Beam-target survey of US Study 2a and CERN neutrino factory front-ends

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Introduction

- one of the ISS machine group front-end tasks is to compare the performance of existing NF front-end designs

- use similar approximations and level of detail for all designs
- use same simulation code
- use same initial beam distributions
- FOM is number of muons inside accelerator acceptance per incident proton per GeV of incident beam power

Survey

- presently considering 4 schemes
  - KEK
  - CERN with horn
  - CERN with solenoid (not baseline)
  - US Study 2a

- using 5 beam/target combinations to sample phase space
  - 4 GeV – C
  - 40 GeV – C
  - 10 GeV - Ta
  - 4 GeV – Hg
  - 40 GeV – Hg
- making relative comparison now
- validate absolute values with HARP/MIPP later

Reference production files

- prepared by Stephen Brooks using MARS15
- proton bunch length is 1 ns
  (performance decreases 10% going from 1 -> 3 ns)
- target lengths

Ta	20 cm
Hg	25 cm
C	66 cm

- radius = 1 cm
- aligned with solenoid axis
- re-interactions included
- no B on target

Transverse momentum at production

Table 1: Transverse momentum on target surface

		positive		negative	
	E [GeV]	$< p_T >$ [GeV/c]	$\sigma(p_T)$ [GeV/c]	$< p_T >$ [GeV/c]	$\sigma(p_T)$ [GeV/c]
C	4	305	212	298	206
Hg	4	333	216	279	205
Ta	10	409	301	386	292
C	40	385	298	392	306
Hg	40	372	280	352	275

ICOOL input

- ICOOL needs beam distribution at z-plane at end of the target
- wrote code MARS2IC to
  - track particles from target cylinder to end of target
  - convert variables to ICOOL format

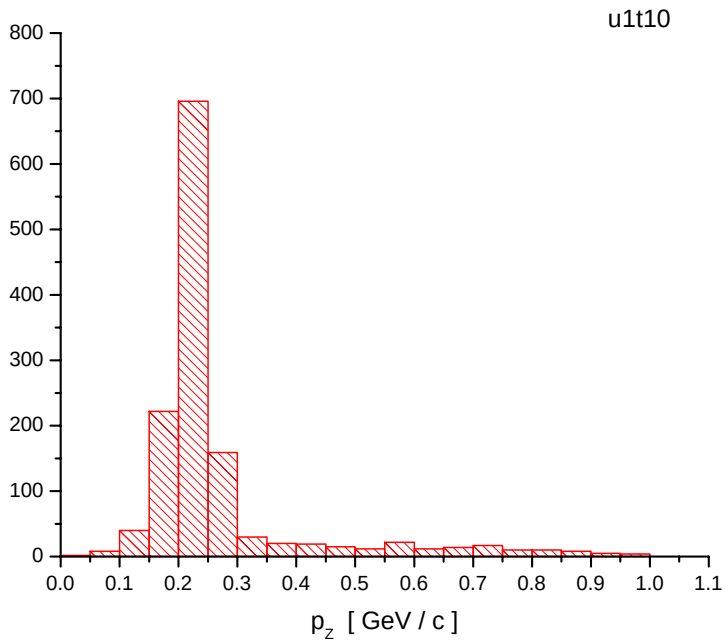
tantalum	tapered solenoid
carbon	constant solenoid
mercury	tapered solenoid
	CERN horn

- tapered solenoid used US Study 2 profile around target

US Study 2a

- Accelerator normalized acceptance
  - 30 mm transverse
  - 150 mm longitudinal
  - 100 < p < 300 MeV/c
- reference FOM is 0.17 / 24 = 0.007

p distribution
at end of channel



US Study 2a – positive particles

Table 2: ST2a positive beam-target survey.

E_b [GeV]	target	L [cm]	μ / π	μ_A / π	μ_A / p	μ_A / p GeV
4	C	66	0.256	0.133	0.045	0.0114
4	Hg	25	0.221	0.131	0.027	0.0066
10	Ta	20	0.187	0.097	0.087	0.0087
40	C	66	0.190	0.065	0.171	0.0043
40	Hg	25	0.156	0.071	0.271	0.0068

US Study 2a – negative particles

Table 3: ST2a negative beam-target survey.

E_b [GeV]	target	L [cm]	μ / π	μ_A / π	μ_A / p	μ_A / p GeV
4	C	66	0.267	0.151	0.045	0.0113
4	Hg	25	0.244	0.157	0.039	0.0098
10	Ta	20	0.199	0.113	0.107	0.0108
40	C	66	0.197	0.081	0.184	0.0046
40	Hg	25	0.171	0.085	0.330	0.0083

CERN neutrino factory

- many variations, not all documented!
  - horn or solenoid capture
  - 44/88 MHz or all-88 MHz front end
  - 2.2 or 3.5 GeV beam energy
  - constant channel solenoid or NF-087 field or ???
- Accelerator normalized acceptance
  - 30 mm transverse
  - 300 mm longitudinal
  - $100 < p < 500$ MeV/c

CERN 44/88 MHz front-end

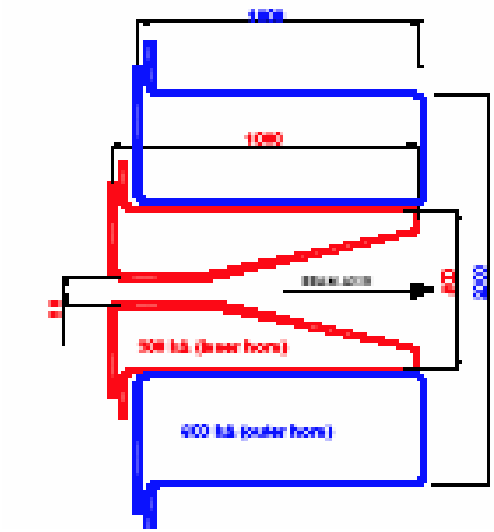
- horn was designed for 2 GeV (very compact)
- needs missing matching optics to solenoid channel
- needs all new design for higher energies
- 44/88 MHz design is complicated

  B: 1.8 -> 5 T

  p_{REF}: 200 -> 300 MeV

  2 cooling stages with accelerator in between
- had to increase acceleration length by 10 m to get 200 -> 280 MeV/c

- horn radius = 1 m
- channel radius = 0.3 m
- want 0.5 m no-field gap



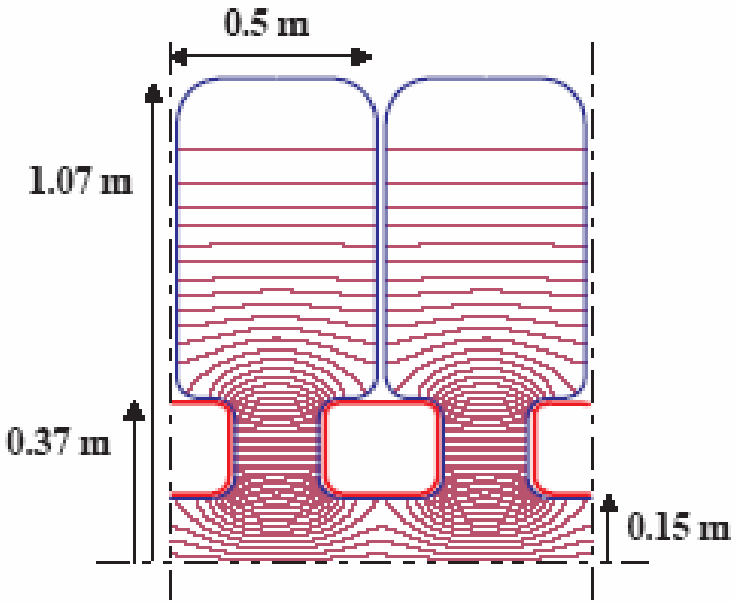
(Simon Gilardoni)

CERN 44/88 MHz front-end

E_b [GeV]	target	L [cm]	collection	μ / π	μ_A / π	μ_A / p	μ_A / p GeV
10	Ta	20	solenoid	0.129	0.011	0.010	0.0010
4	Hg	25	horn	0.007	0.001	0.0002	0.00004

CERN – focusing in all-88 MHz channel

- last CERN front-end design
  - simpler design
  - shorter
- design of 0.5 m "matching" regions in cooling cell is not clear
- NF-087 design gives large (68%) modulation of on-axis solenoid field
- set up low (7%) modulation periodic channel for comparison



(note NF-087)

CERN – focusing in all-88 MHz channel

design	μ / π	μ_A / π	μ_A / p	μ_A / p GeV
continuous	0.236	0.015	0.013	0.0013
NF-087	0.098	0.008	0.008	0.0008
low modulation	0.226	0.016	0.014	0.0014

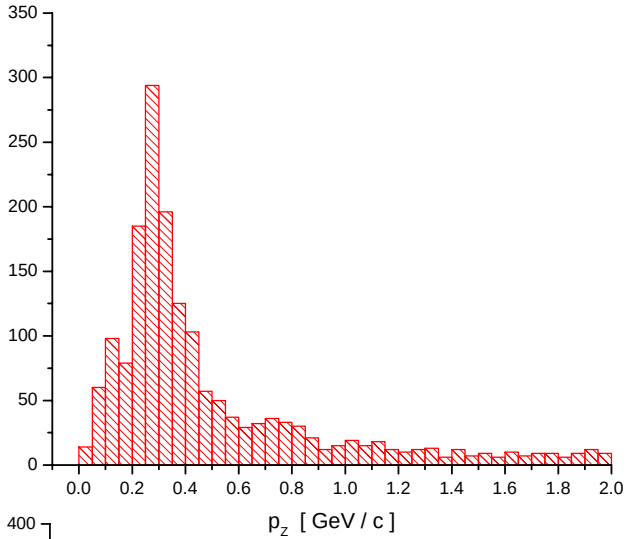
- low modulation channel gives same performance as continuous channel

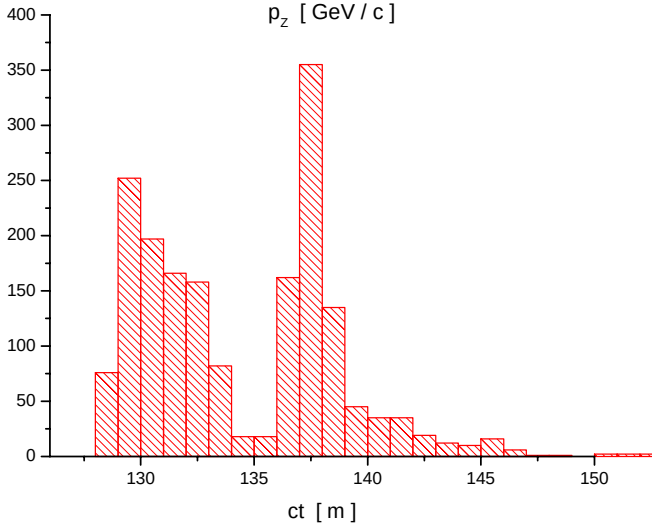
CERN – beam-target survey for positive muons

Table 3: CERN all-88 MHz beam-target survey.

E_b [GeV]	target	L [cm]	μ / π	μ_A / π	μ_A / p	μ_A / p GeV
4	C	66	0.286	0.018	0.006	0.0015
4	Hg	25	0.210	0.017	0.003	0.0009
10	Ta	20	0.226	0.016	0.014	0.0014
40	C	66	0.271	0.010	0.026	0.0007
40	Hg	25	0.206	0.011	0.043	0.0011

CERN – end of all-88 MHz channel

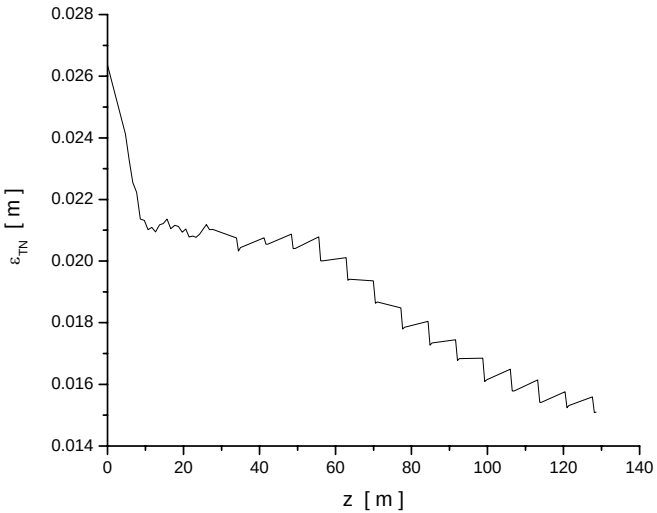


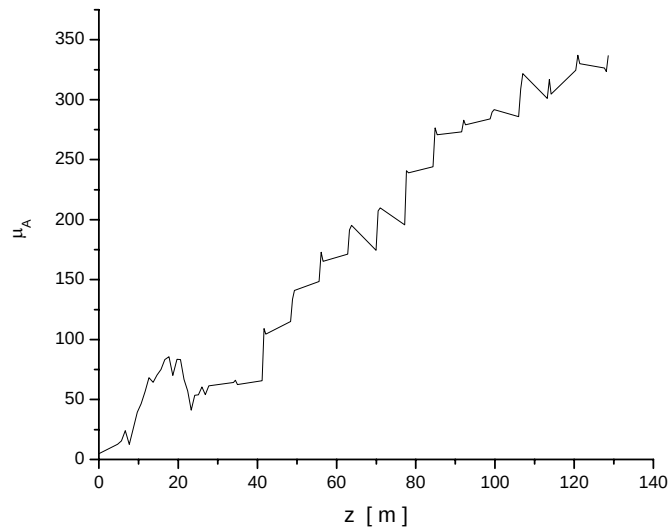


momentum:
long high energy tail

time:
spilling into 2nd bunch

CERN – all-88 MHz performance vs z





normalized transverse emittance hasn't reached equilibrium

muons in accelerator acceptance are still increasing

Conclusions

- US2a results for Ta better than reference value
- negative Ta about 20% higher than positive
- US2a shows higher FOM than CERN
- still have uncertainties about CERN design
- CERN 88 MHz front end better than the 44/88 MHz
- CERN could use longer cooling channel