Status of the muon front-end & NF efforts @CERN

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EUROnu Meeting

June 3rd, 2010

Plan

Status of the muon front-end:

- **revision of baseline as of after 2010 IDS-NF meeting.**
- **alternatives to baseline.**
- **work plan for the IDR/RDR.**

NF efforts at CERN:

- **particle production simulation with MARS15 (m1507).**
- **revision of the CERN 44-88 MHz front-end scenario.**
- **LiH models study in Geant4.**
- **exploration of possible use of a CERN magnet & exp. Hall for an RF R&D experiment.**

EUROnu WP3 deliverables/milestones contributing to:

IDR Fall 2010

RDR Fall 2012

Status of the muon front-end

Where we stand

Baseline design frozen April 2010

- Opt for cheapest, but riskiest design
- Risk is that RF cavities may not sustain high gradients in B-field

Developed risk mitigating lattices

- More expensive
- Some have other risks associated
- Continuing in parallel until we understand the RF / B-field issue

Now starting engineering of the baseline

- Preliminary engineering by Autumn 2010
- Full engineering by Autumn 2012

Muon front end

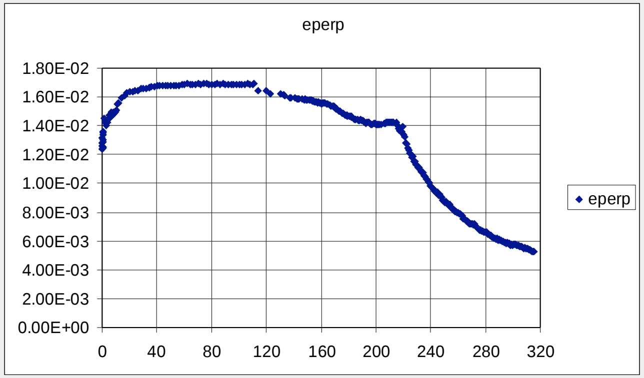
Adiabatic B-field taper from Hg target to longitudinal drift

Drift in ~1.5 T, ~100 m solenoid

Adiabatically bring on RF voltage to bunch beam

Phase rotation using variable frequencies

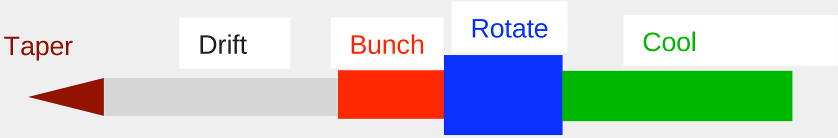
- High energy front sees -ve E-field
- Low energy tail sees +ve E-field
- End up with smaller energy spread

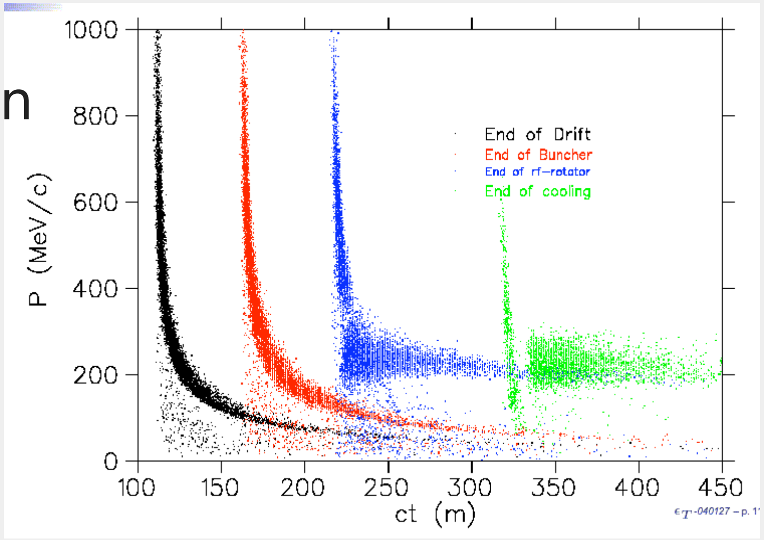


Ionization Cooling

- Try to reduce transverse beam size
- Prototyped by MICE

Results in a beam suitable for acceleration





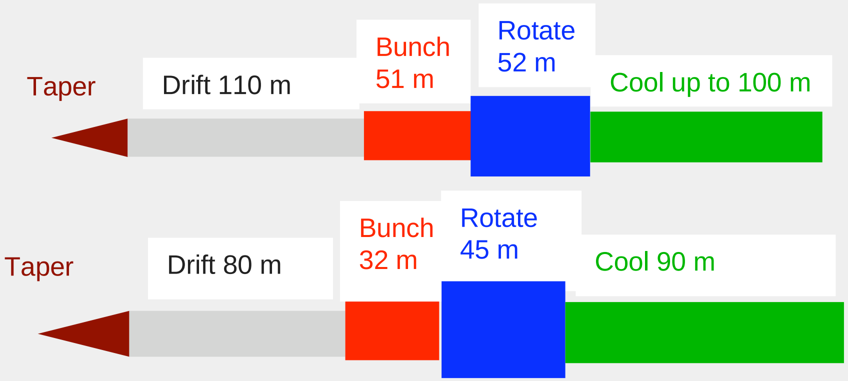
Baseline revision & freeze

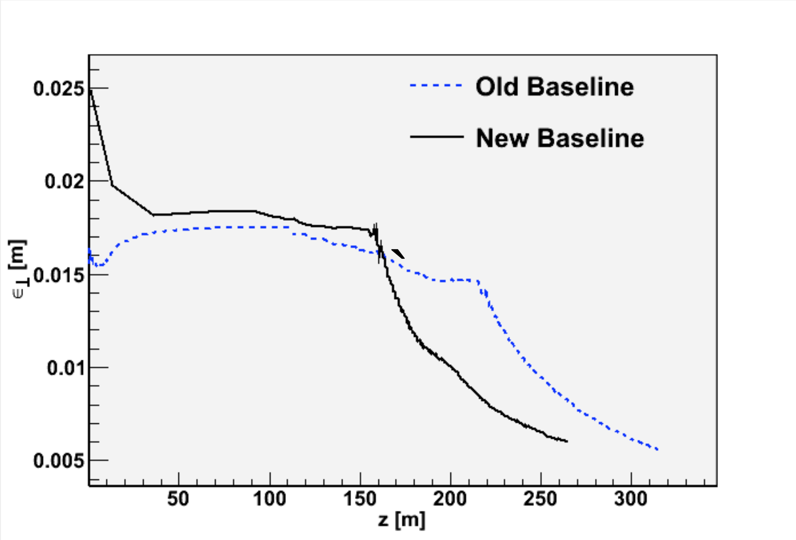
Shorter front end Need to evaluate performance with thicker windows

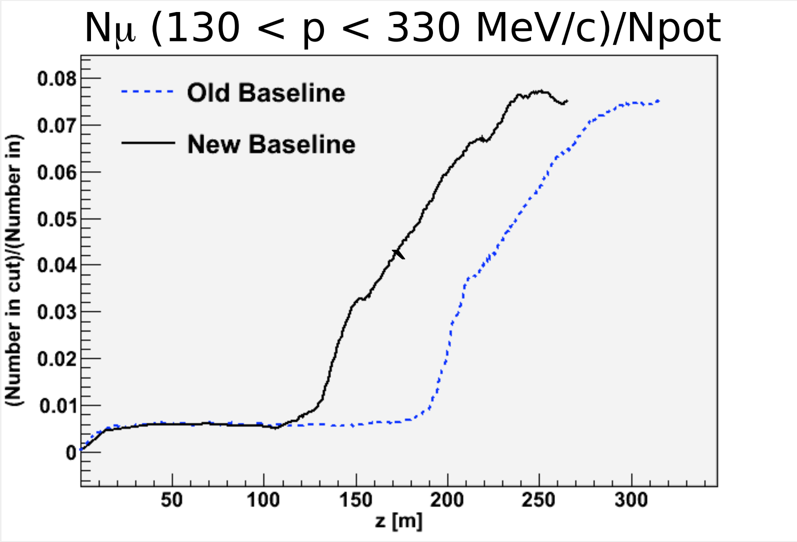
Shorter bunch train = shorter decay ring

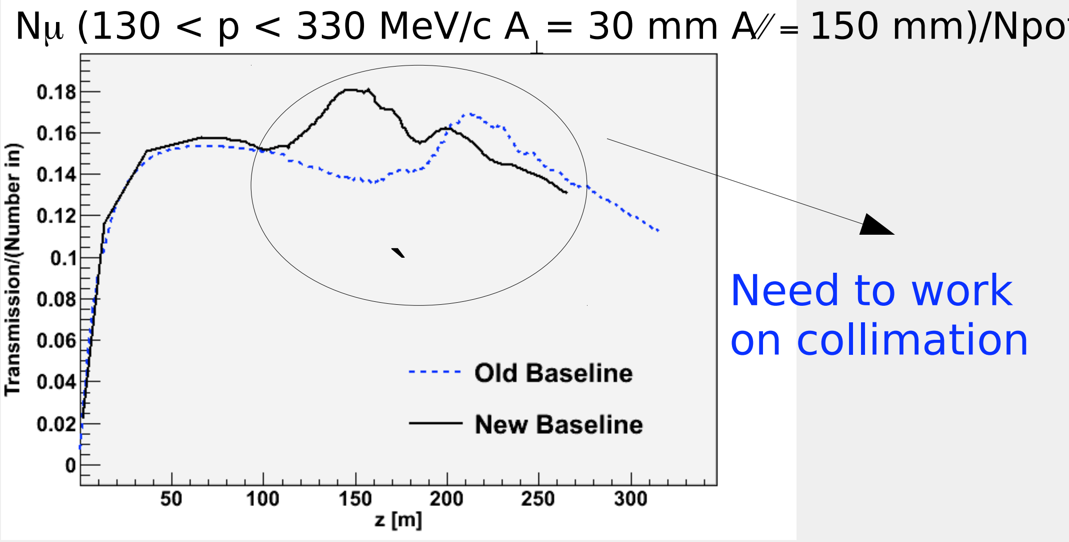
Less hardware = cheaper front end

Muon capture similar performance









Need to work on collimation

RF Problem

We need lots of RF in the front end

We have significant longitudinal manipulations to perform

Ionization cooling needs strong acceleration

We need lots of solenoidal focussing in the front end

Try to contain large transverse emittance beam

Ionization cooling needs tight focussing to reduce multiple scattering effects

Leads us to overlapping solenoidal focussing with RF cavities

RF cavities sit in ~1-2 T fields

Some empirical evidence that RF cavities and magnetic fields don't co-exist well

Somehow the B-field induces breakdown in the RF cavity

Possibly limits peak field to ~ 1/2 expected limit in > 1 Tesla fields

Not well understood, many caveats

Prepare risk mitigating options

Alternative: Low B-field Lattice

Take RF cavities out of B-field

Difficult to maintain big enough acceptance

Difficult to maintain tight enough focussing

Shielding introduces spherical aberrations

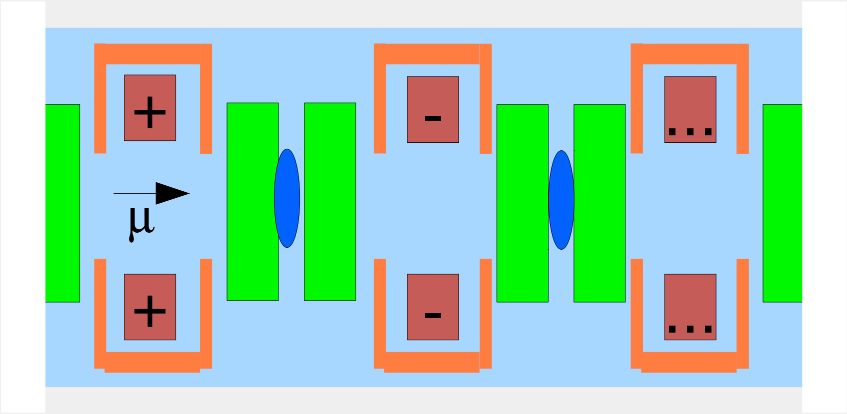
Stretching the lattice reduces acceptance

Can get close to original performance

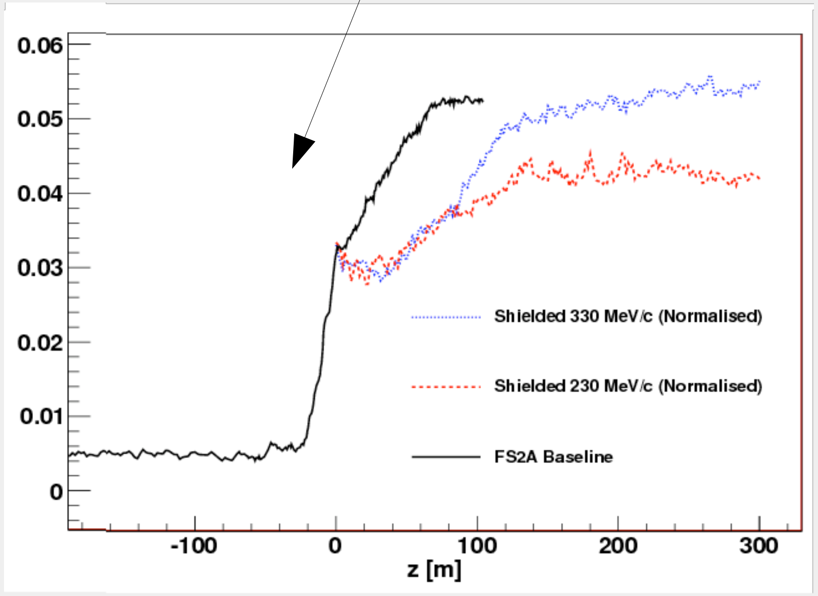
Further optimization may improve this

Only cooling section studied so far

Need to tackle phase rotation



Number captured
(in accelerator acceptance)



Other alternatives

Hybrid HPG lattice: See M. Zisman talk

Lower frequency (44-88 MHz) lattice: second part of talk

Magnetically Insulated

One theory is that emitted electrons are focussed by B-field and accelerated by E-field

Results in significant energy deposition in small area => thermal stressing and material fatigue. Keep E perpendicular to B: electrons are redirected to cavity surface without acceleration or focussing. Less heating (but multipacting?)

Beryllium cavities

Low Z material => less energy deposited per volume. Good material properties => less damage from thermal stress. Beryllium dust is toxic => handling and safety issues. Needs hardware program.

Longitudinally cooling lattices (Helical SfoFo, tilted RFoFo)

May be possible to improve cooling, thus reducing need for RF.

IDR Jobs (Autumn 2010)

IDR Jobs	Description
Drift	Effect of windows, magnet design
Buncher	Effect of windows, how many RF frequencies ? Magnet & RF cavity design
Rotator	Effect of windows, how many RF frequencies ? Magnet & RF cavity design
Cooler	Magnet, RF design, LiH design, heat load on LiH (needs active cooling?)
LiH preliminary design	Magnet, RF design, LiH design, heat load on LiH (needs active cooling?)
Beam cuts, time spread	Effect of time spread (proton bunch length) on beam
Activation	Activation from protons – need for proton absorber?
Energy Deposition, losses	Transmission losses from muons, how do we deal with muons not in accelerator acceptance? Preliminary plan for collimation, etc
Rad Shielding + Collimation preliminary design	Transmission losses from muons, how do we deal with muons not in accelerator acceptance? Preliminary plan for collimation, etc
Civil engineering preliminaries	Tunnel? Cut and cover?
Preliminary costing	
G4Beamline deck	Set-up baseline in G4Beamline
ICOOL person	Comparing/verifying different ICOOL versions
G4Beamline person	Comparing/verifying different G4Beamline versions
Tapering beta function	Optimisation of lattices
Longitudinal/transverse matching	Optimisation of lattices
44-88 MHz Lattice	Optimisation of lattices
HARP vs Simulation	Optimisation of codes
MARS/LAQGSM Production	Optimisation of codes
G4 Particle Production off target	Optimisation of lattices
Low B-field Lattice	Optimisation of lattices
HPRF Lattice	Optimisation of lattices

RDR Jobs (Autumn 2012)

Bigger jobs, lower granularity

- Some IDR jobs carry over (not listed)

More work may arise

RDR	
Second tracking code	Simulation in G4Beamline or equivalent
Alignments and Tolerances	Requirement for magnet and RF alignment
3D magnet designs	Including trim magnets, etc
3D RF designs	Including power couplers, window design, power supply
Heat loads, activation and	Detailed design for collimation scheme in muon front end
Backup option if required	Further lattice work depending on progress in MTA
Civil engineering	
Beam Instrumentation	What do we need?
Services	Vacuum, cryogenics, etc
Costing	

Summary

Baseline design is frozen and engineering is in progress

Several mature options for risk mitigation

We are pretty much on schedule

- Missing most milestones by about a month (perfect!)

But we have a lot to do

- 3-4 months to get preliminary engineering together
- Will be tight

More help always welcome

NF efforts @CERN

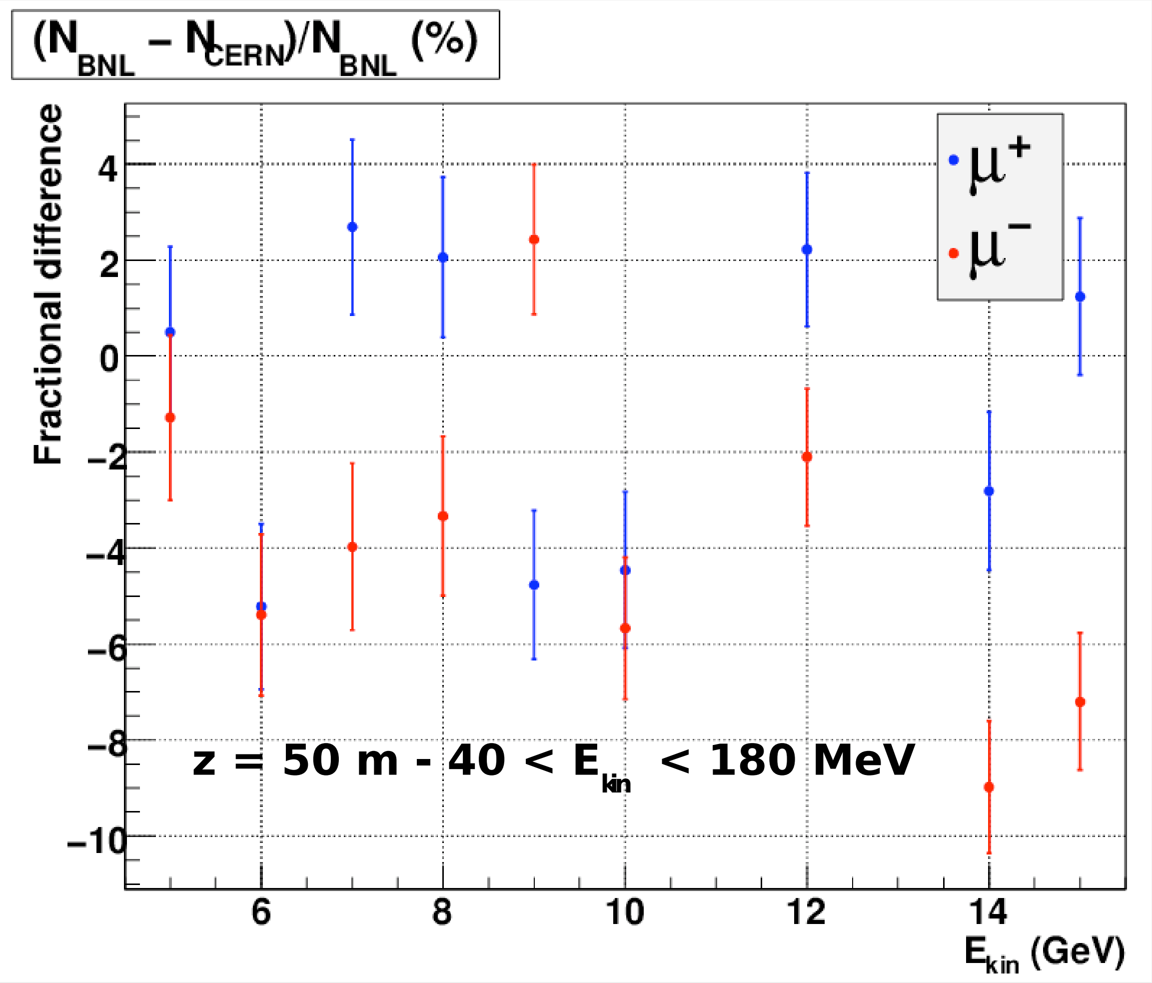
June 3rd 2010

Particles production (coll. with BNL)

Tested the exact same input files on 2 different machines:

- SL4 2.6.9-89.0.11.EL.smp – 32x – little endian (BNL)

- SLC4 2.6.9-89.0.18.EL.cern – 32x – little endian (CERN)

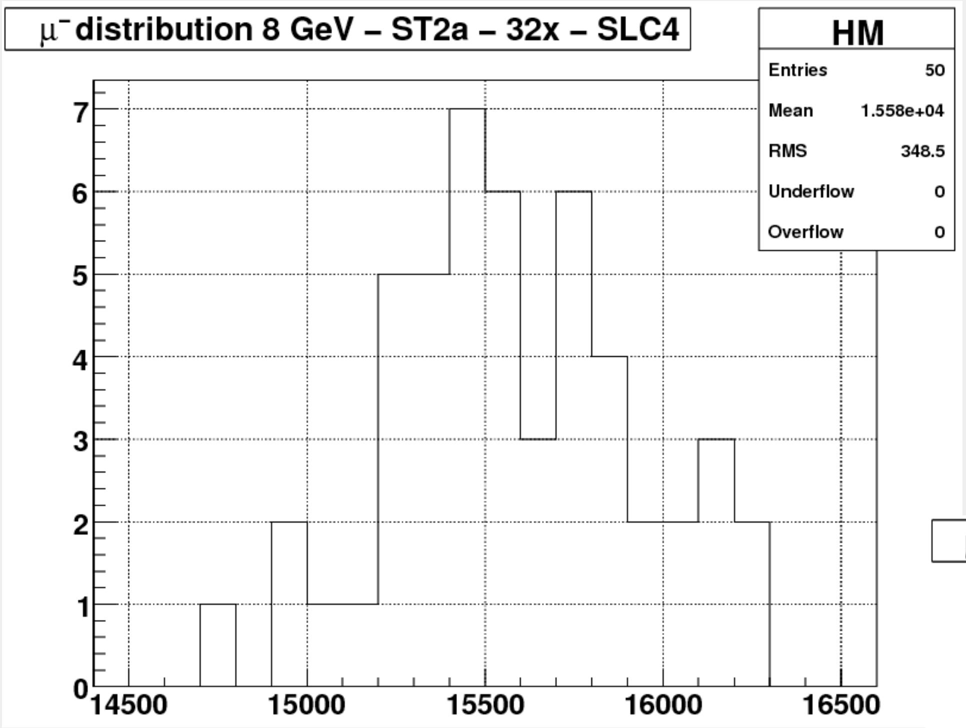


$$Error = \sqrt{(N.s_2 - s_1^2)/(N-1)}$$

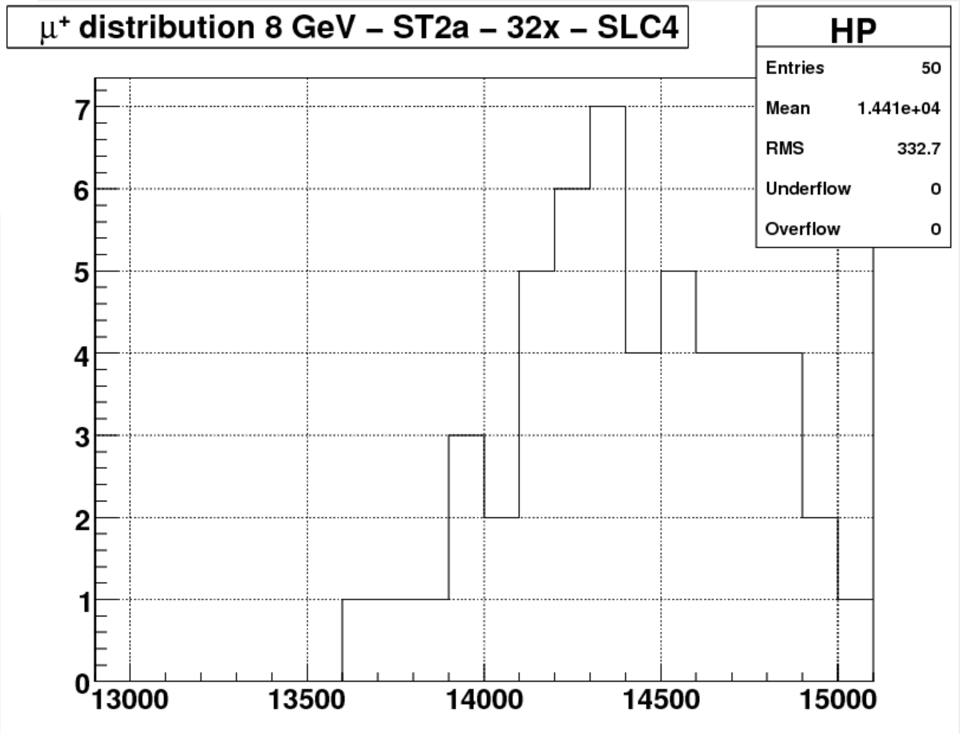
$$s_2 = \sum w_i^2 \qquad s_1 = \sum w_i$$

Difference in the yield HAS to come from different code versions: need to be confirmed by the MARS developers as we don't have access to the source files.

Muon distribution



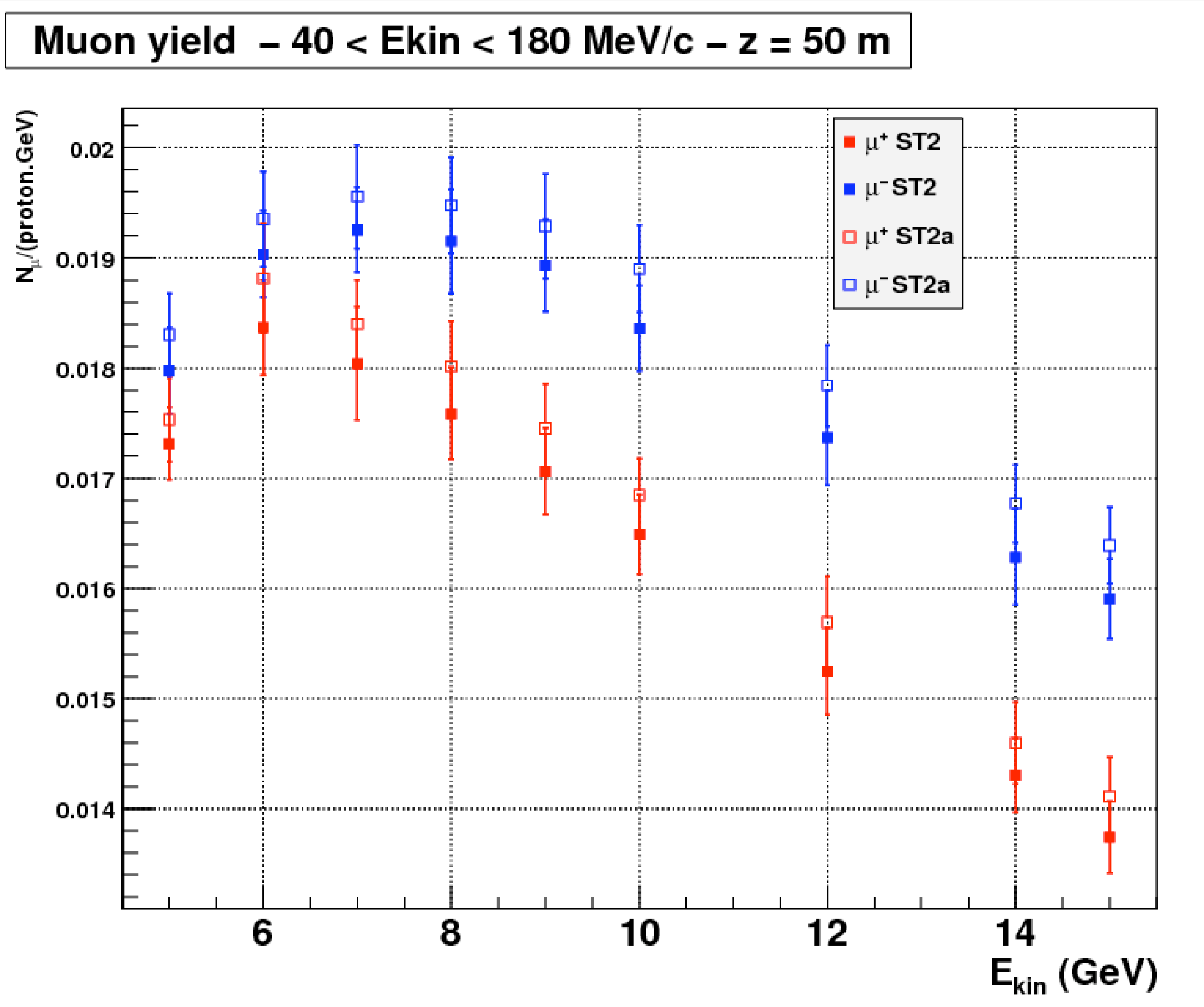
Get distribution from 50 runs with different start random SEED.



! RMS in ROOT = STD.

STD ~ 2% of distribution.

ST2/ST2a comparison



Yield = MEAN

Error = STD

ST2a slightly better than ST2 (within the errors bars).

Advantage of a higher field at end of taper but ST2 magnet configuration in a more mature design.

Optimum at 7-8 GeV and yield difference between muon signs is likely to be model dependent.

Conclusion & todo list

Field map:

@IDS-NF meeting value of 1.5 T at end of taper was chosen.

Need to redo the target (20 T) to taper (1.5 T) field map.

Need to work on realistic magnets currents, coils size and position.

MARS simulation:

Waiting for the MARS15 (m1509) release at CERN (contains a validated low-energy model called LAQGSM).

Study muon yield with new taper (20 T to 1.5 T).

Study dependence of muon yield as function of bunch length.

CERN 44-88 MHz scenario

Lattice:

CERN front-end design based on a scenario using 2 GeV protons from SPL on a Hg target, particle sign selection with a horn, single bunch-to-bucket lattice.

History:

2000-2001 simulation using PATH (code developed at CERN based on TRAVEL/TURTLE/TRANSPORT). [A. Lombardi]
2001-2003 simulation/comparison performed in ICOOL with more pessimistic results. [E.B. Holzer]
Then no more simulation were done and scenario was dropped.

In the spirit of “alternative to baseline” design, we decided to look again at it.

44-88 MHz scenario

Pion production: 2 GeV proton beam on a 26 cm-long Hg target in 20 T field.

Drift: 30 m decay in 1.8 T field.

Rotation: 30 1m-long cavities at 44 MHz (2 MV/m) in 1.8 T solenoid. Phasing by 1 degree shift from -121 to -4 deg.

(energy spread reduction by 2)

Cooling I: 44 MHz RF + H_2 absorbers. ($\varepsilon_\perp$ reduced by 40%)

Acceleration: 44 MHz RF provide acceleration to 300 MeV/c.

Cooling II: 88 MHz RF (4 MV/m) + H_2 absorbers.

($\varepsilon_\perp$ reduced by 30%)

ICOOL deck (rotation)

Pion production: using a 8 GeV-ST2a negative beam file from IDS-NF at 12 m (field 1.75 T – time ~ 50 ns).

Drift: testing 10-30 m length in 1.8 T field.

Rotation: trying initial phasing -121 to -4.

Cooling: to be studied after fixing preliminary drift length and phase adjustment.

Definition/convention of the phase in ICOOL & PATH quite different.

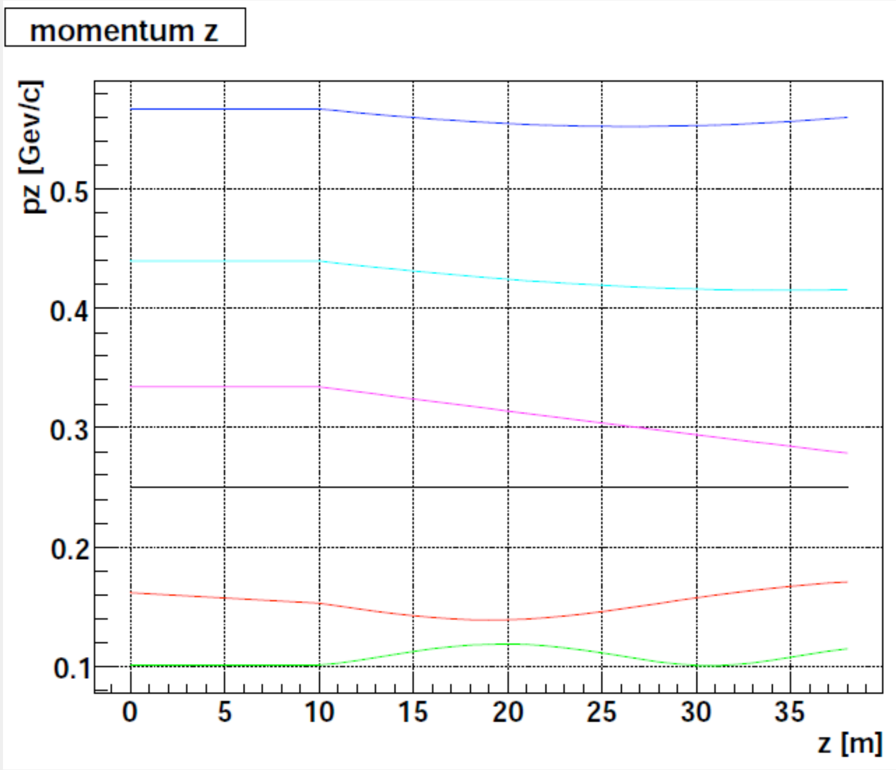
ICOOL use a constant velocity reference particle to time for the field zero-crossing.
Don't know how PATH is doing the job.

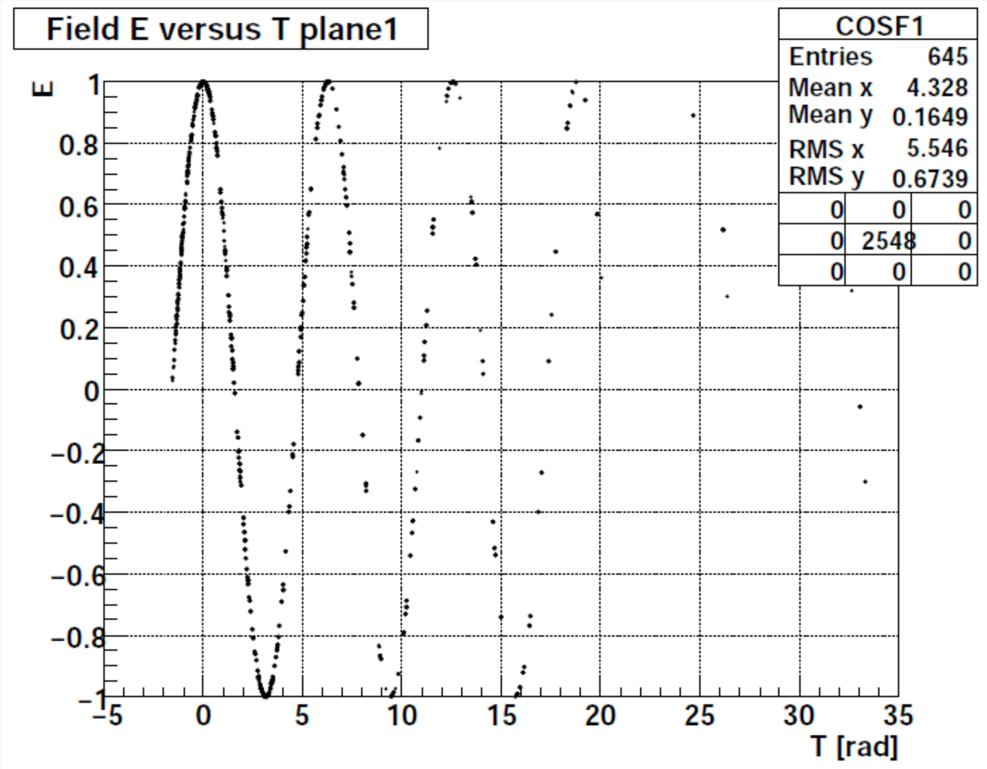
ICOOL deck (rotation)

Believe that the phase difference in ICOOL & PATH is 90°.

First simulation with -31 to 86° no clear rotation, particles with p > 250 MeV/c accelerating and with p < 250 MeV/c decelerating.

New simulation with constant phasing, trying to optimize the phase for maximum rotation (e.g 10 m drift, 180° phase):





Conclusion & todo list

Work in progress in defining drift length and phasing of the rotation part.

Need to simulate the 44 & 88 MHz cooling stages.

Worth re-examining to assess performance in the standard code environment of IDS-NF (MARS/ICOOL).

If performance satisfactory may think if we would get around the high gradient in magnetic field problem with a realistic RF+magnet lattice design.

LiH model study in Geant4

Simulations in G4MICE & ICOOL with reduced gradients giving different results likely due to difference in the LiH models.

Comparison of different ICOOL version (C. Rogers) give also different results where LiH model in ICOOL was changed.

M. Tech student (S. Vij) coming at CERN for a 5-months internship. Will look at LiH compound models in Geant4 and (if time) in ICOOL.

Magnet for an RF R&D experiment

Looking into possible use of a CERN large bore magnet in support of the MTA for an RF R&D experiment.

A magnet and an experimental hall have been identified.

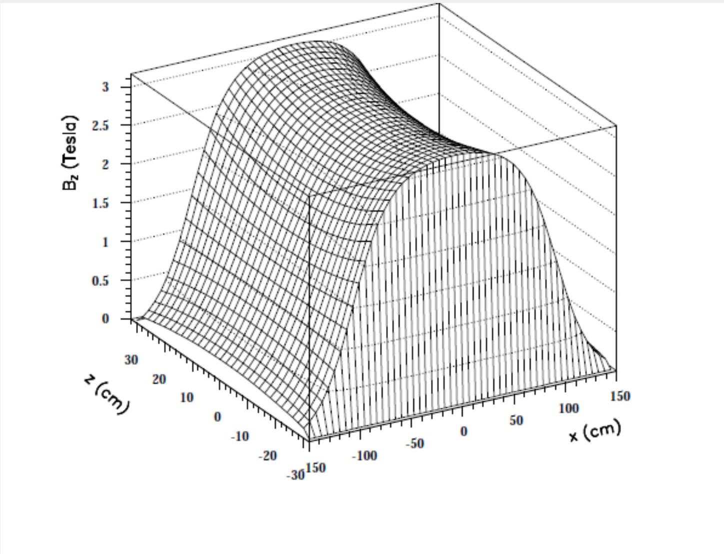


Figure 2: The z-component of the magnetic field in M1, plotted as a function of x and z. The x-direction is parallel to the beam, while z-direction is transverse to the beam.

Positive feedback received on trying to identify the resources needed for this experiment.

Need to identify RF cavity / power units and RF experts.

Putting up a proposal for possible use of the area in 2011.

Summary

Particle production:

- ST2/ST2a comparison, no big improvement on particles production (ST2 more mature, bunching/rotation likes high B).

Baseline revision is now at 1.5 T.

- waiting for release of MARS15 (m1509).

44-88 MHz lattice:

- working on drift & phasing (previous iterative phasing performance could not be reproduced) for rotation.
- need to simulate further cooling stages

LiH model in G4:

- hope to get some results for August.

RF R&D experiment

- hope to circulate a proposal draft by the end of this month.