

If You Build It, They Will Come

Concept: Low Energy Low Intensity NF with ProjectX

$\sim 10^{20}$ mu/year

<http://map-docdb.fnal.gov/cgi-bin/ShowDocument?docid=4333>

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Sep. 22, 2012



Background

K. Long, IDS-Arlington, 8-Dec-2011

..... So, need to evaluate options:

Accelerator:

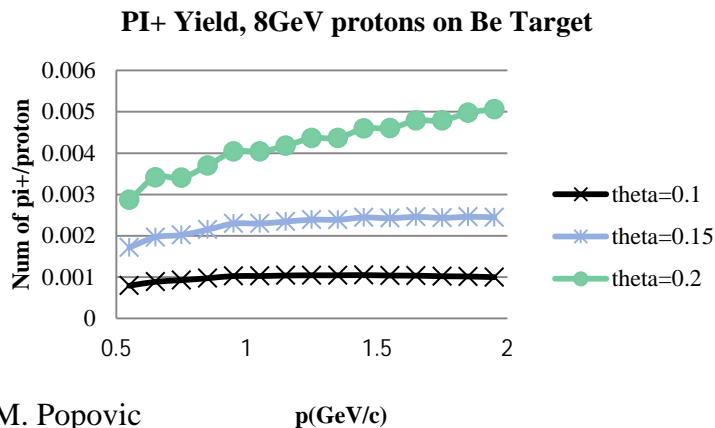
Consider strategies to deliver:

5×10^{19} ; 1×10^{20} ; 5×10^{20} ; 1×10^{21}

Detector:

Evaluate feasibility of surface detector:

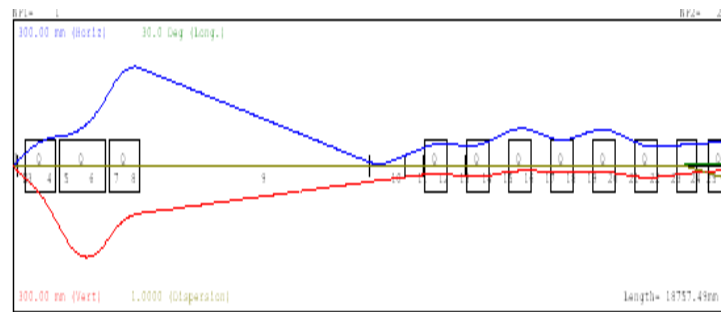
Conversation with Striganov



M. Popovic

p(GeV/c)

VLENF, g-2 Muon Collection



Some Work from 2000

XX International Linac Conference, Monterey, California

2GeV SUPERCONDUCTING MUON LINAC

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Abstract

A muon collider as well as a neutrino factory requires a large number of muons with a kinetic energy of 50GeV or more. Muon survival demands a high gradient linac. The large transverse and longitudinal emittance of the muon beam coming from a muon cooling system implies the need for a large acceptance, acceleration system. These two requirements point clearly to a linac based on superconducting technology. The

distributed in four pulses trains, 160ns long and 300ns apart. The transverse rms beam size is 55um with an unnormalized rms beam emittance of 5×10^6 mm-mrad. The beam has an energy spread of ± 40 MeV and the 200MHz bunches have a total length of 70cm.

Beam	Value
Repetition Rate	15 Hz
Beam RF Character	200MHz
Number of Muons	4×10^{11}



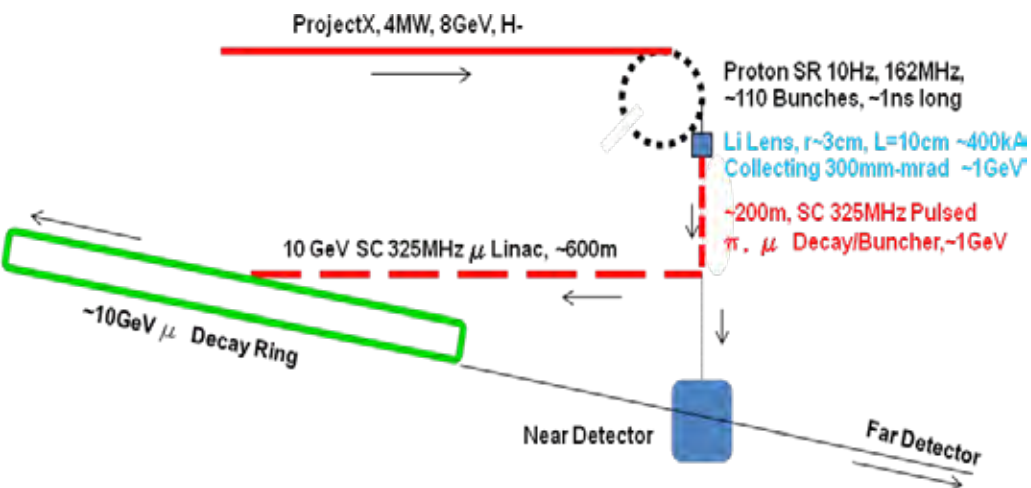
Motivation

- Unique Physics Opportunity
- Facility based on established technologies
- Affordable Price Tag
- No need for extensive R&D for Initial Stage
- Upgradable Facility to High Energies and High Intensities
- Can be seen as Extension of VLENF(nuSTORM)
(As VLENF is Extension of Present Programs)
- Stepping Stone toward Muon Collider

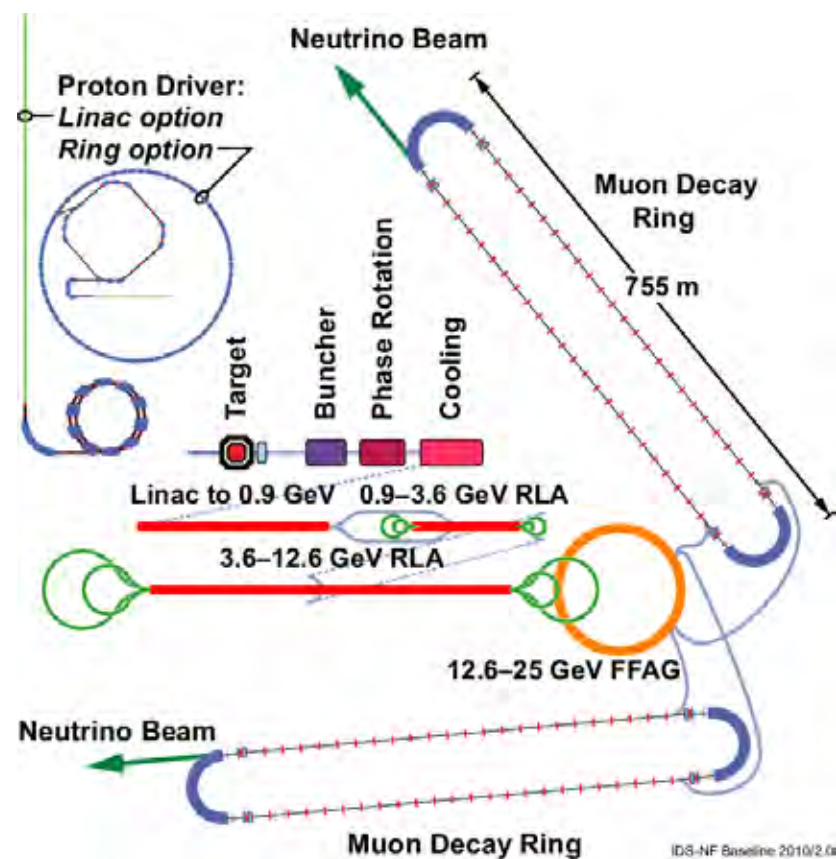


What are Differences

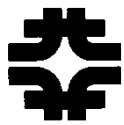
This Concept



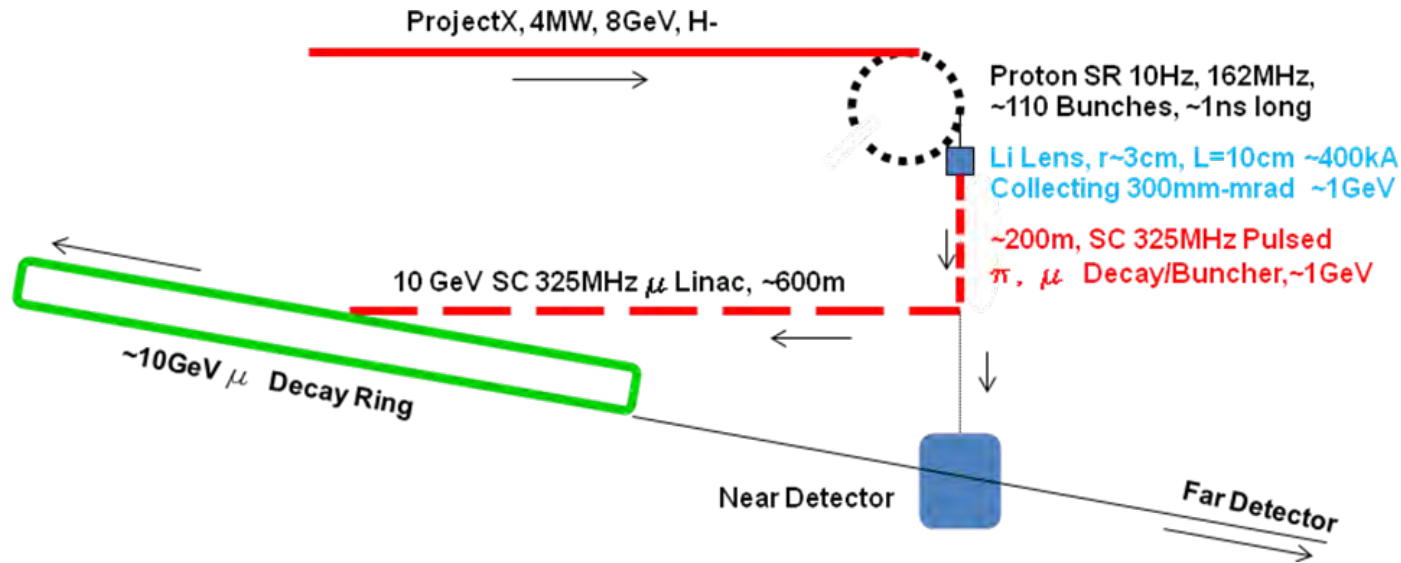
NF as proposed in IDS



IDS-NF Baseline 2010/2.0



What is Proposed-Whole Facility



- ProjectX is based on 162.5MHz or lower bunch structure, pulsed, 10Hz, or CW, 4MW Linac in Stage 4
- Accumulation Ring, 8 GeV, up to $\sim 4 \times 10^{14}$ protons per pulse.
- Lithium Lens based collection system, collecting pions/muons of $1. \pm 0.15$ GeV or higher, $\sim 3 \times 10^{-3}$ pi/proton
- 325MHz based, SC pulsed 10Hz Linac and Buncher
- Decay Ring, 10 GeV Muons, $\sim 10^{20}$ mu/year

For 4MW, 3.12×10^{15} p/sec $\times 3 \times 10^{-3}$ pi/p $\times 3.15 \times 10^7$ sec/year = 2.95×10^{20} pi/year



Components/Parameters

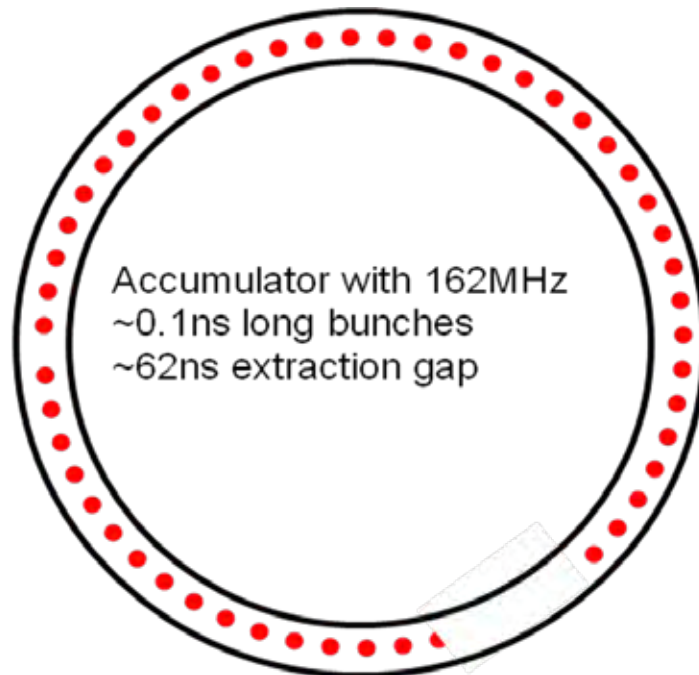
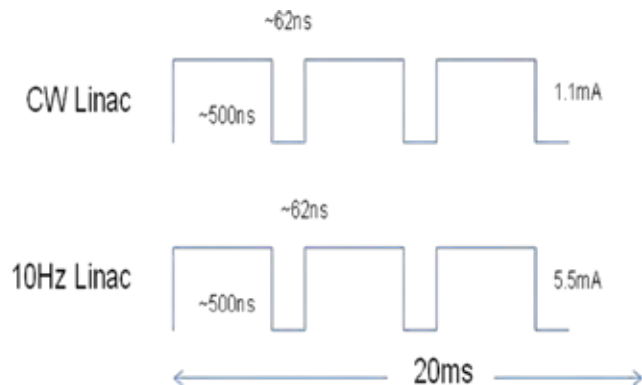
Protons	
Linac, H- Beam, 650MHz SC RF	Beam Power=4MW, CW Average_I=0.5mA ~600ns on, ~60ns off, or 10Hz, 16ms E _{kin} =8GeV, Bunch Structure=162MHz
Proton Accumulation Ring	RingLength~200m, h=110, of 162MHz, 0.4MW stored per pulse, 100 bunches, $\sim 4 \times 10^{12}$ protons per bunch, bunch length ~ 1ns, emittance 50mm-mrad, SC tune~0.005 LongLimit ~ 0.1MW per bunch
Pions/Muons	
Target & Collection & Matching, at 1 GeV, energy spread of +/-0.15GeV. Collecting E _{un} 95%=300mm-mrad, L=3.5m, Yield~ 5×10^{-3} pi ⁺ /proton	Target: Be or Hg, Li Lens, 15cm long, 3 cm radius, 10 Hz, Peak Current ~ 600kA, Focal length ~ 20cm. Quad doublet, Q1 g=4.1T/m, l _{q1} =0.35m, Q2 g=9T/m l _{q2} =0.7m
Linac/Pi Decay Chanel from 1.0 to 1.2 GeV, SC, pulsed, 325MHz	~20 FODO cells, ~8m, two 3-cell cavities beta=1, ~17MV/m, Cavity bore radius 0.2m L _{quad} =0.35m, g ~3T/m, Synch Phase~0 degree, Bunching mode
Linac/Mu from 1.2 to 10 GeV, SC, pulsed, 325MHz	~100 FODO cells, ~8m, two 3-cell cavities beta=1 , ~17MV/m, Cavity bore radius 0.2m L _{quad} =0.35m, g from 3T/m, rumped
Decay Ring, Racetrack	Conventional, with 200m long straits



Accumulation/Timing- Linac/Ring

Linac Parameters

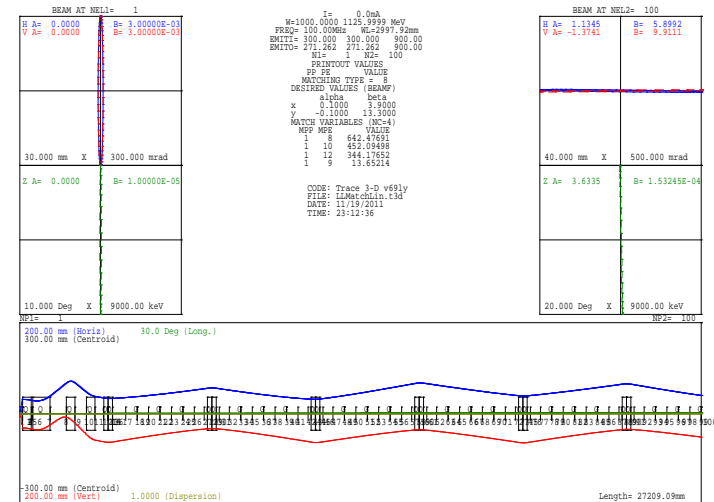
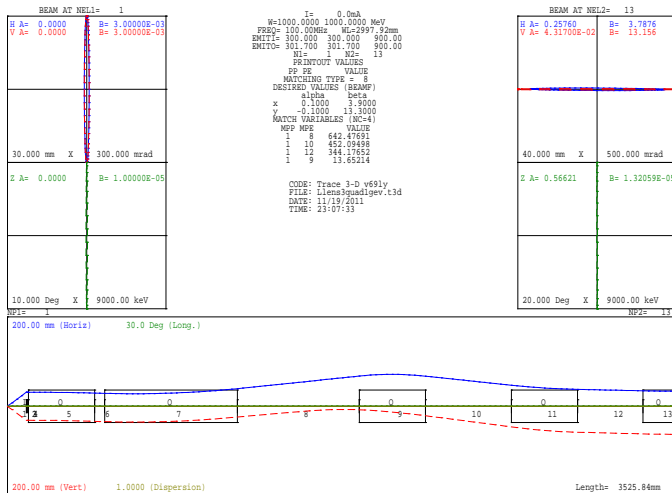
- Pulsed 10 Hz
- 162.5MHz bunch structure
- Chopping at 2 MeV
- $E_{kin}=8 + /-0.005$ GeV
- Emit_{n95%}~ 1mm-mrad,





Target and Pion Collection

Proton beam is extracted every 100 ms and targeted on Hg jet, or Be target. The beam power of each pulse is 0.4 MW and beam train is ~600 ns long. Beam has bunch structure of 162 MHz with bunch length of ~ <1ns. Right after the target there will be Lithium Lens and set of collection quads. We collect pions and muons from 1 mm spot with kinetic energy of 1 GeV and within 0.3 radians in forward direction. The Lithium lens is $L=15$ cm, with $r=3$ cm, I of 600kA and $f_l \sim 0.2$ m.



Target, Li Lens, matching

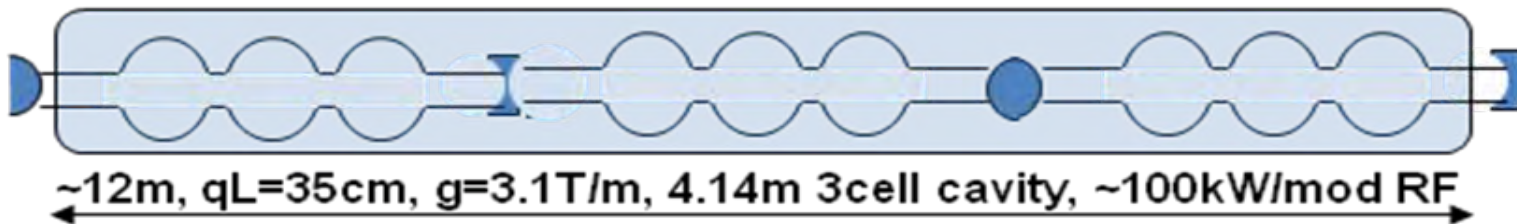
The total length of the collection plus matching line is ~ 3.5 meters.



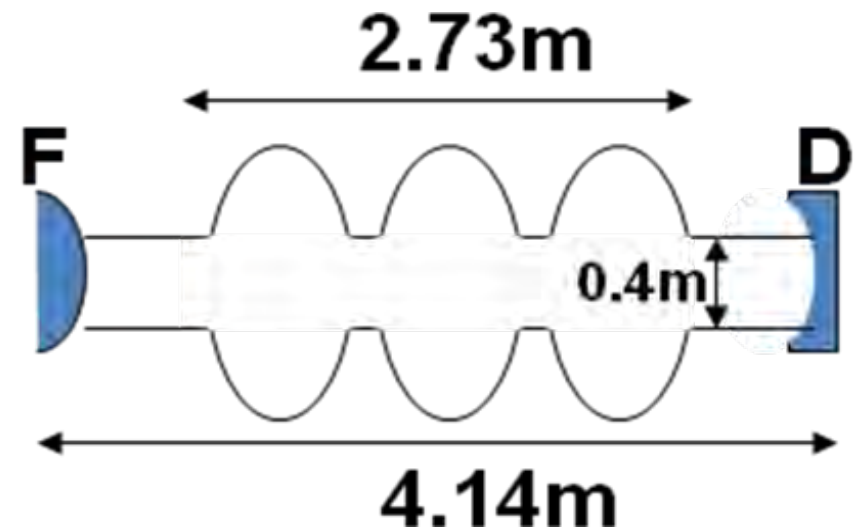
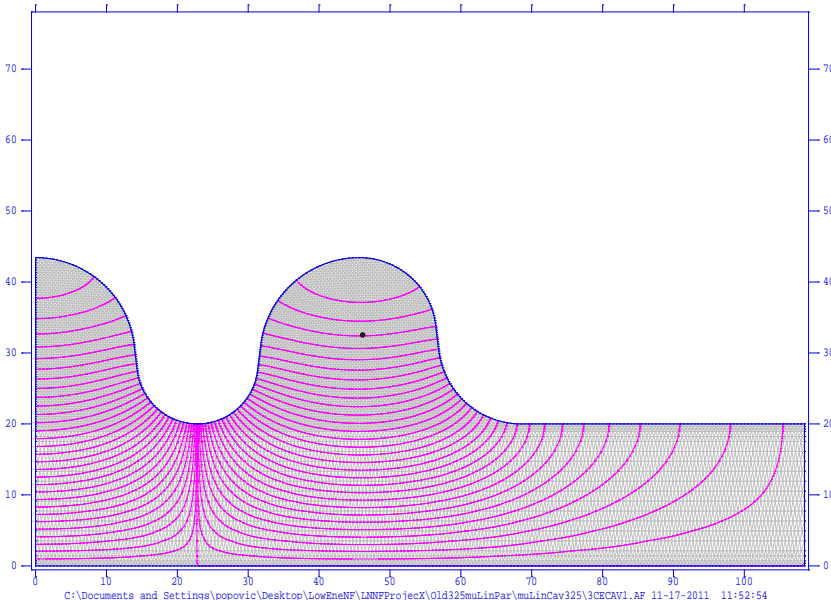
Muon Acceleration

Pion/Muon bunching starts 3.5m after the target. The linac is based on 325MHz SC 3 cell cavities with FODO focusing. SuperFish calculation and dimensions of basic FODO cell.

~20MV/m, Pulsed, ~1msec, 2usec flat, 60+20 Cryo Modules



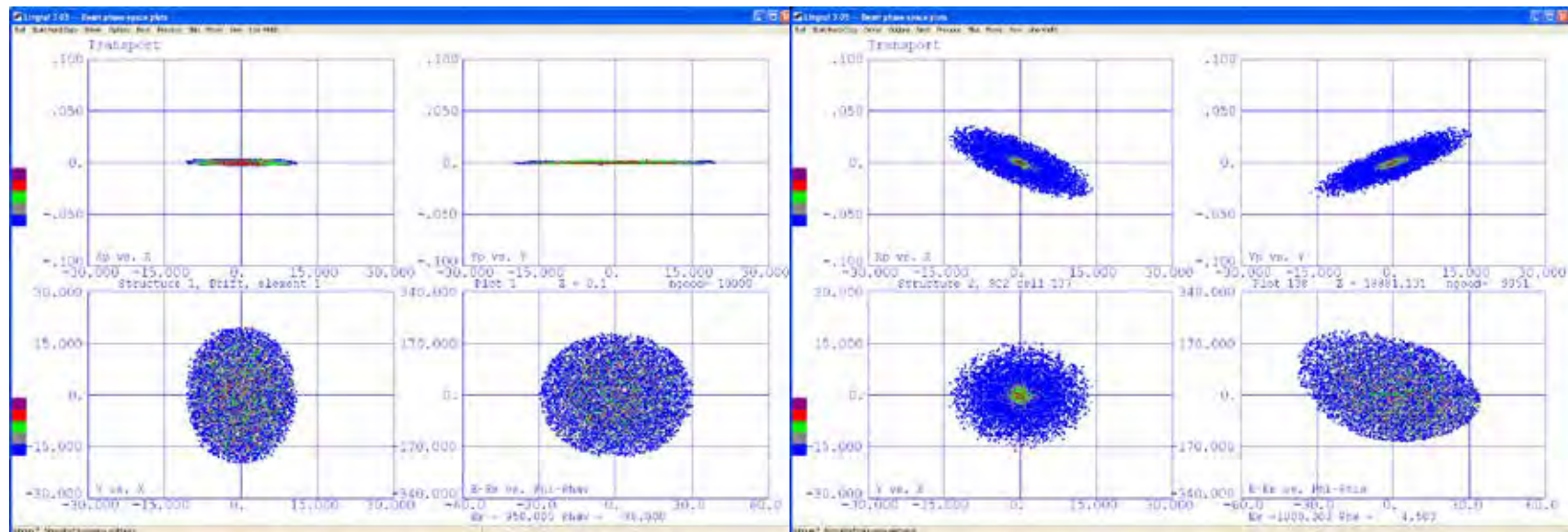
Elliptical cavity, bore =20cm, beta=0.95 F = 324.90408 MHz





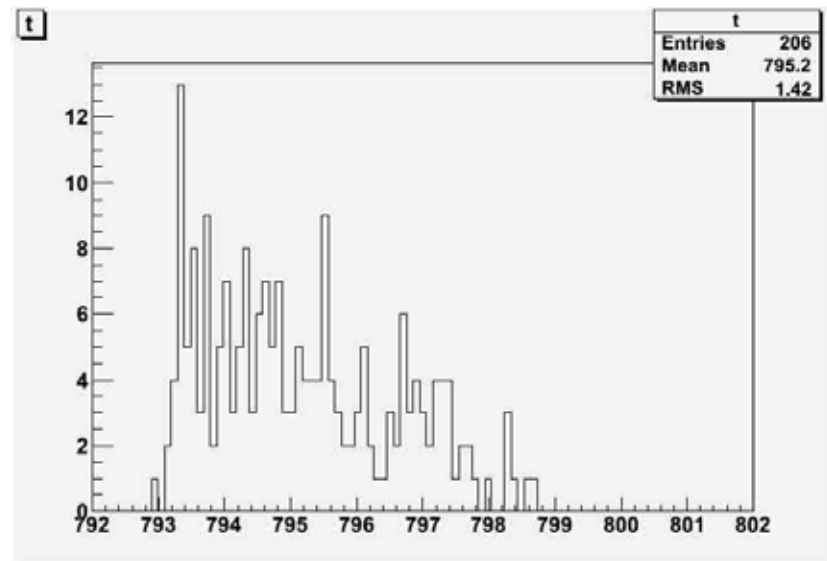
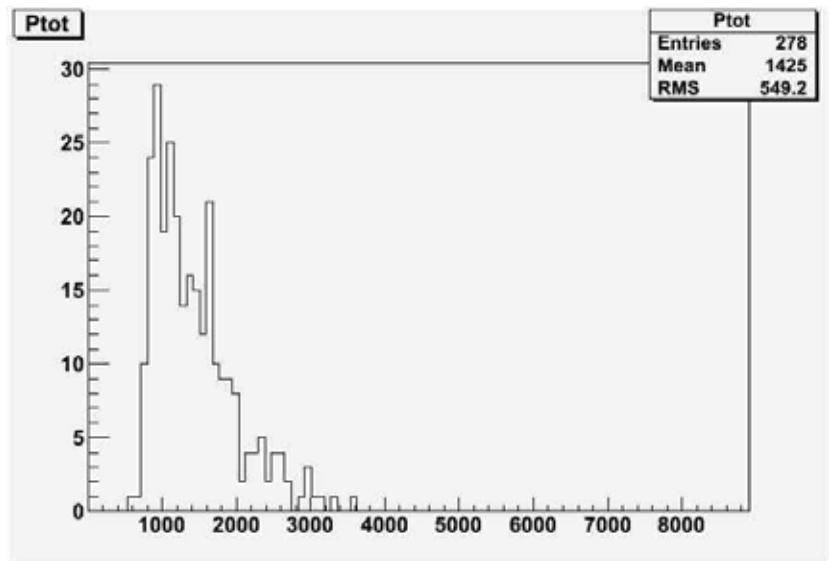
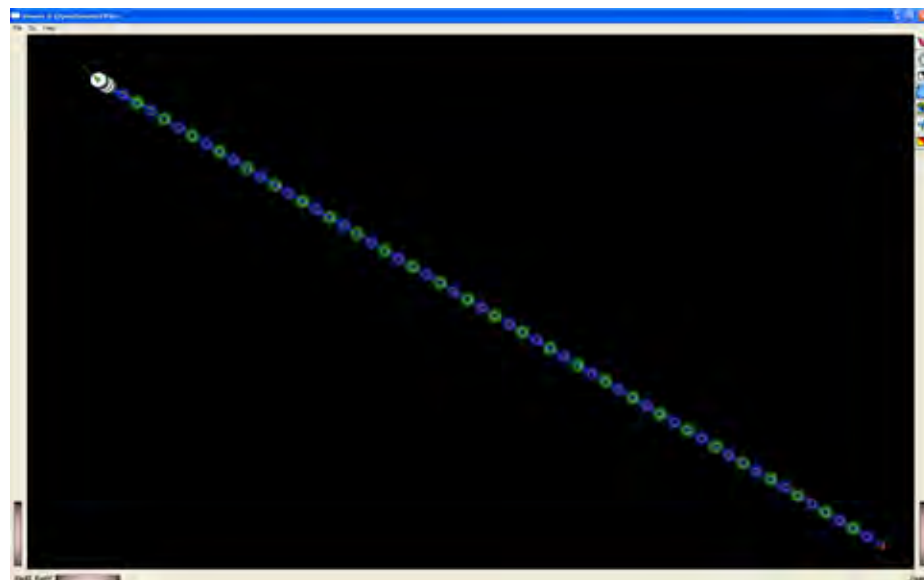
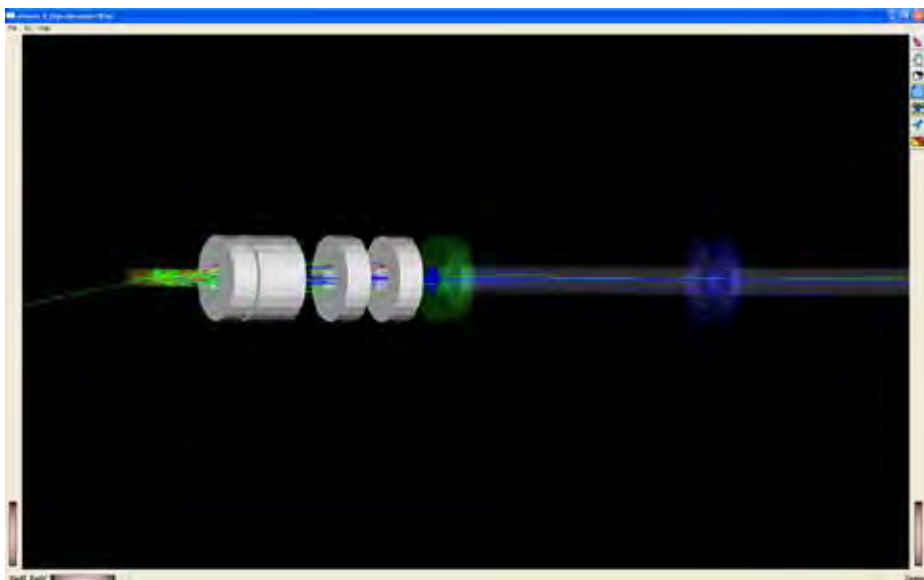
Pion Decay Channel

This section is identical to the Acceleration Linac. It is about 200 meters long with the RF phase close to zero so that the Linac is effectively a long decay channel with bunching cavities. The particles from the target are captured in the RF buckets, preserving the bunching structure and reducing the momentum spread off the target. The beam collected off the target is 1 GeV, with an unnormalized 95% transversal emittance of 300mm-mrad and energy spread of ± 200 MeV. The bunch is 30 degrees (of 325MHz) long.



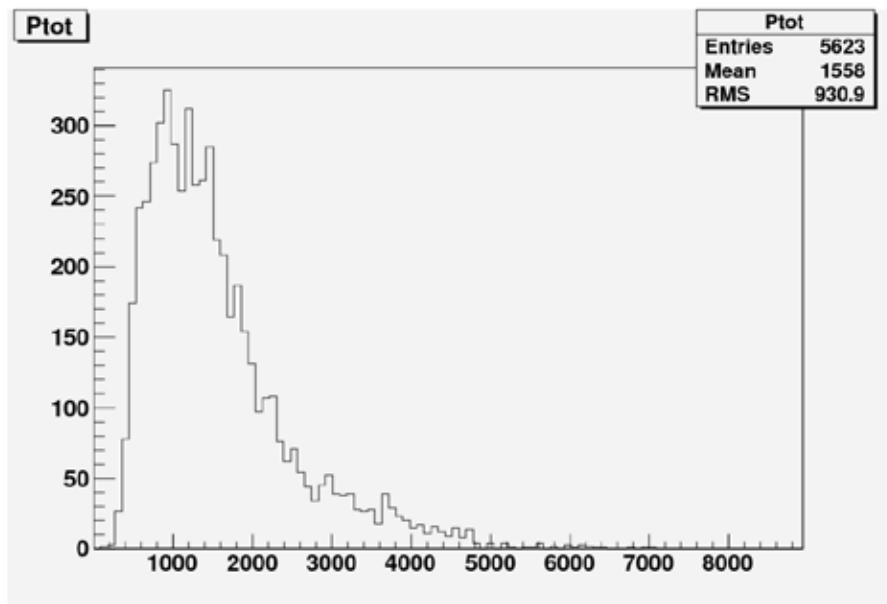


G4bl, no RF, just FODO(at this time)

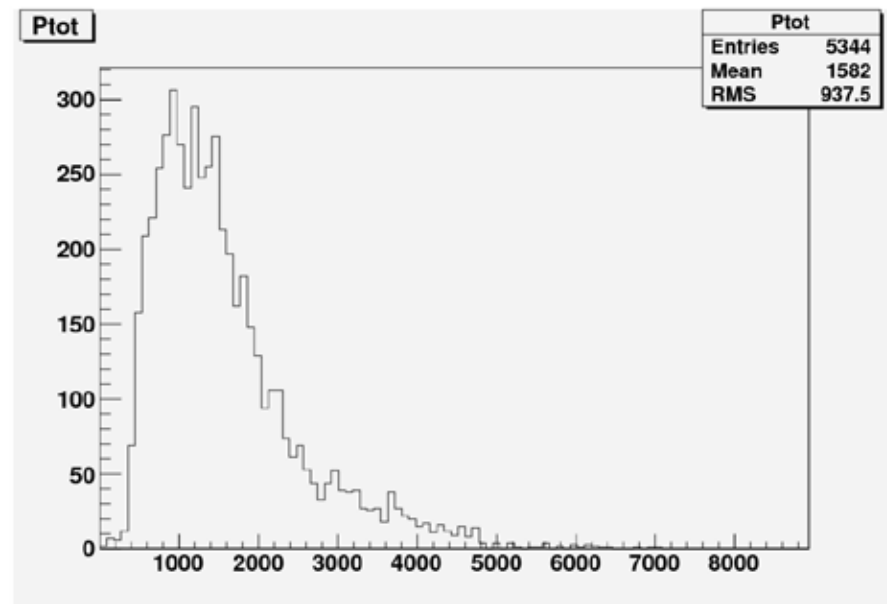




At Entrance to the Buncher, G4b1



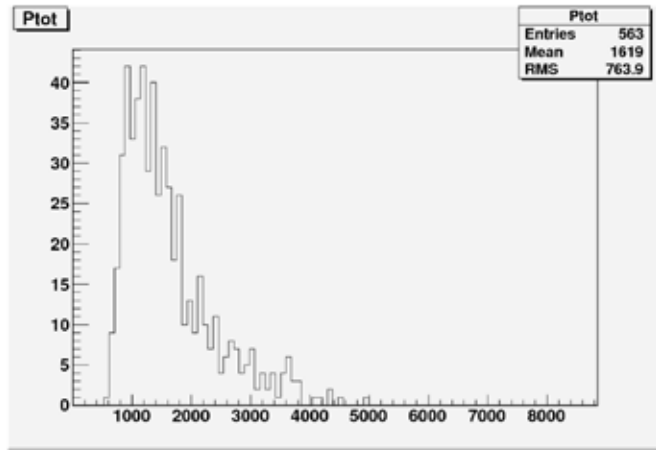
Positive Pions + Muons



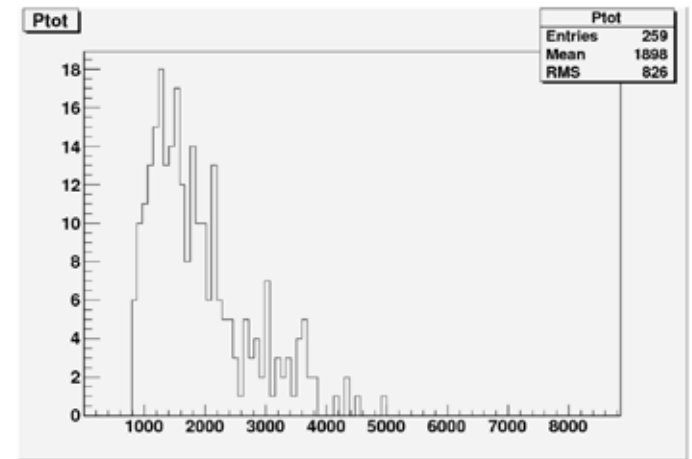
Positive Pions Only



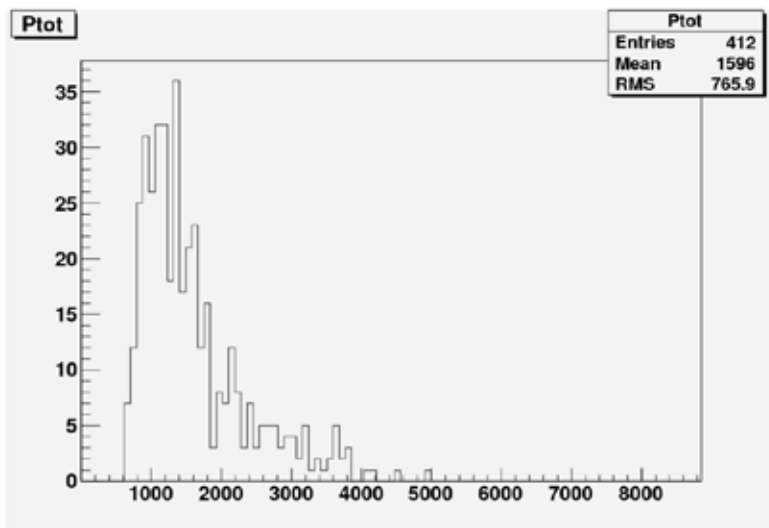
G4bl, Middle & End



**Middle of
Buncher**

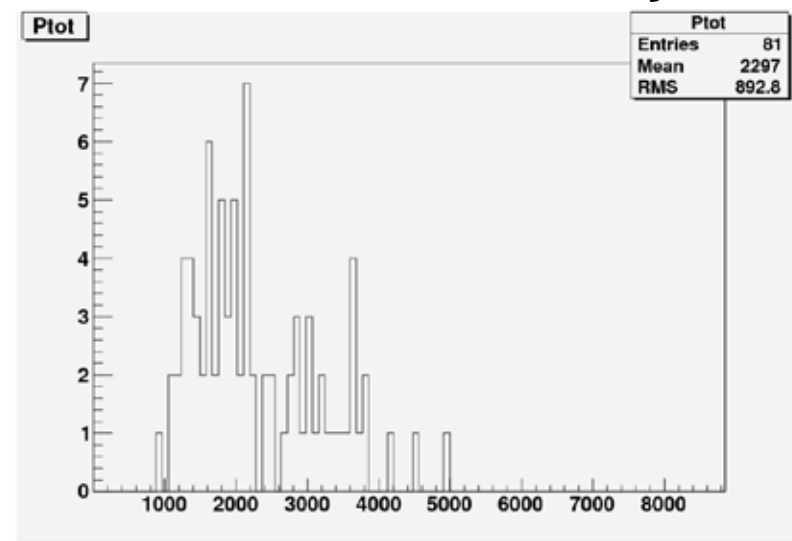


Positive Pions+Muons



**At the
end**

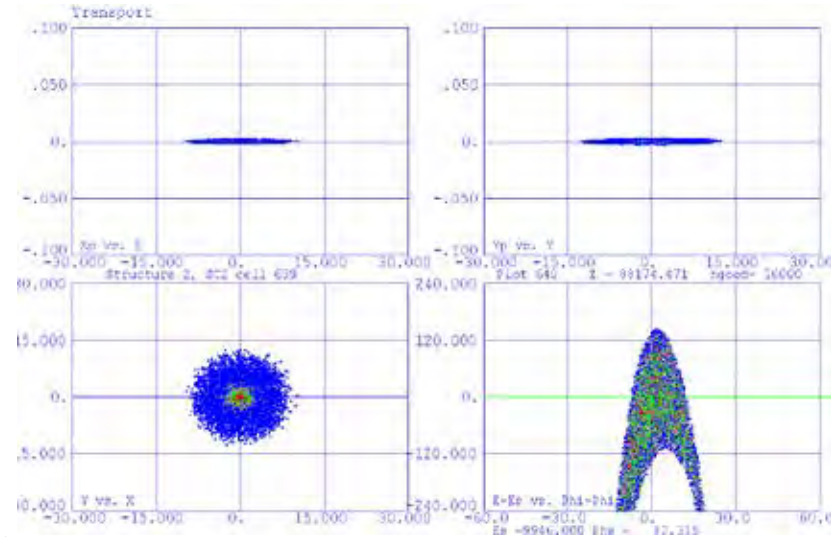
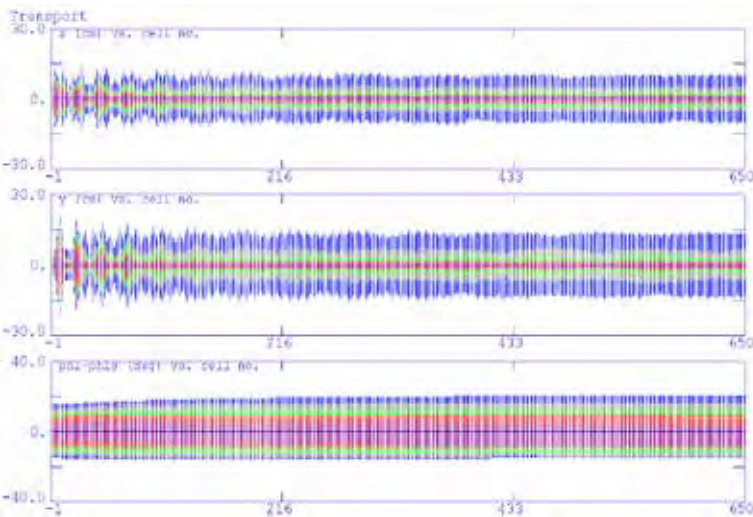
Positive Pions Only





Linac

- To design Linac PARMILA code was used. FODO lattice starts with 3.1T/m quads gradients and rump to 6T/m.
- Distance between quads is 4.14m and it is constant along whole Linac.
- Acceleration is done using SC 3cell Beta=1 cavity with resonant frequency of 325MHz.
- Design requires constant energy gain per cavity to be 42MeV. The linac has -20 degree synchronous phase which is ramped to -5 degree in first 3GeV.
- Injected beam has $E_{un95\%}=300$ mm-mrad, energy spread of ± 150 MeV particle in the bunch are spread for ± 15 degree (of 162.5MHz) around synchronous particle



PARMILA outputs,

Whole linac is ~900 meters long. Muon beam at 10 GeV has more than ± 150 MeV spread. If needed energy spread can be made smaller using couple RF cavities with higher synchronous phase.



CONCLUSIONS

A phased approach towards a Low Luminosity Low Energy Neutrino Factory has been presented.

Collecting ~ 1 GeV, bunched pions and muons produced with micro-bunched protons using Li lens eliminates:

- Large field (~ 20 T) and a long SC solenoid channel (30+50m),**
- Buncher/Rotator (~ 100 RF copper cavities, ~ 100 MW RF power, with ~ 10 different frequencies) ,**
- ~ 1 GeV Large bore SC Muon Linac**

In comparison with Conventional NF, L³ENF performance is reduced by factor ~ 30 (of stored Muons).



Concept 1: nuSTORM from AP0

**“Far Detector”
at Meson Area**

