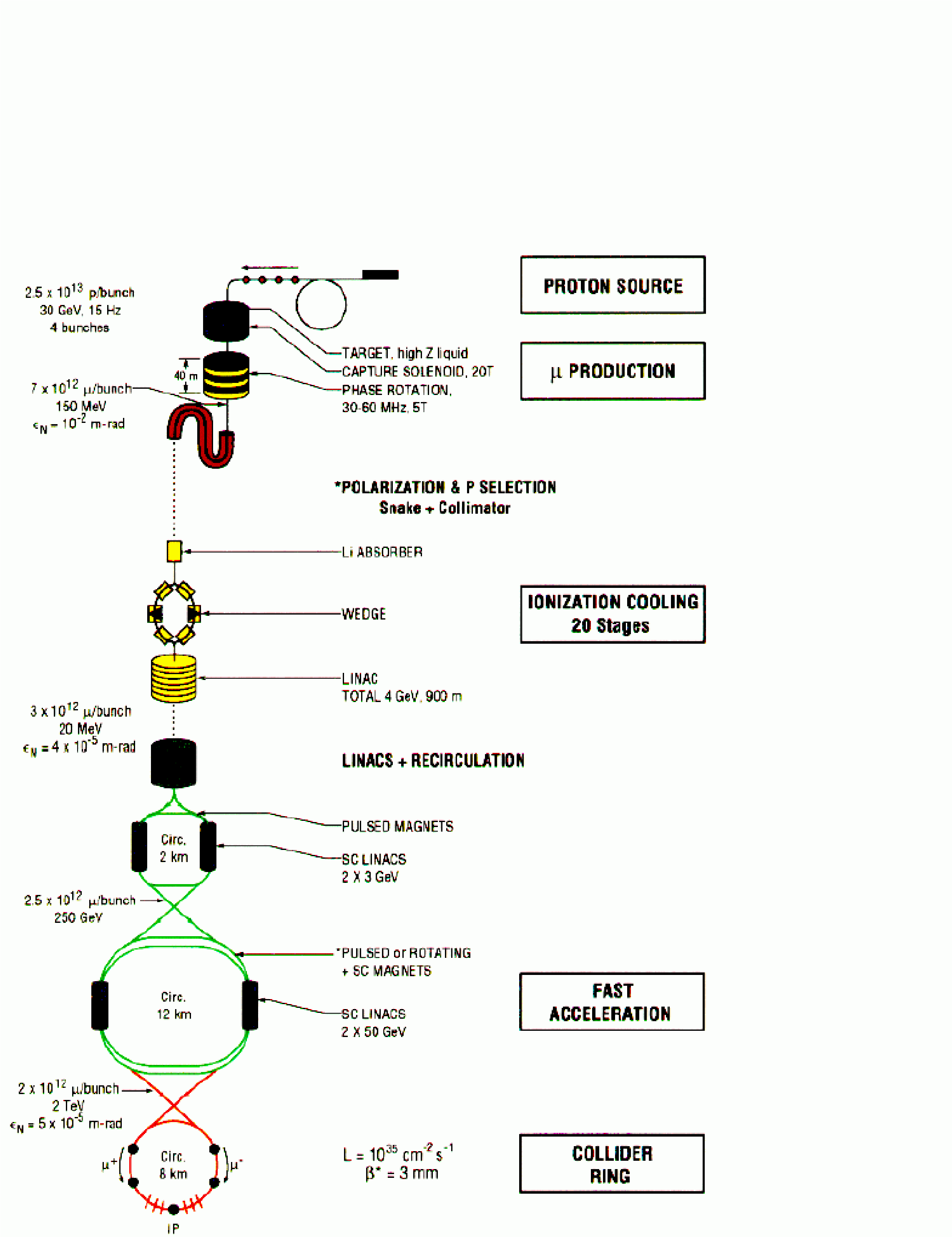


Figure 1: Footprint (to scale) of the whole facility.

layout of a muon collider
US Muon Collider Collaboration

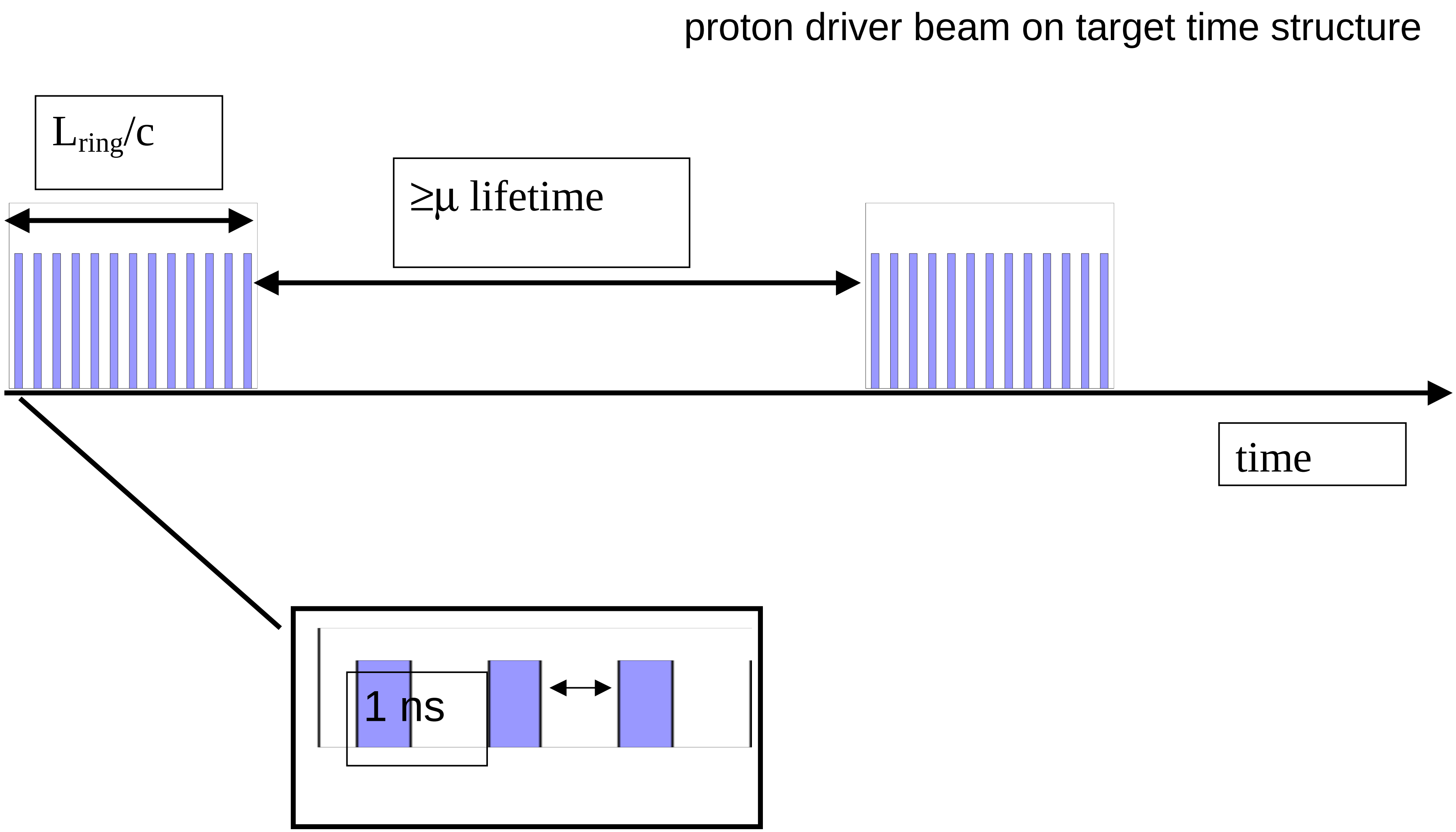


proton drivers

produce a proton beam suitable for pion production

proton driver beam characteristics

- Beam power 4 MW ("standardisation" after Nufact99)
- minimum energy : 2 GeV
- repetition rate matched to the muon lifetime
- macro-time structure must be matched to smallest of the muons rings
- micro-time structure should (but not necessary in all NF scheme) be of the order of few ns (less is not important as 1 ns is the time jitter of pions decay)



proton driver beam on target time structure
L_{ring}/c
≥μ lifetime
time
1 ns

High power
(4 MW or more!)

- Existing machine can provide beam power of 0.1-0.2 MW

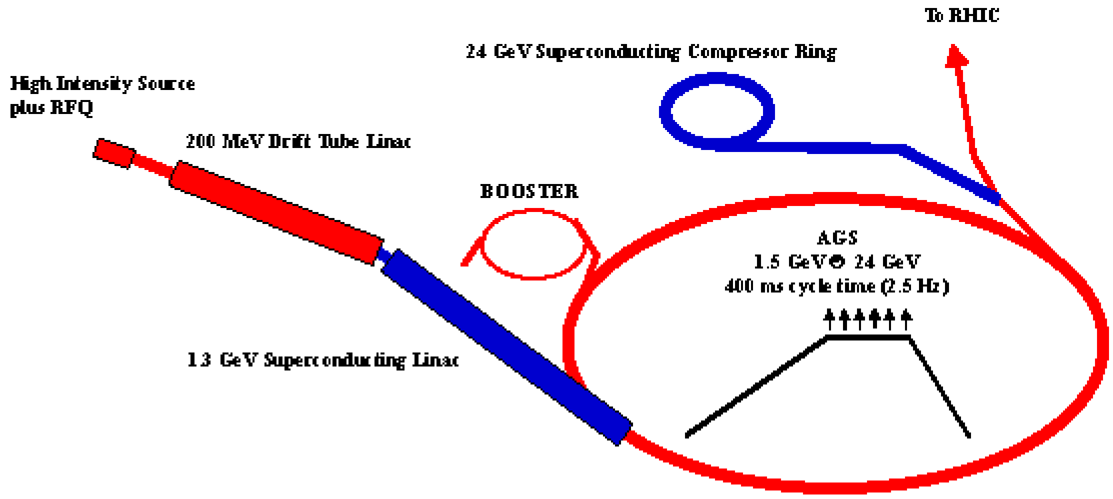
Power= (Number proton/bunch) (rep rate) (energy)

- Upgrade existing machine vs. designing new (space charge limits, radiation limits and magnet cycling limits)

- High energy vs fast repetition rate

upgrade of AGS

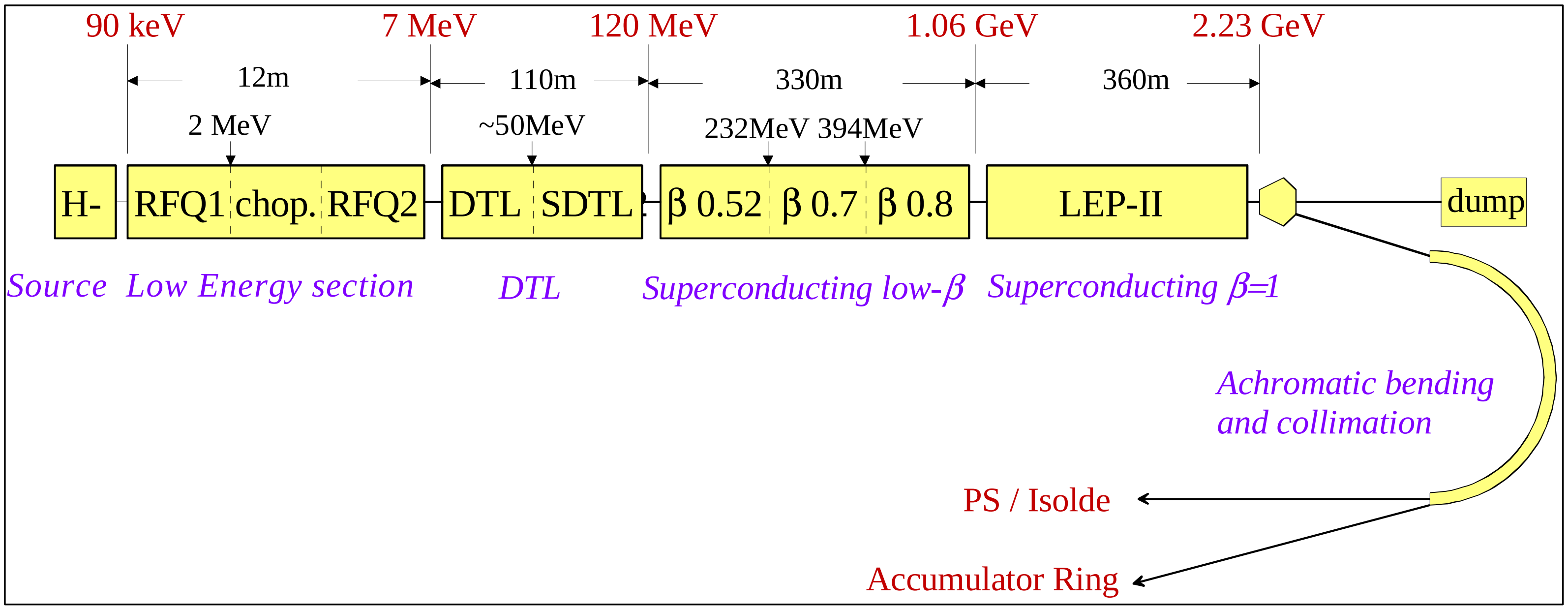
AGS proton driver layout



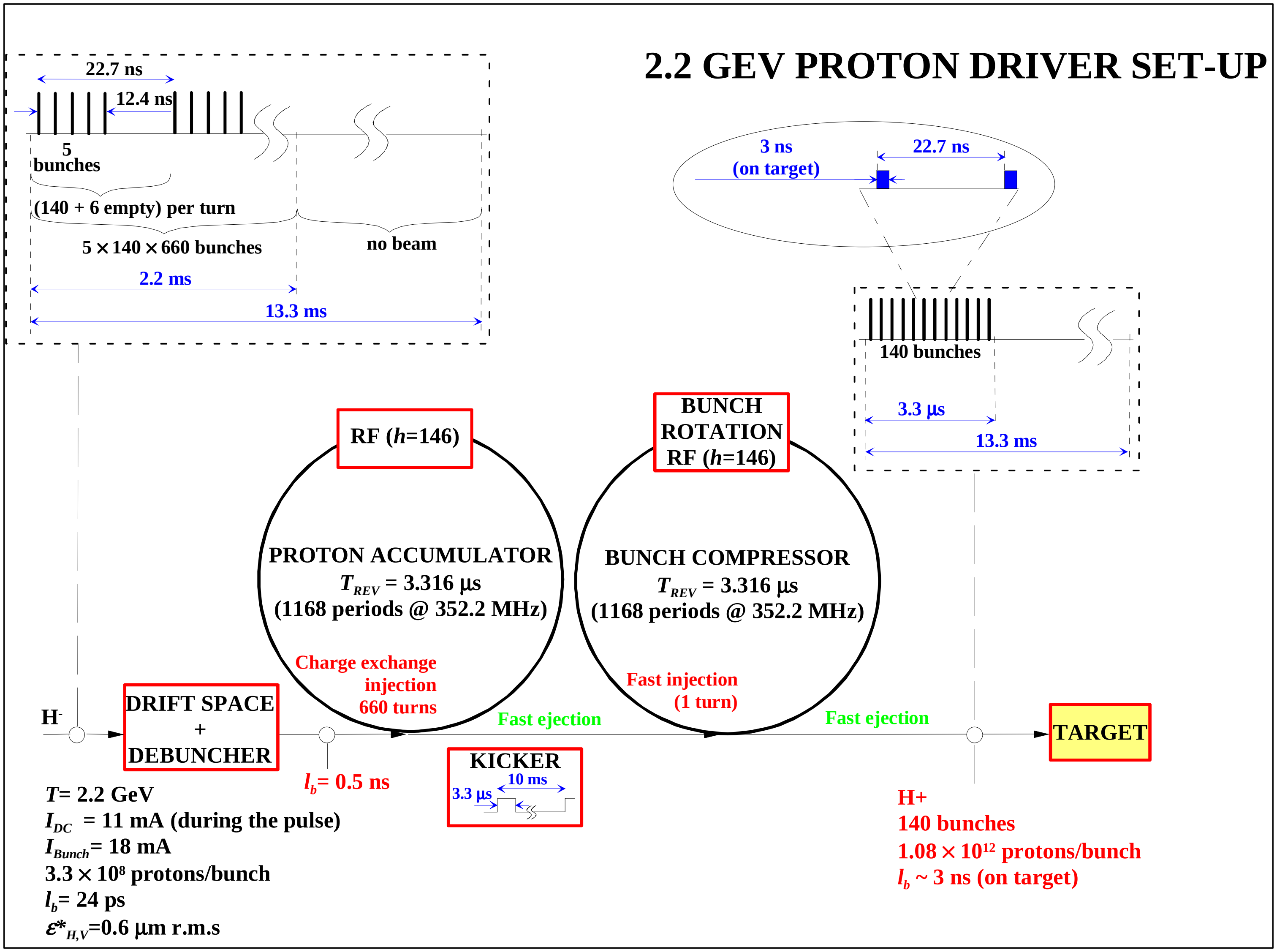
BROOKHAVEN NATIONAL LABORATORY

T. Roser
Nov. 2000

(CERN-NEW SPL linac)



accumulator and compressor rings



Proton Drivers R&D Needs

- upgrade of existing machines
  - demonstrate short bunches (order 1 nsec) : this has been tested and proved at BNL
  - faster cycling
- new machines (spallation neutron source drivers with short bunches)
  - high space charge (halo control for hands-on maintenance)
  - fast rising chopper
  - low beta SC cavities development

1. Room Temperature Structures
   a. Installation of a test stand (352 MHz, 50 kW CW, 100 kW pulsed)
   b. Test of the CEA IPHI DTL model (5 MeV, 3 drift tubes)
   c. Development and test of a CCDTL model (20 MeV)
   d. Development and test of a π-mode 7-cell model cavity (100 MeV)

2. Superconducting Cavities
   a. Cryostat test of the 4-cell β=0.7 cavities
   b. R&D for a 4-cell β=0.52 cavity

3. Chopper
   Construction of a prototype chopper amplifier

4. Pulsed mode operation
   a. Test of a LEP Klystron in pulsed mode
   b. Test of the beta 0.8 SC cavity in pulsed mode

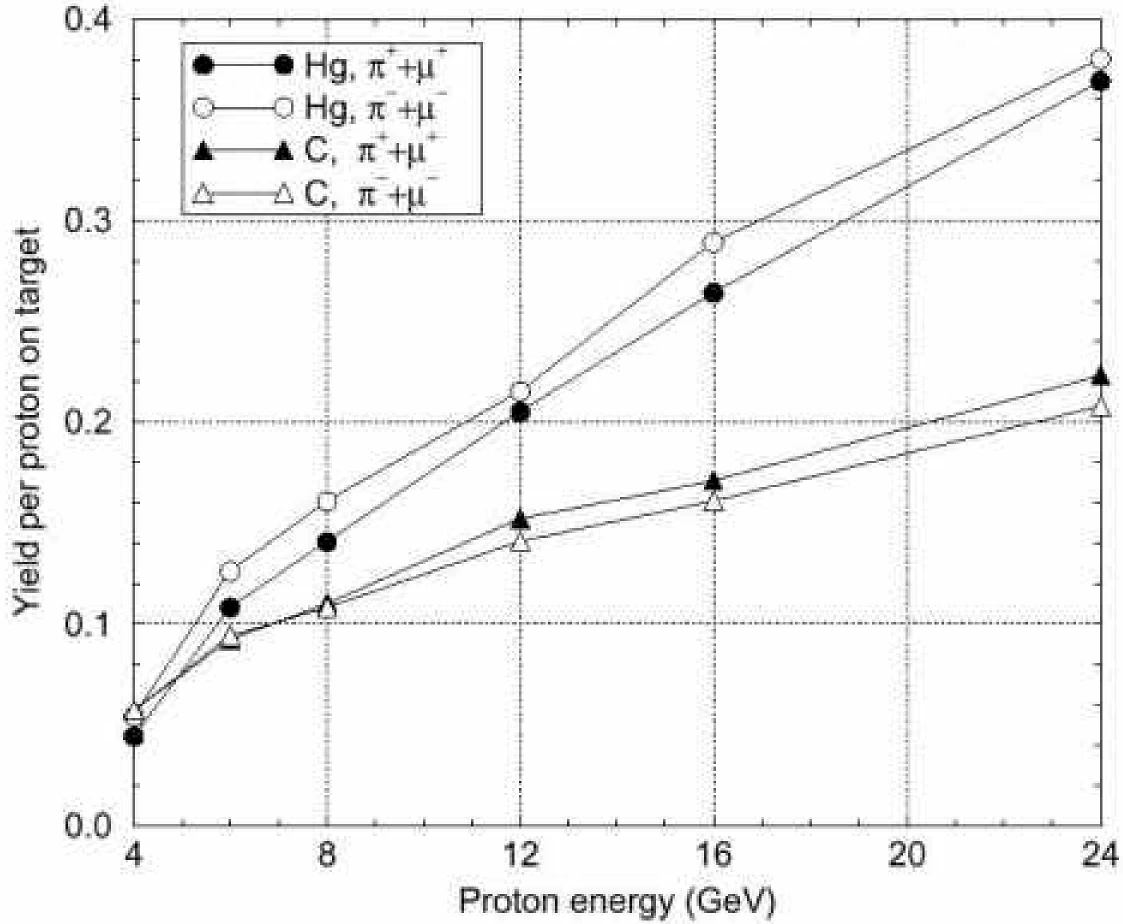
pion production and transverse capture

MAXIMISE the production of pions in the MINIMUM phase space volume

target design

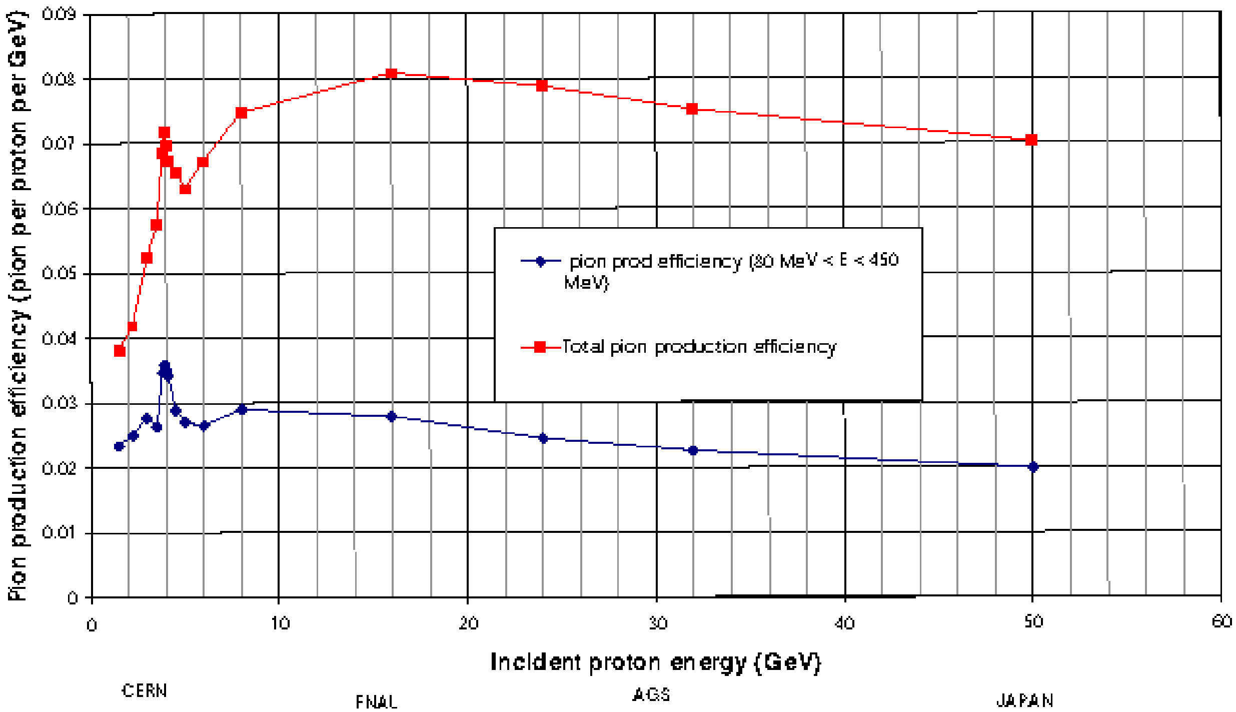
- geometry (length : production /reabsorption)
- material
- focusing system
- engineering, radiation issues

target material : mercury vs carbon

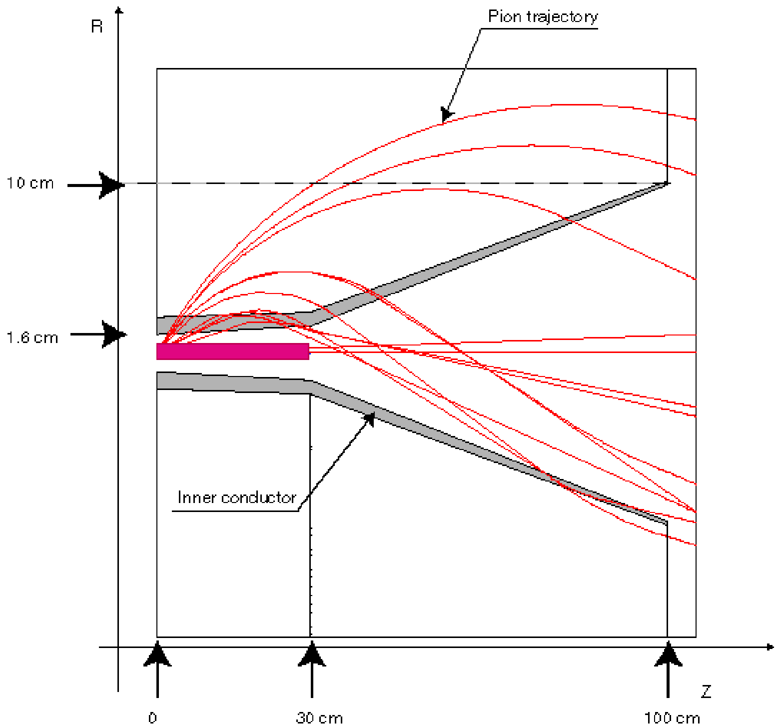


Nikolai Mokhov, FERMILAB -Conf-00/208

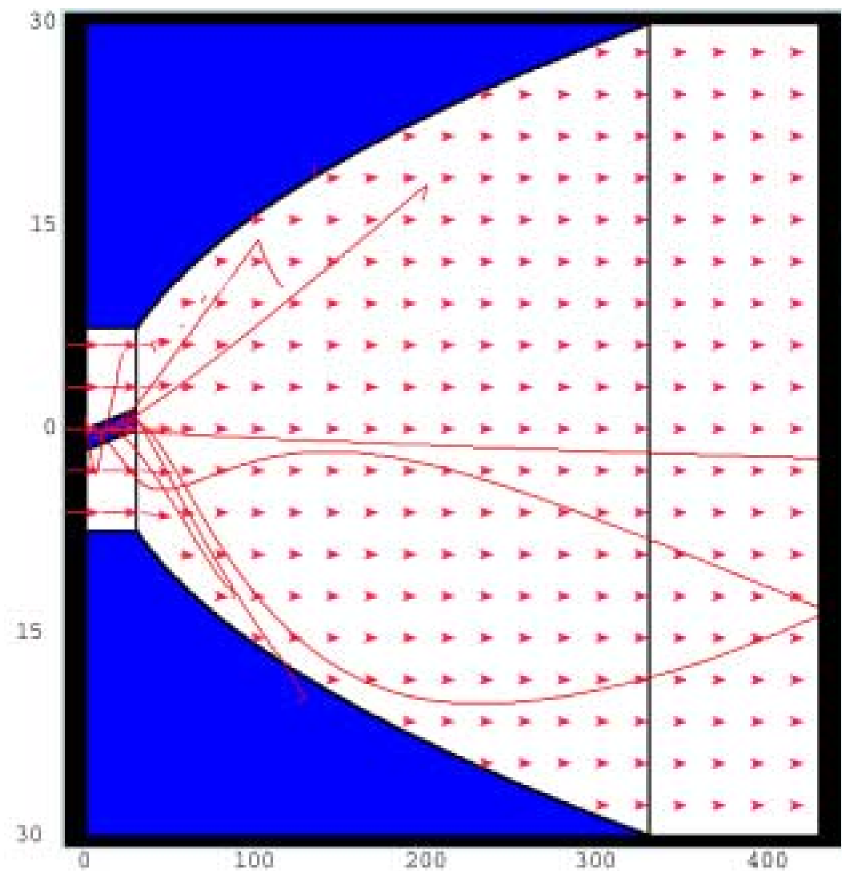
pion production vs. incoming proton beam energy (30 cm long mercury target)



target focusing : mainstream systems

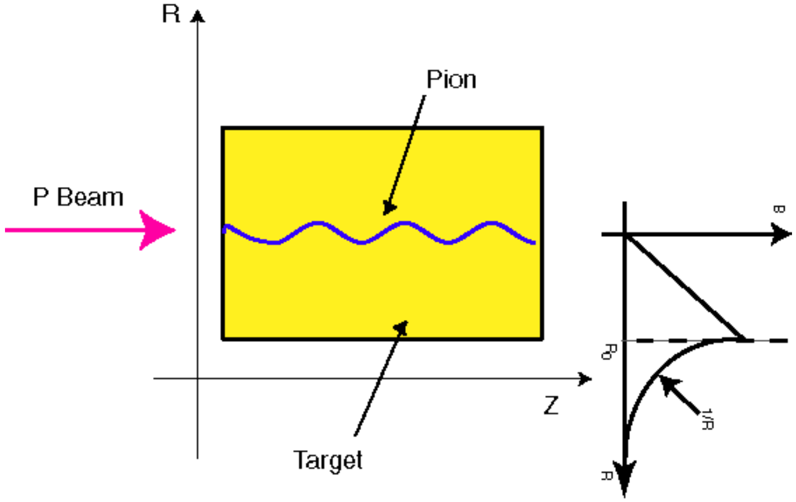


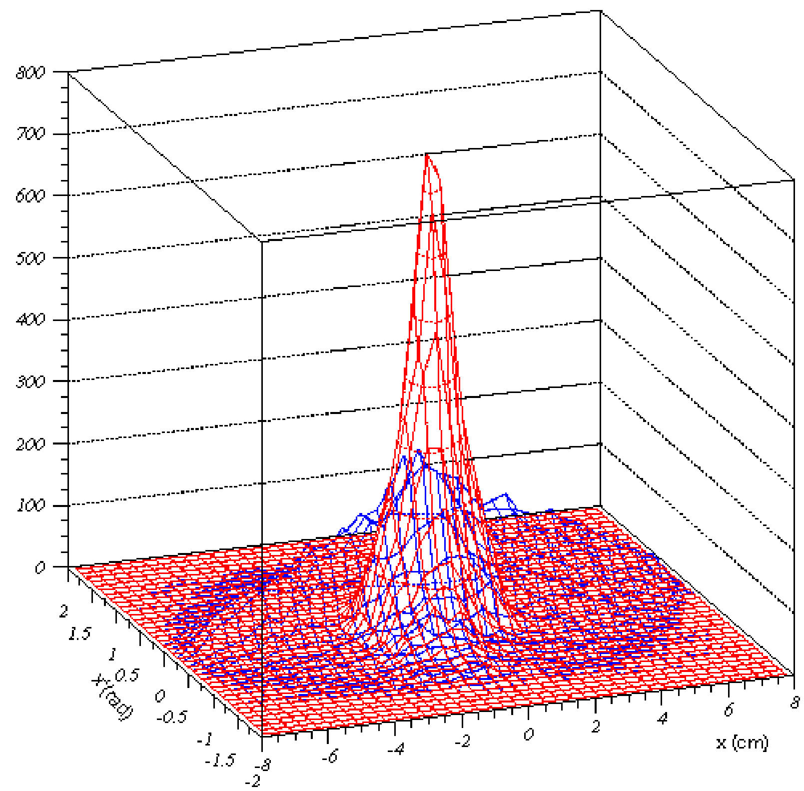
CERN-300kA horn



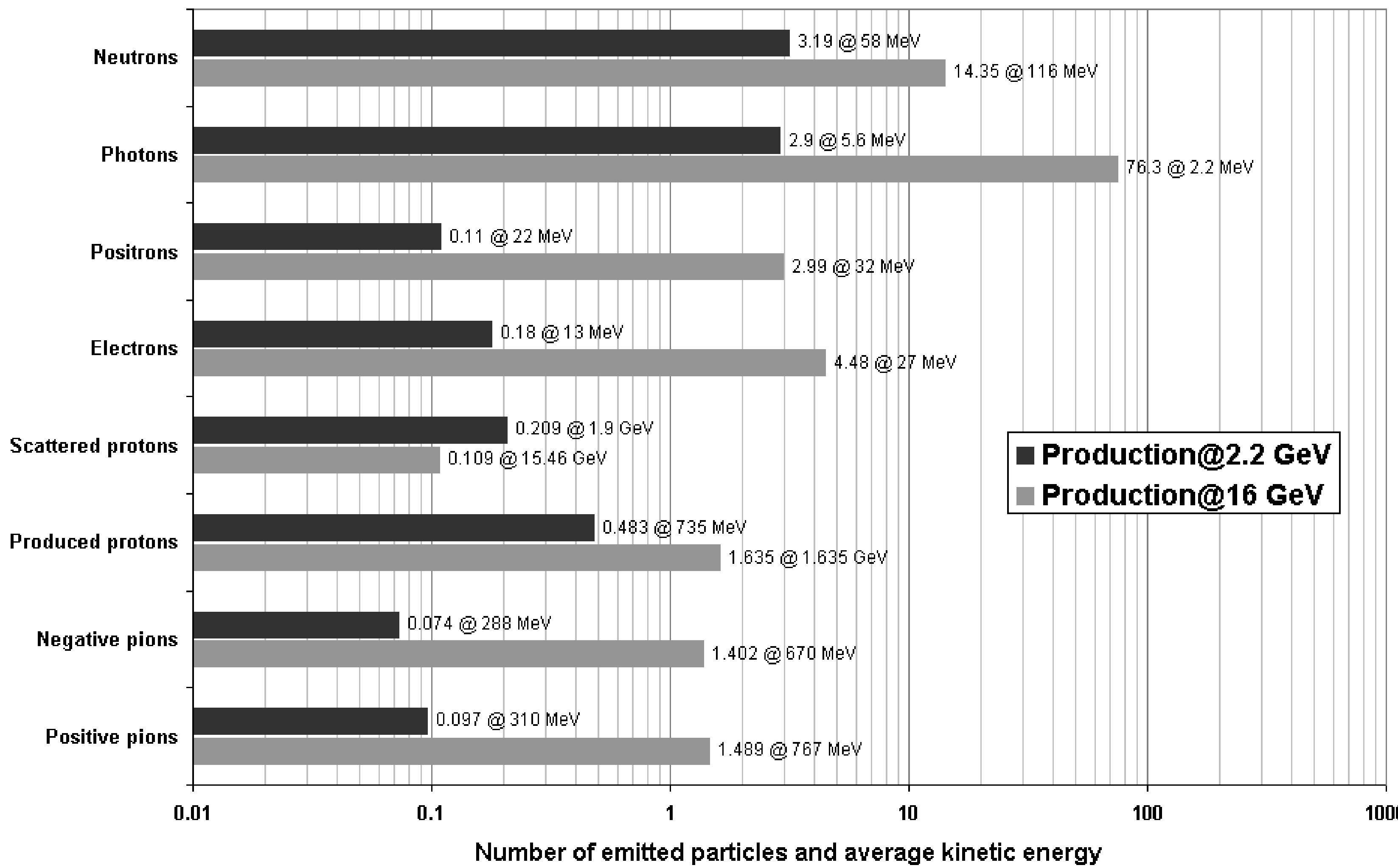
US collaboration 20 T solenoid

technical issue (the phase space at the output is comparable) target focusing : alternative system



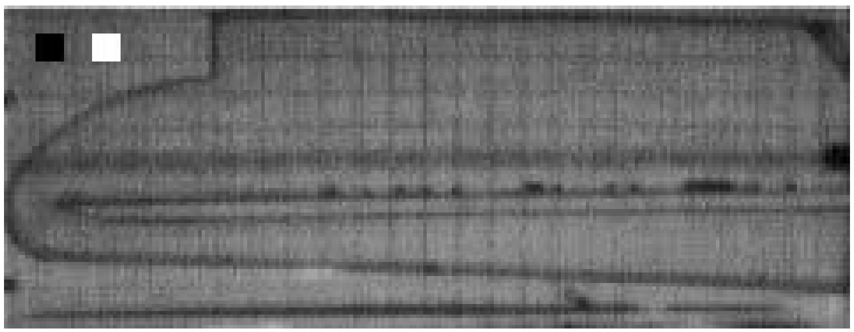


target radiation issues

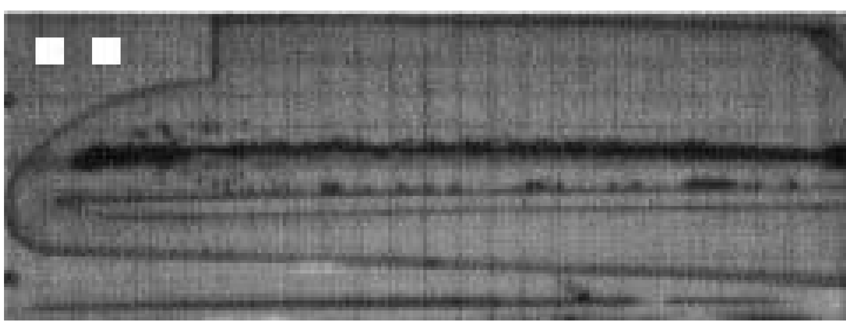


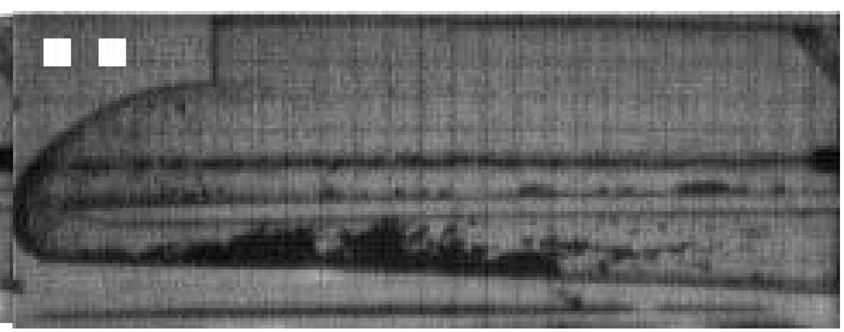
target test (CERN and BNL)

it all started with water…..



and now there is a mercury jet
12.5 m/s (70 bar driving pressure)





target test (CERN and BNL)

mercury jet in a 1.4 Tesla solenoid

will be put into a 20 Tesla solenoid
(Grenoble and Florida)

before being put into a proton beam line at ISOLDE and AGS

HARP will measure......

Hadronic production cross sections $(d\sigma/dP_T.dP_L)$ at various energies and with various targets

Goal: 2% accuracy over all phase space

$O(10^6)$ events/setting, low systematic error

CERN PS, T9 beam, 2 GeV/c – 15 GeV/c

"Stage 0"

Technical run with partial set-up, 25 September – 25 October 2000

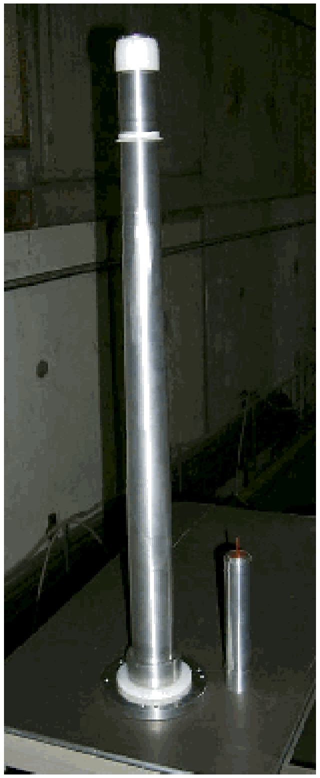
Stage 1

Measurements with solid and crygenic targets, 2001

Future plans:

- ***Measurements with incoming Deuterium and Helium, 2002***
- **~100 GeV incoming beam, using NA49 set-up**

Targets



target tube
target holder

Solid targets

target	Z	thin l (cm)	thick l (cm)
Be	4	0.81	
C	6	0.76	38
Al	13	0.79	
Cu	29	0.30	15
Sn	50	0.45	
Ta	73	0.22	11.14
Pb	82	0.34	

Cryogenic targets
all 6 cm long

H_2	D_2	N_2	O_2

Special targets

K2K target	~60 cm Al
MiniBooNE target	~65 cm Be

don'rt use mercury in HARO????

this is not a target experiment because the ps beam is….