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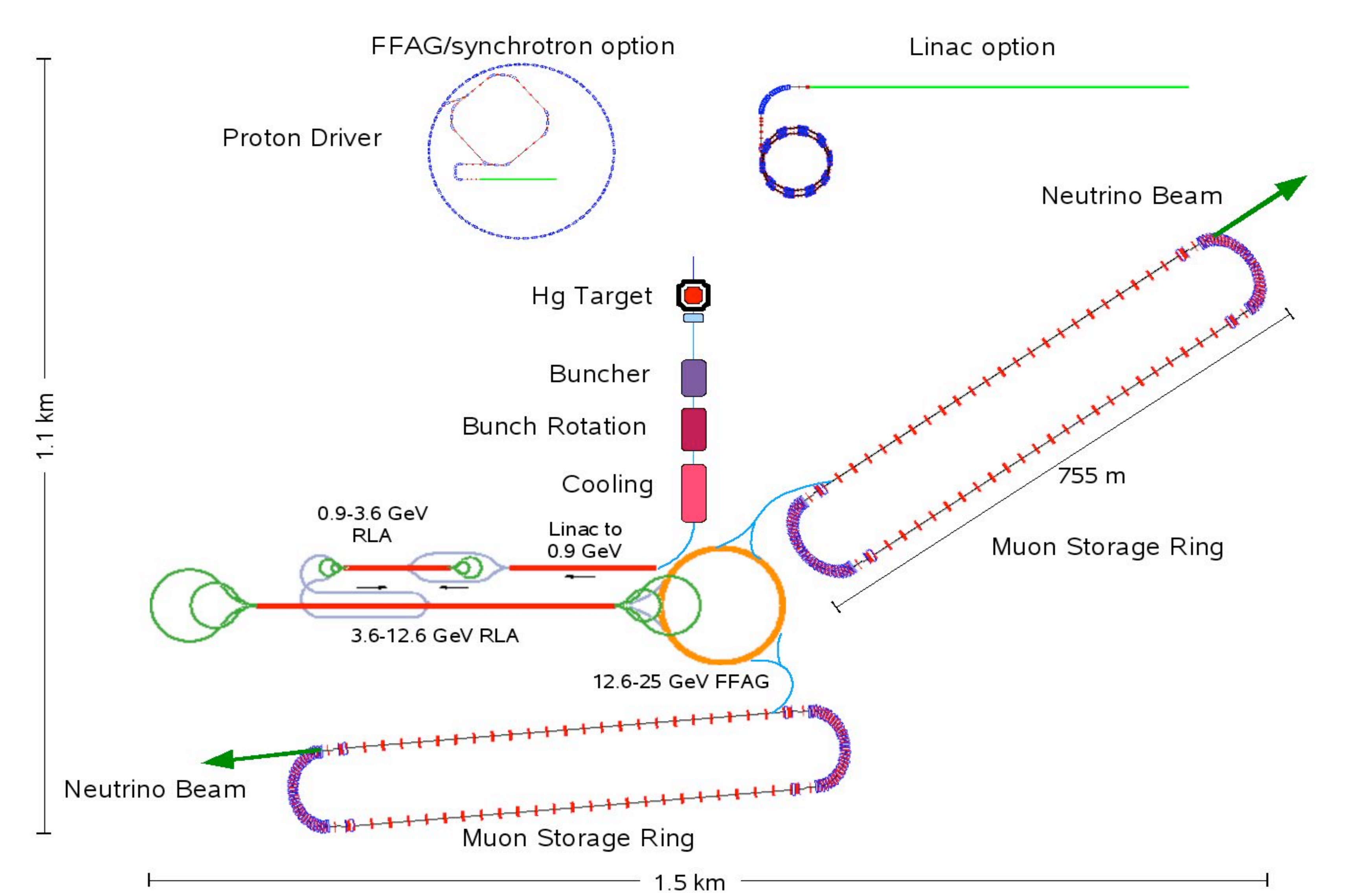
Status of Neutrino Factory R & D including IDR

Overview


FFAG/synchrotron option
Linac option
Proton Driver
Neutrino Beam
Hg Target
Buncher
Bunch Rotation
Cooling
0.9-3.6 GeV
RLA
Linac to
0.9 GeV
755 m
Muon Storage Ring
3.6-12.6 GeV RLA
12.6-25 GeV FFAG
Neutrino Beam
Muon Storage Ring
1.1 km
1.5 km

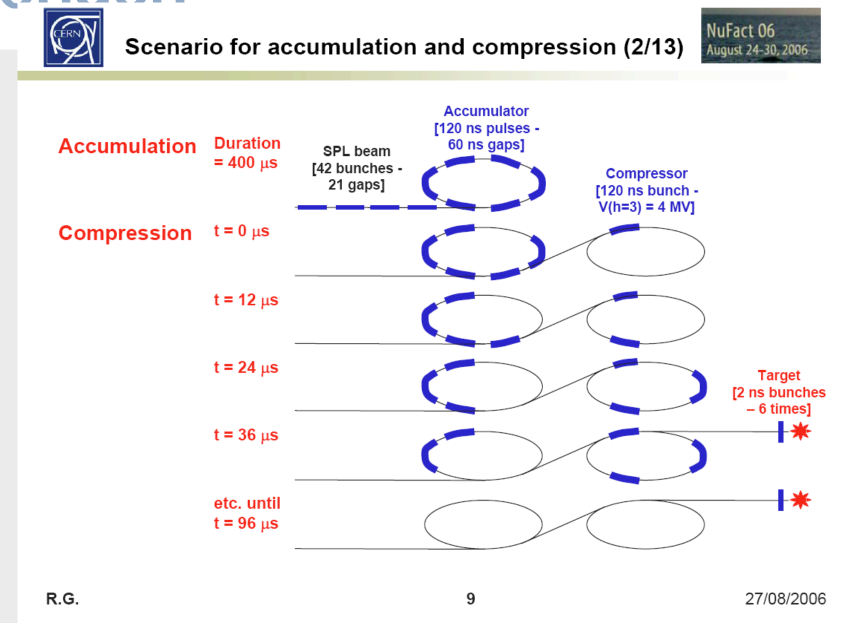
Proton driver status

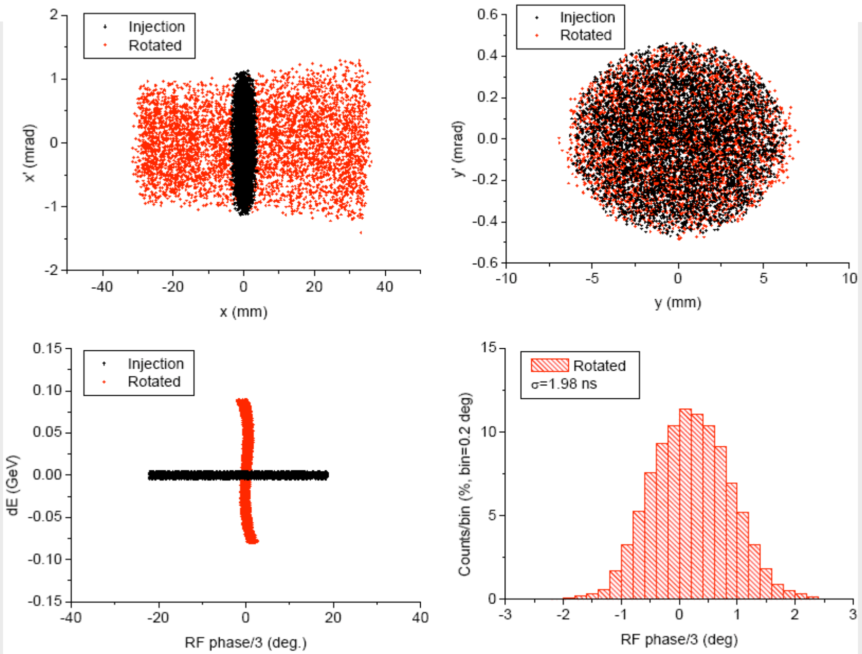
- Interested laboratories have been invited to contribute to the IDR.
- Neutrinofactory proton driver parameters will be defined in main text, a detailed description of site specific solution (and costing) will be in annex.

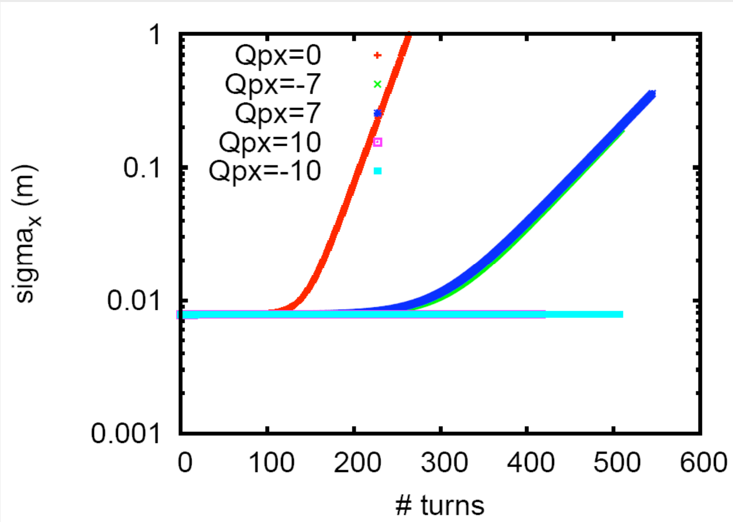
The following labs have agreed to contribute and contact persons identified:

- CERN: SPL based solution, detailed design and costing available, lattice design for compressor/holding rings available.
- Fermilab : Project X based solution with lattice designs and rough costing available
- RAL: Based on ISIS upgrade : Detailed designs and costing up to 3.2 GeV available, lattice design for final RCS available. Detailing and costing started.

SPL based CERN proton driver





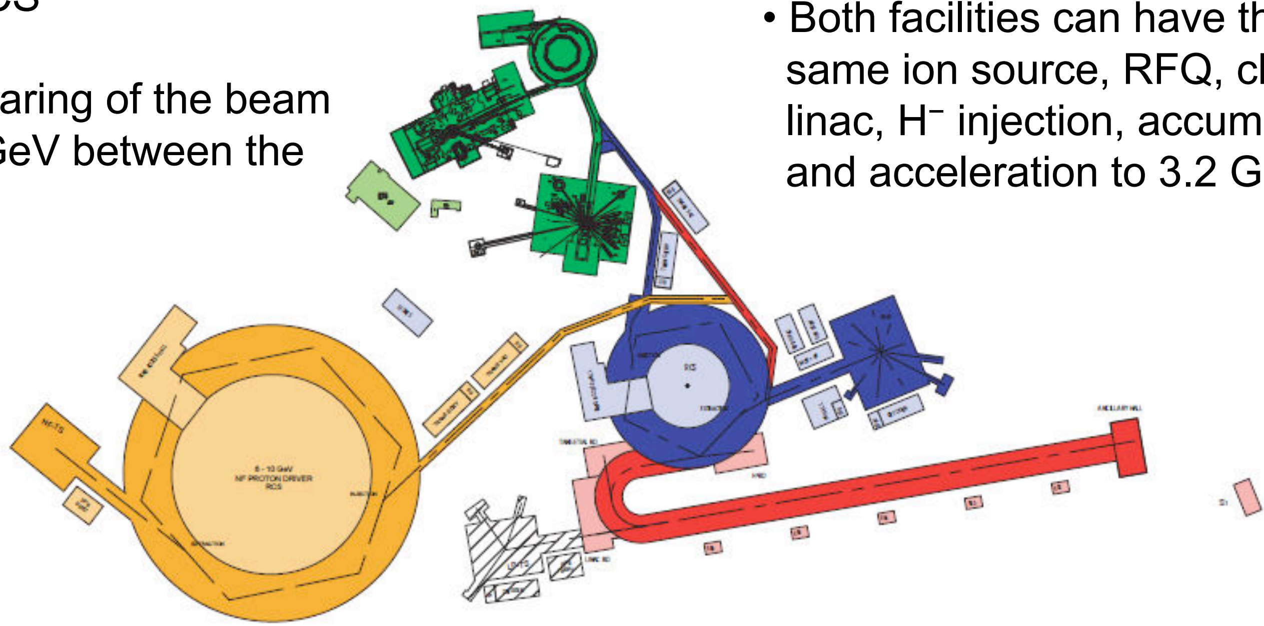


- Both rings designed and tracked!
- Study of instabilities during accumulation – chromaticity helps.
- Orbit simulations of bunch compression – large dispersion helps!

Common Proton Driver for Neutron Source and the Neutrino Factory at RAL

- Based on MW ISIS upgrade with 800 MeV Linac and 3.2 (~3.3) GeV RCS

- Assumes a sharing of the beam power at 3.2 GeV between the two facilities



- Both facilities can have the same ion source, RFQ, chopper, linac, H^- injection, accumulation and acceleration to 3.2 GeV

- Requires additional RCS machine in order to meet the power and energy needs of the Neutrino Factory

Project X to Proton Driver

- Proton Driver energy 5-15 GeV
  - Project X delivers top energy of 8 GeV
- Proton Driver beam power of 4 MW
  - Project X designed to deliver 400 kW at 8 GeV
- Proton Driver 1-3 ns bunch length at 50 Hz
  - Will require a Proton Accumulation Ring
  - Will require a Bunching Compressor Ring

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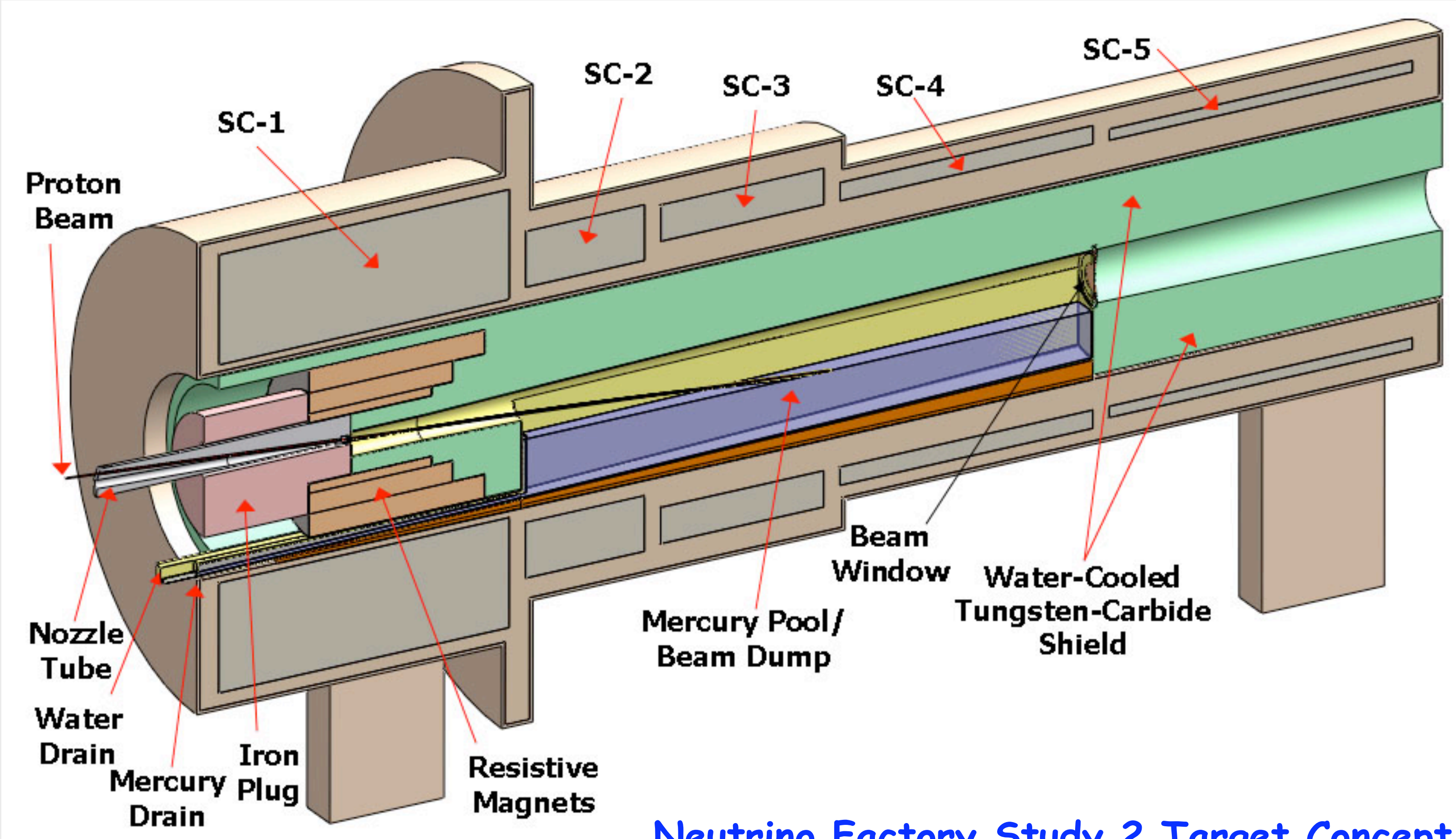
Baseline liquid mercury target



Neutrino Factory Study 2 Target Concept

2 main issues : Safety working with liquid mercury => solid targets
Heat deposition in SC magnets

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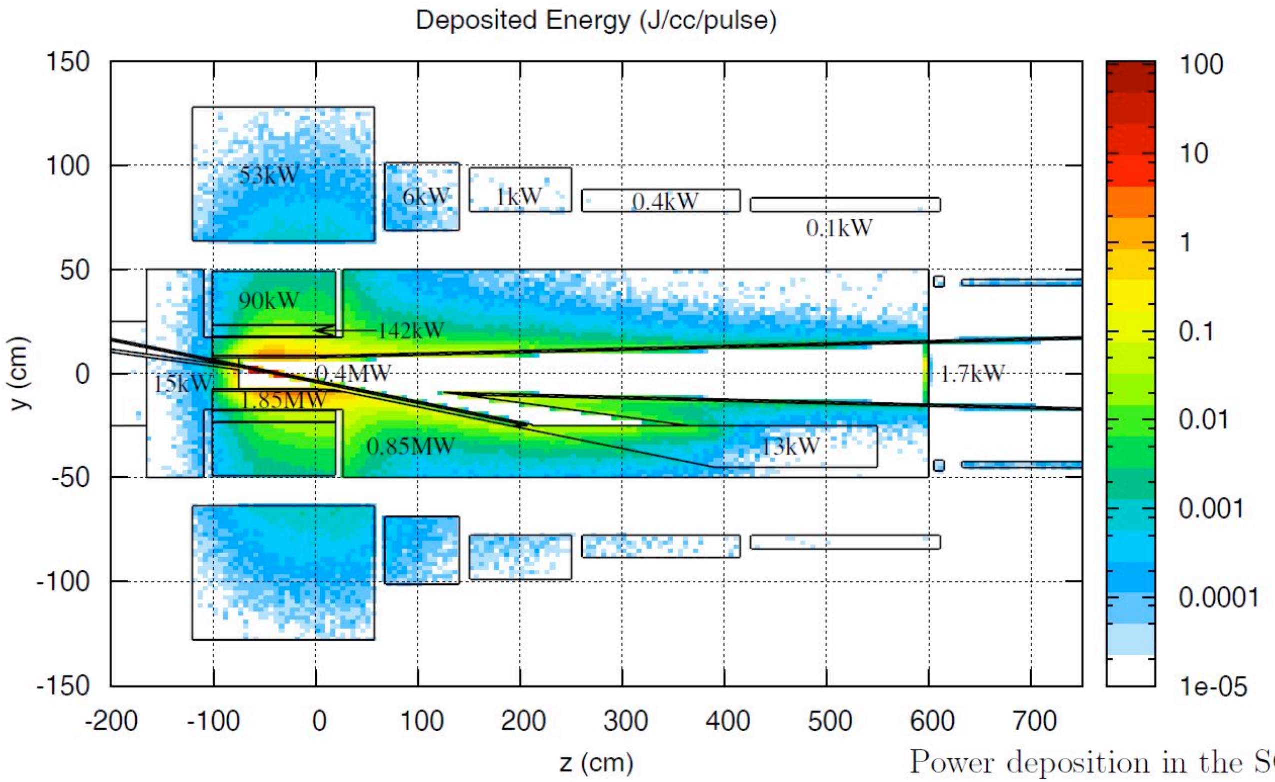
Risk mitigation - heat deposition



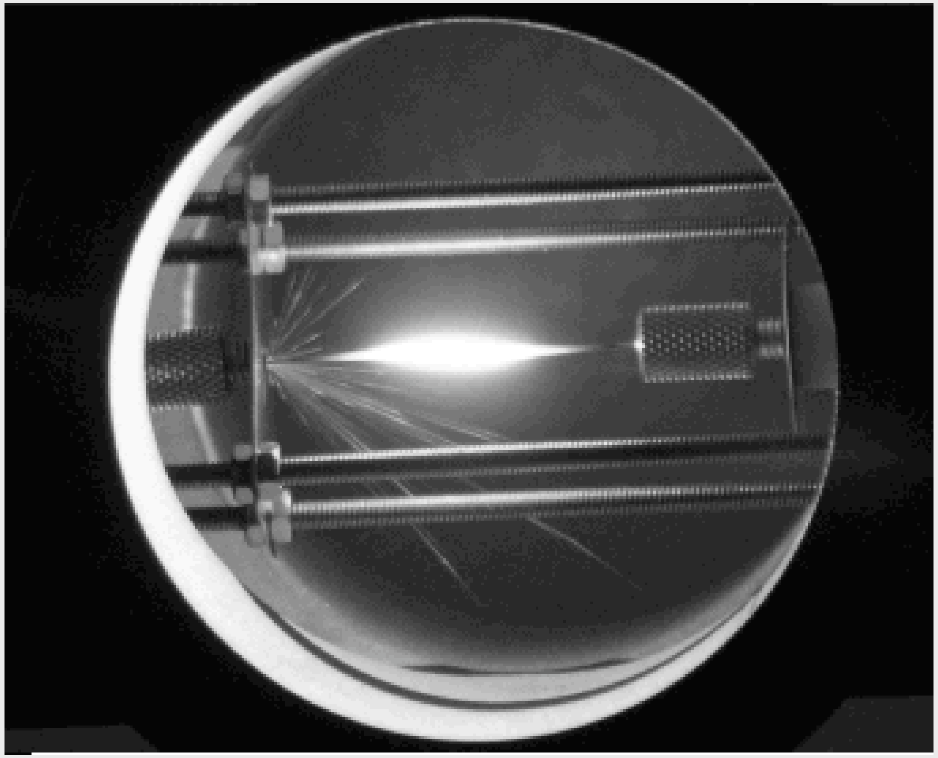
Power deposition in the SC coils & the shielding for Mars & Fluka

Shielding Material	SC1	(kW)	SC1-SC13	(kW)	Shielding	(kW)
0.8 WC + 0.2 Water	24.9	53.5	36.1	64.3	1839	2293
100% W	20.9	57.0	30.8	69.8	1826	2231
0.8 W + 0.2 Hg	22.6	62.5	33.2	79.7	1860	2199
0.6 W + 0.4 Hg	23.7	68.6	35.1	90.7	1892	2171
100% Hg	32.5	86.7	61.1	133.9	1651	2083

Risk mitigation : Solid target studies

Solid target tests:

- Shock studied in detail and comparison with simulations show good agreement =>
- Shock and target lifetime is no major issue
- Engineering focuses on implementation of solid target into collection system
- Collaboration with ESS on target wheel, target chain also considered.
- Yield reduction due to “splitting” of magnets



Risk mitigation : Liquidized powder target
Test rig at RAL

Powder tests:

Rig contains 100 kg Tungsten

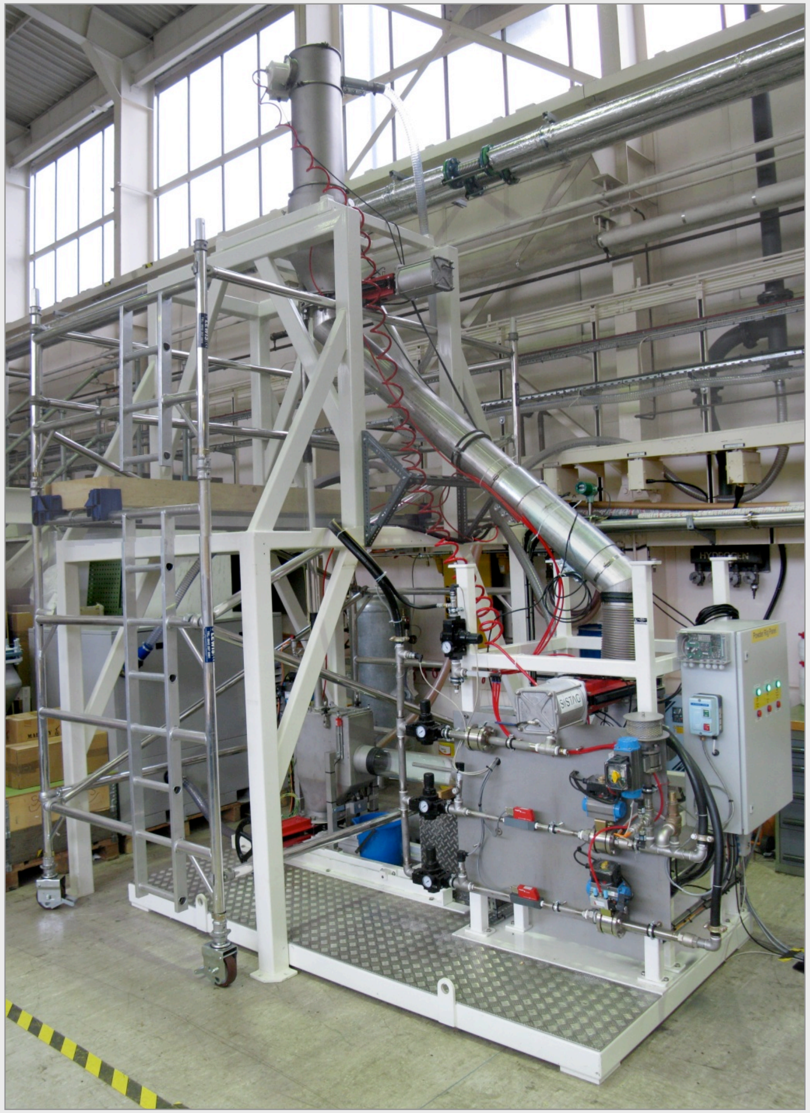
Particle size < 250 microns

Total ~10,000 kg powder conveyed so far

> 100 ejection cycles

Equivalent to 20 mins continuous operation

Liquidized power target seems feasible but at reduced yield due to reduced material density



IDS Baseline Buncher and φ-E Rotator

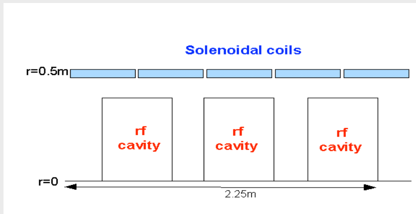
Drift (π→μ)

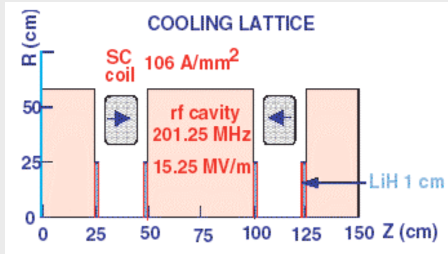
"Adiabatically" bunch beam first (weak 320 to 232 MHz rf)

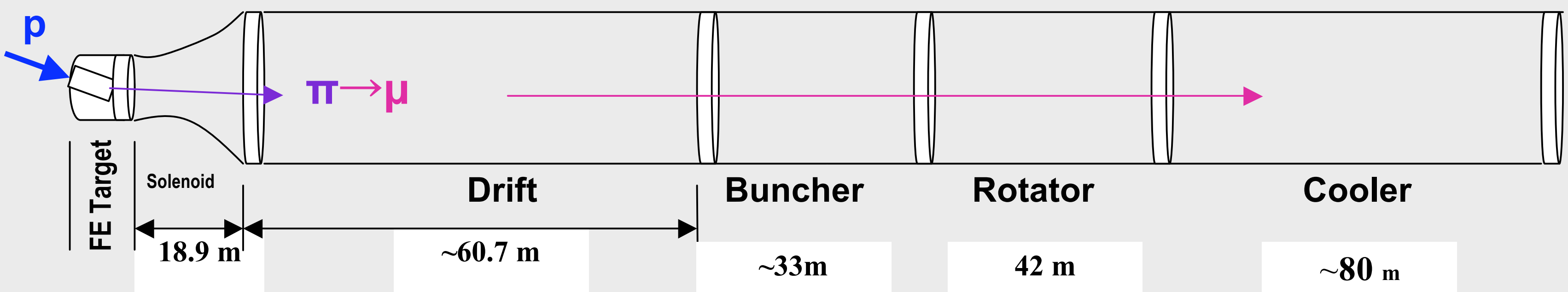
Φ-E rotate bunches – align bunches to ~equal energies

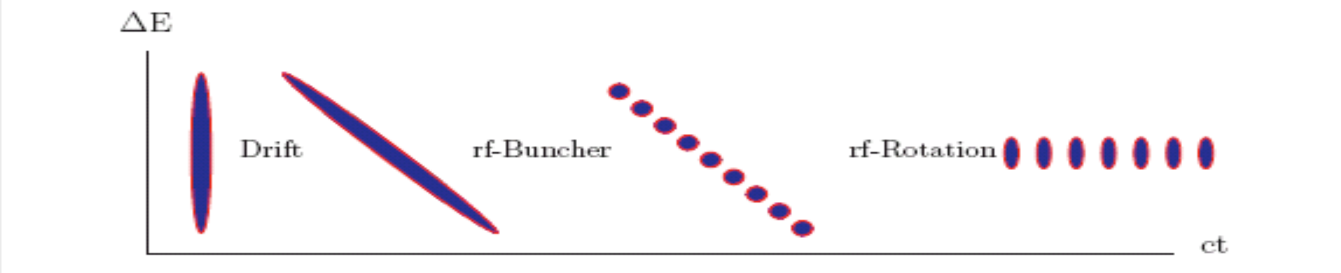
232 to 202 MHz, 12MV/m

Cool beam 201.25MHz









IDR compared with ISS

Acceptance ~same in reference ICOOL aperture

Acceptance increased if long. aperture increased …

But

IDR is ~40m shorter

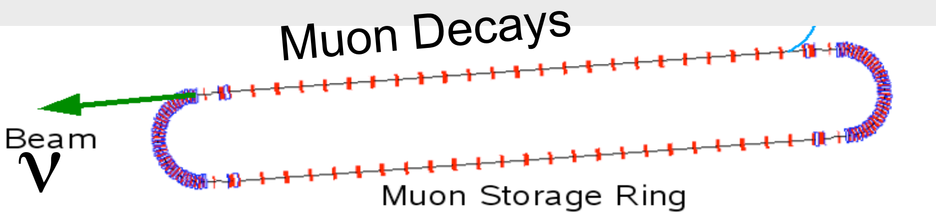
A bit less rf

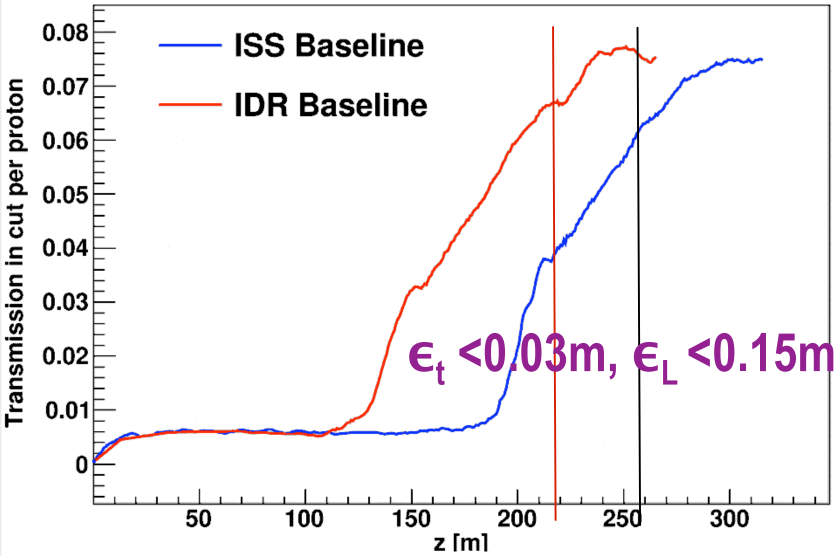
1.75T → 1.5T

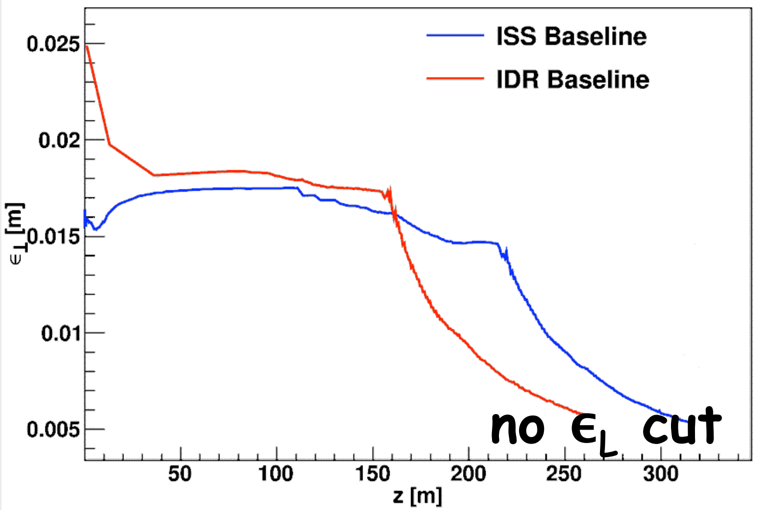
P_f increased from 210 to 230 MeV/c

Bunch train is shorter

- *120m → 80m*



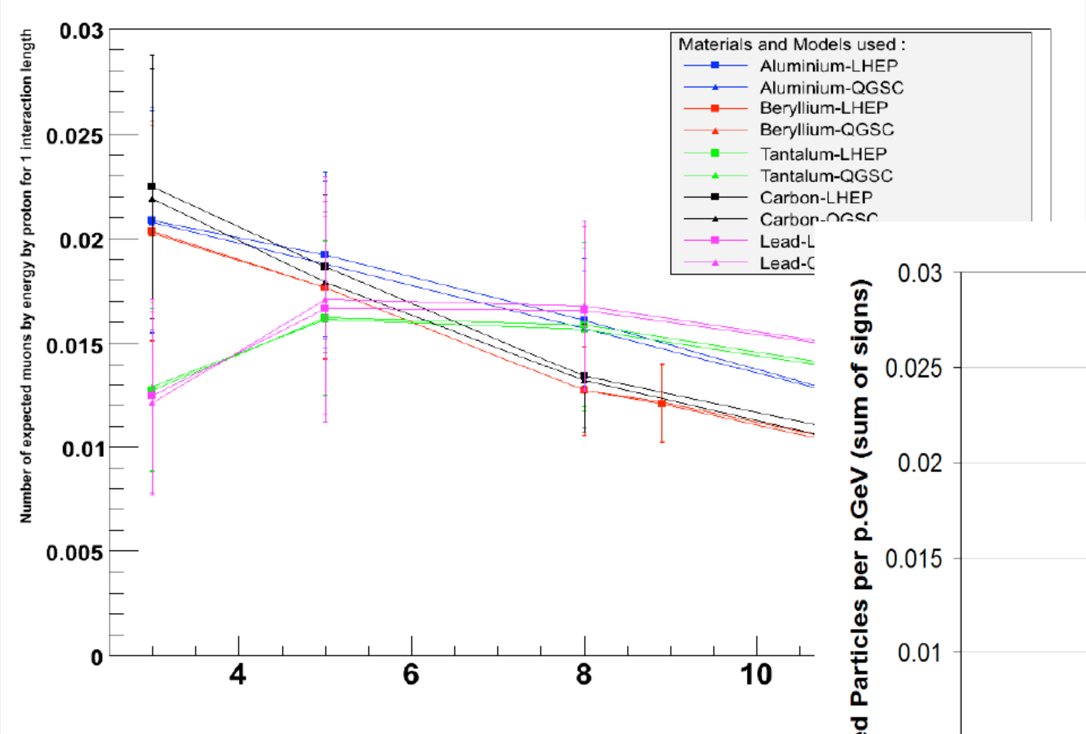




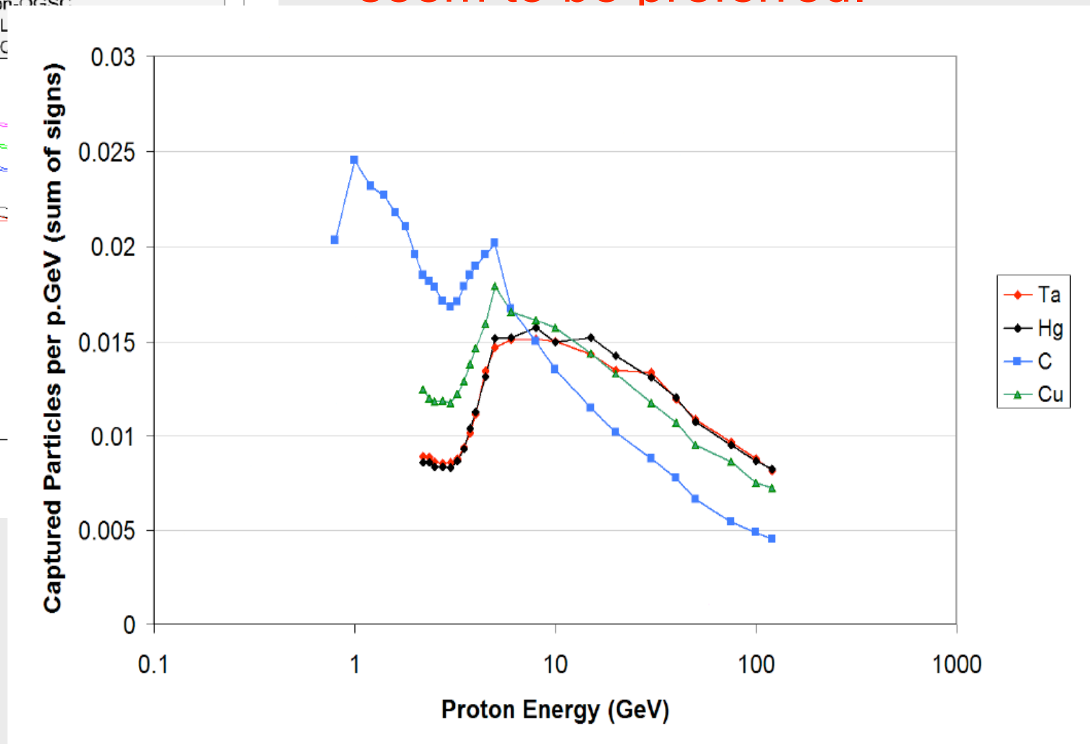
Particle yield and Harp data comparison

Large discrepancy between different simulation packages in yield, await new versions including Harp data, generally lower energies seem to be preferred.

Reweighted Harp results



Comparison to MARS simulations (S.Brooks)



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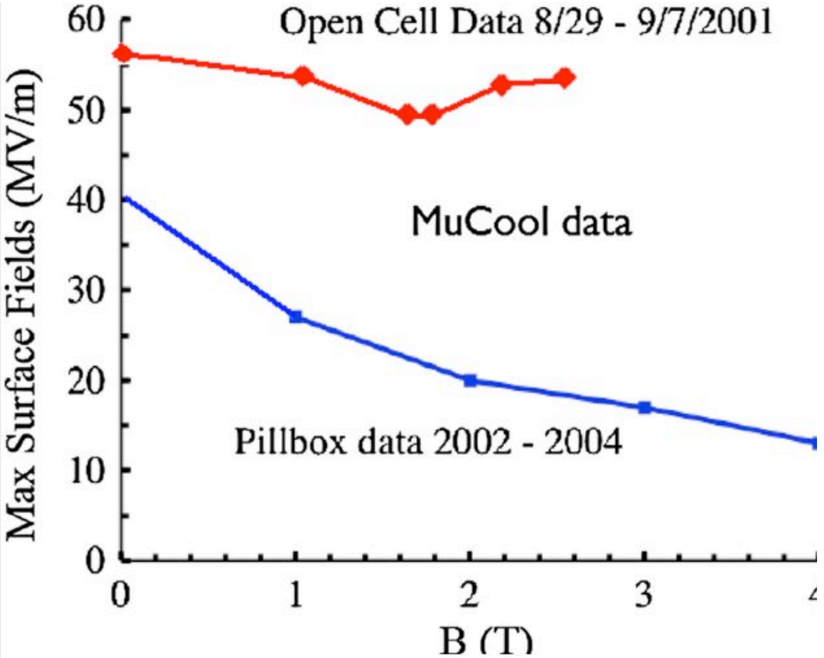
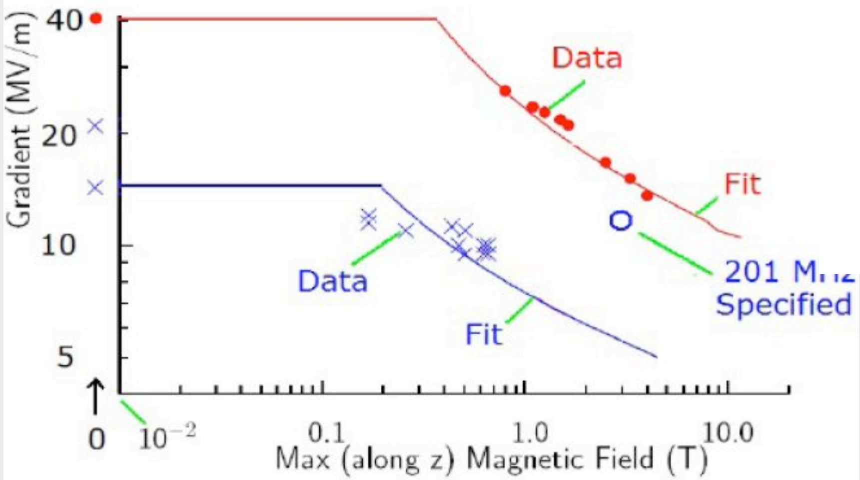
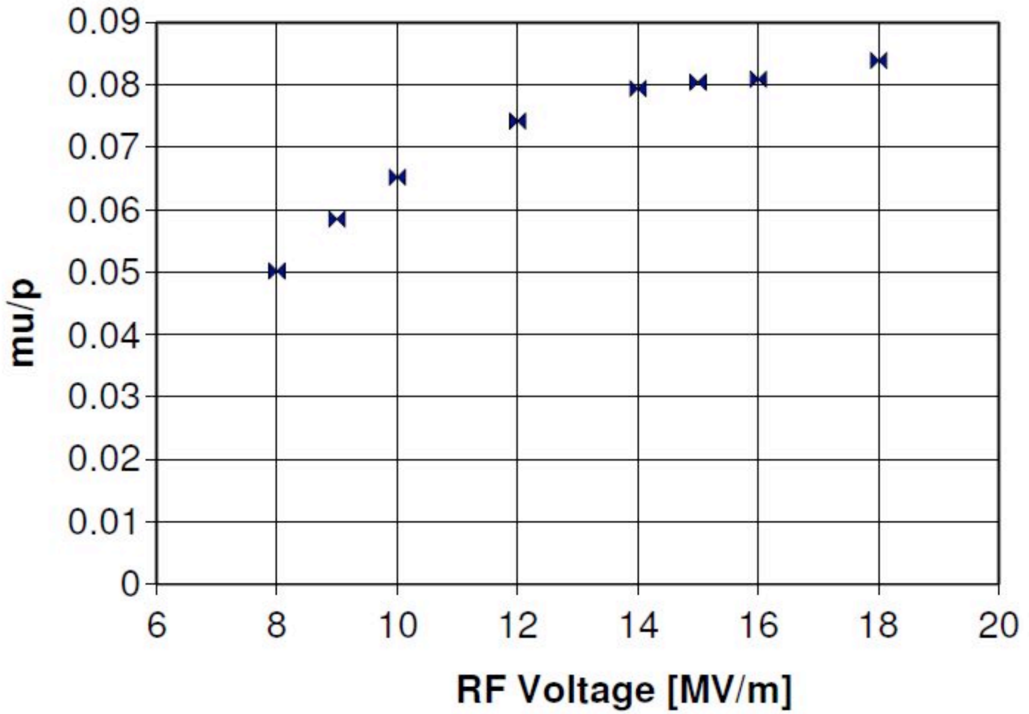
Muon cooling - RF power dependence



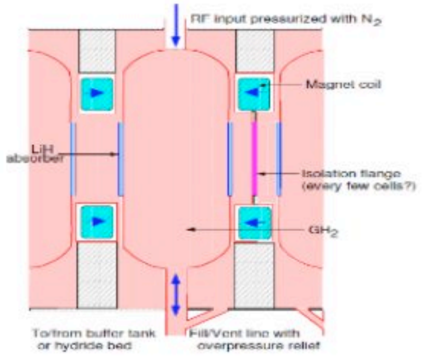


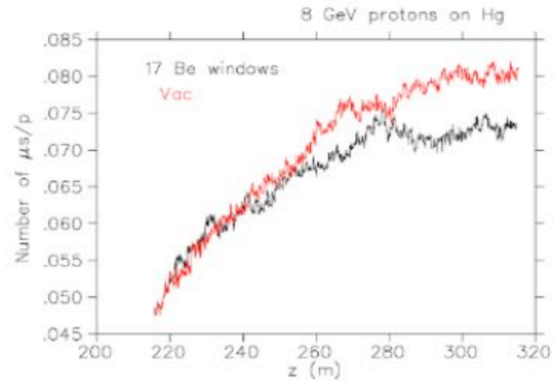


Risk mitigation : Muon cooling

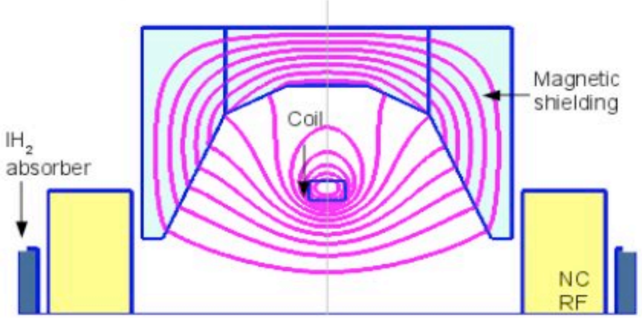
Lower RF fields

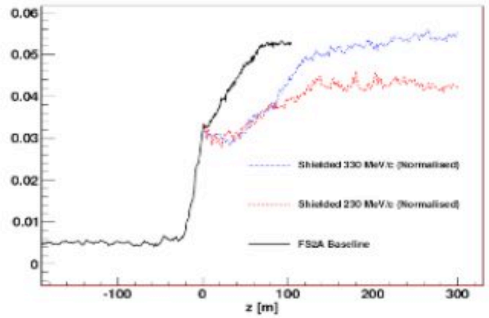
High pressure gas filled cavities



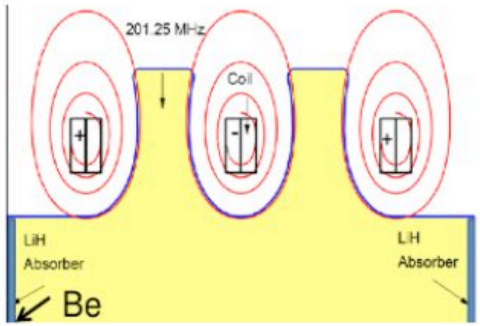


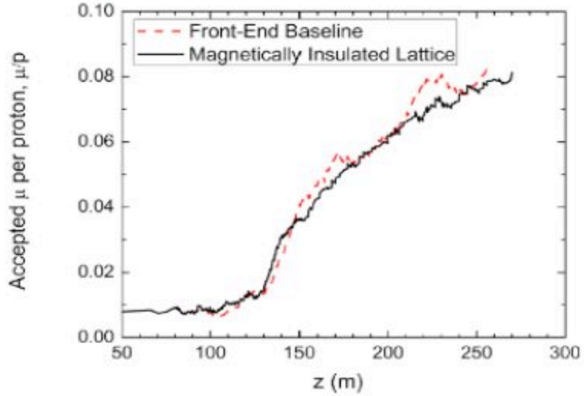
Shielded lattices





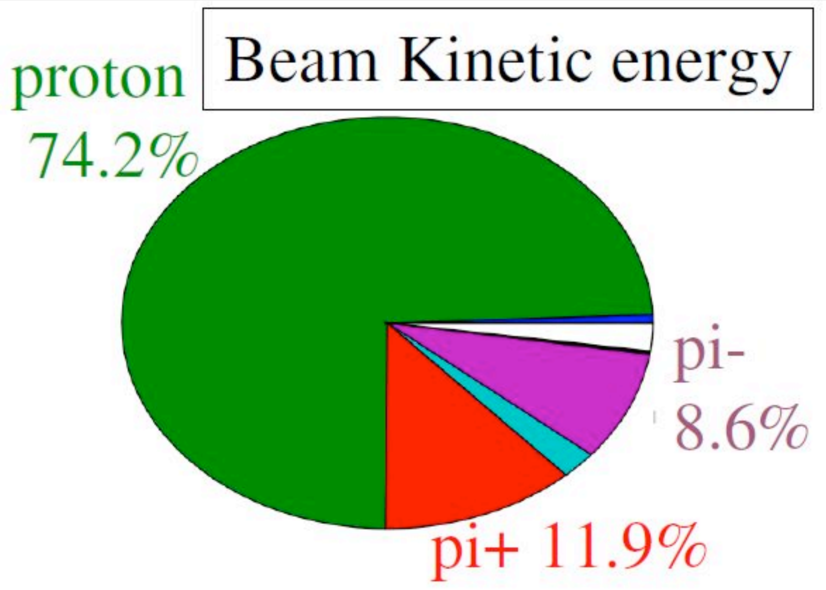
Insulated lattices

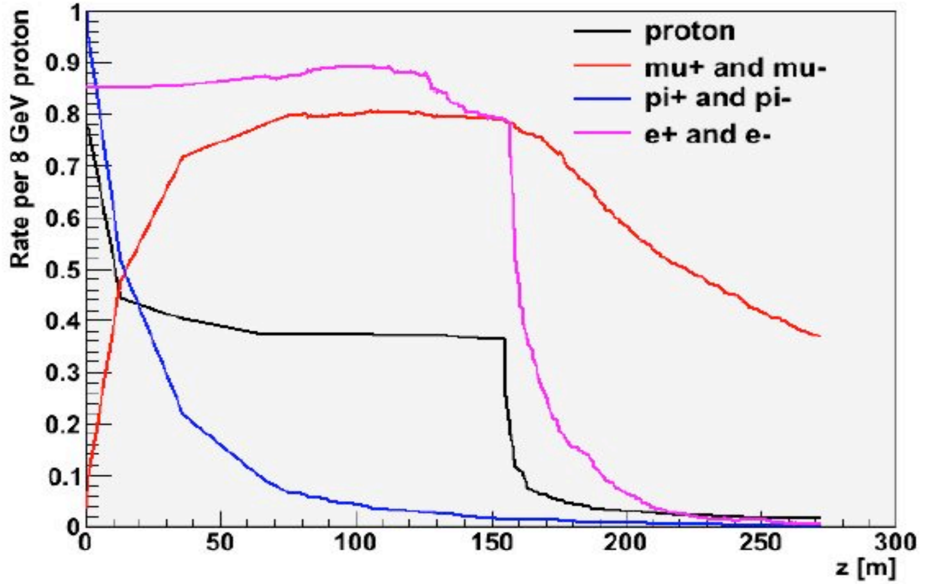


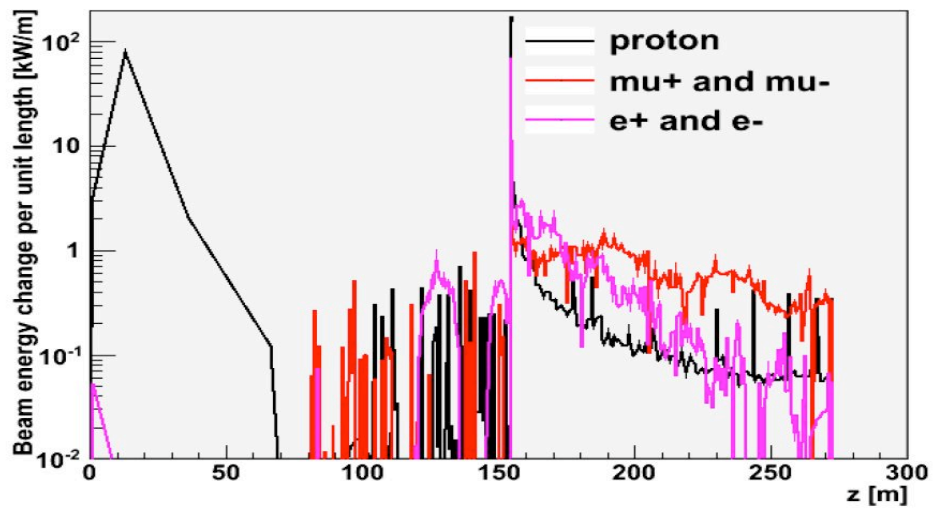


=> Generally reduction in yield

Risk mitigation : power deposition by secondaries

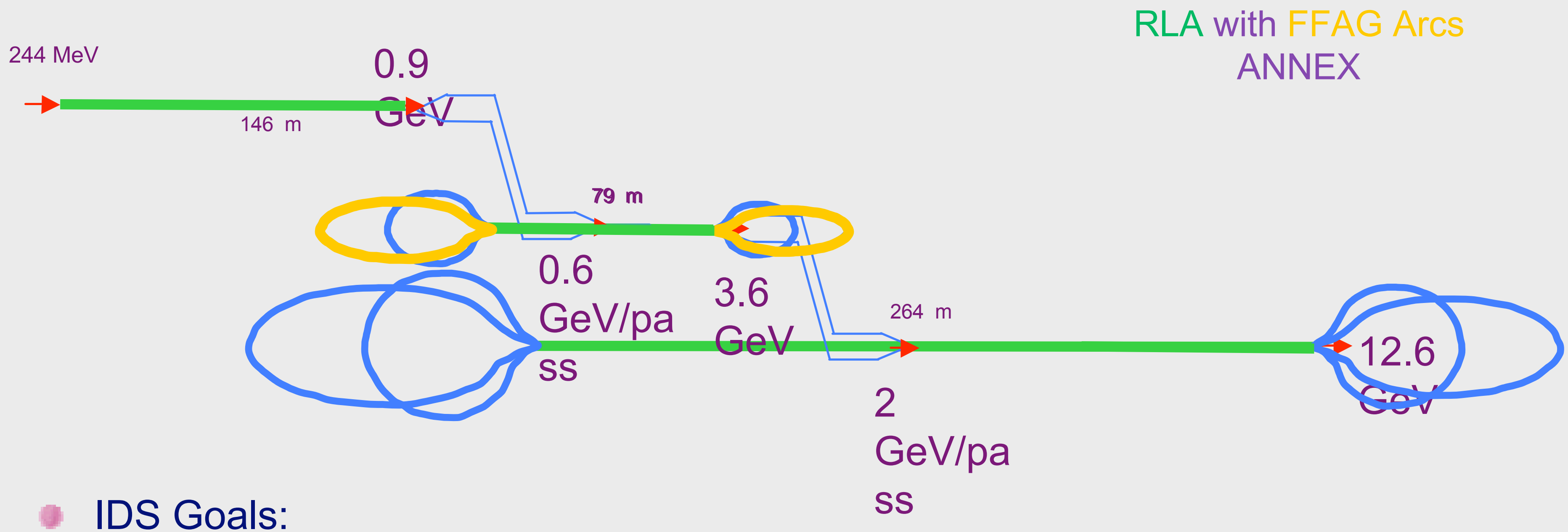






Secondary particles carry a significant amount power which is lost in the FE section => Shielding required

Linac and RLAs – IDS baseline



- IDS Goals:
  - Define beamlines / lattices for all components
  - Matrix based end-to-end simulation (machine acceptance) (OptiM vs ELEGANT)
  - Field map based end-to-end simulation (transmission) GPT vs G4Beamline
  - Error sensitivity analysis
  - **Component count and costing**

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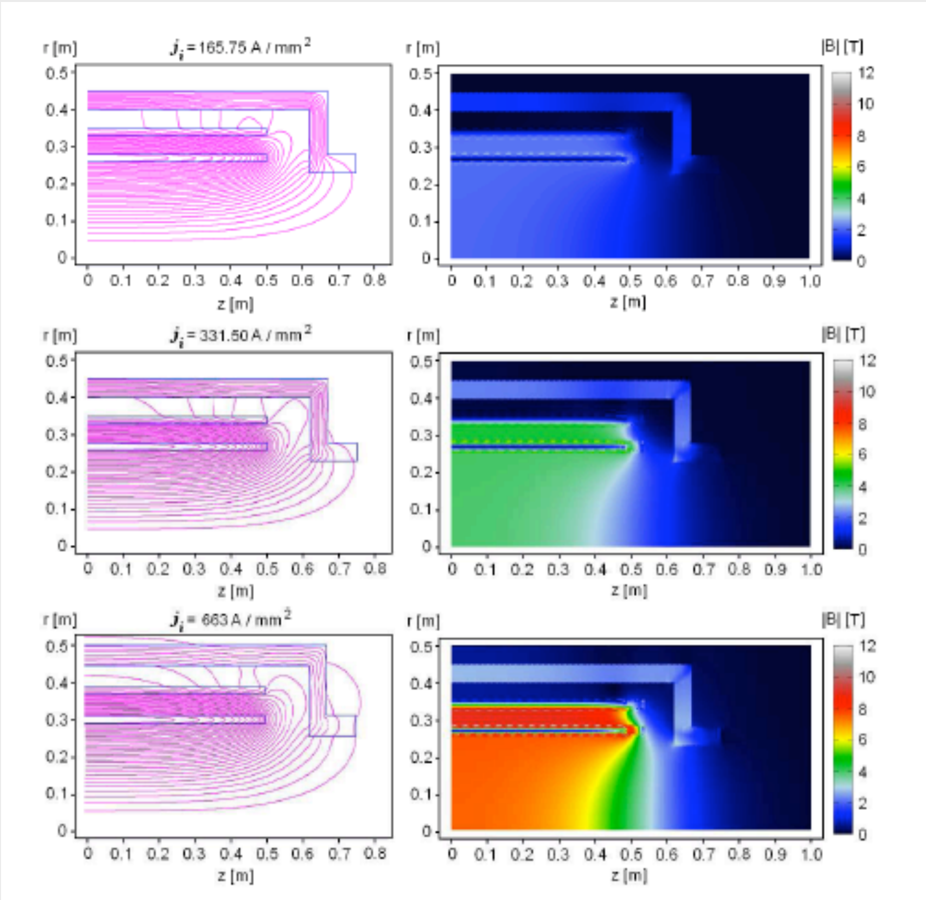
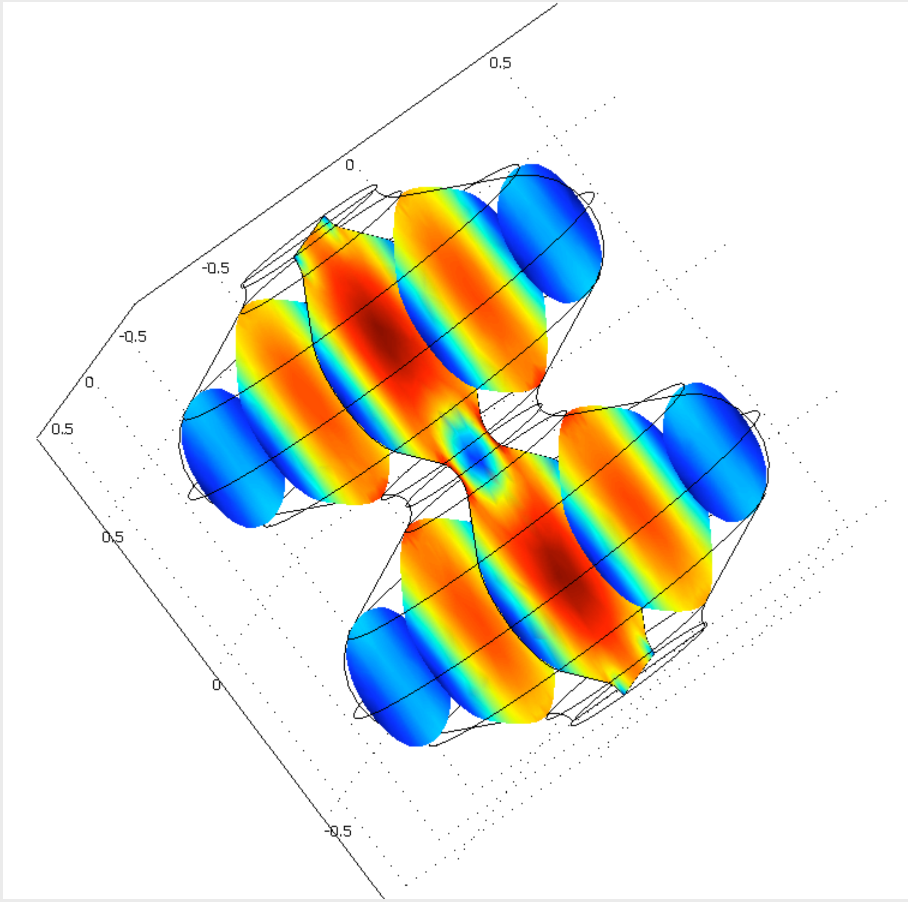
Hardware modeling & field maps

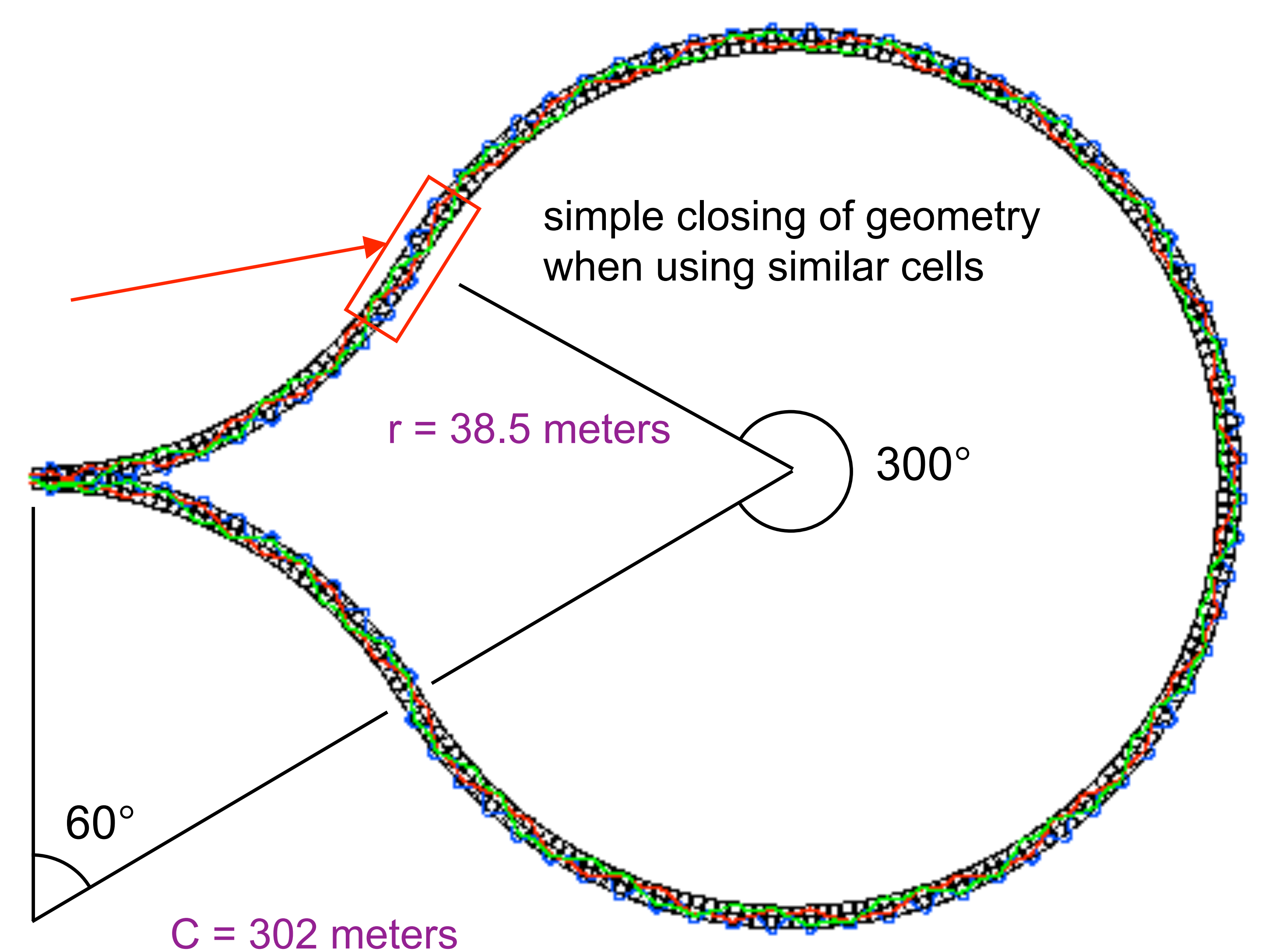
soleniods



cavities



Cost reduction :Multipass FFAG arc



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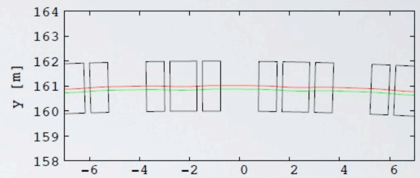
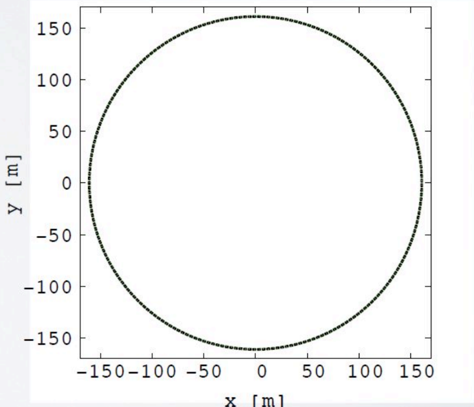
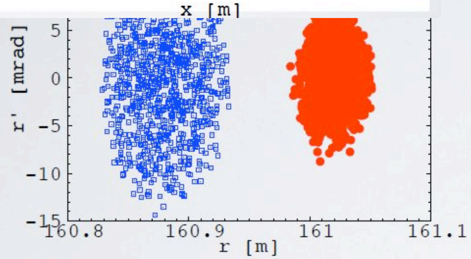
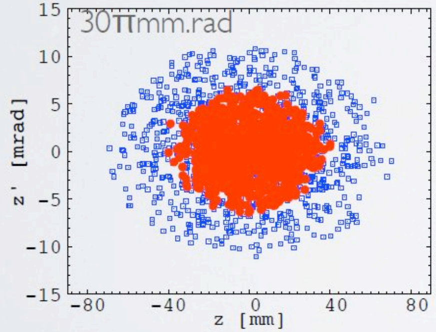
Cost reduction : scaling FFAG

Lattice type	FDF triplet
Injection/extraction energy	3.6/12.6 GeV
RF frequency	200 MHz
Number of turns	6
RF peak voltage (per turn)	1.8 GV
Synchronous energy	8.04 GeV
Mean radius	~160.9 m
B_{max}(@ 12.6 GeV)	3.9 T
Field index k	1390
Total orbit excursion	14.3 cm
Harmonic number h	675
Number of cells	225
Long drift length	~1.5 m
Horiz. phase adv. per cell	85.86 deg.
Vert. phase adv. per cell	33.81 deg.

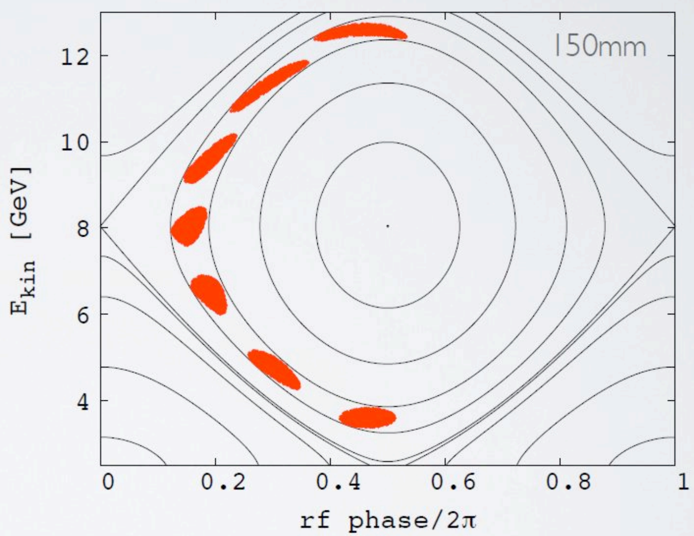








- Tracking results -



FFAG status

FFAG lattice was redesigned to :

•Increase space to facilitate injection & extraction
•To allow acceleration of both sign muons simultaniously
• Identical FDF triplets m
•Superconducting combined-function magnets
•5 m drifts to accommodate septum
•One two-cell 201.25 MHz SCRF cavity in most drifts

Based on new design:

•Injection and extraction studies performed

•Design of components and particle tracking started

FFAG injection & extraction schemes

lattice	3m	3.5m	4m	4.5m	5.0m
Plane (H/V)	H	H	H	H	H
No. Kickers	3	3	2	2	2
Kicker field (T)	0.091	0.084	0.104	0.102	0.089
Kicker Polarity	**+-+**	**+-+**	**+0+**	**+0+**	**+0+**
Septum field (T)	2.66	1.90	1.45	1.12	0.92

0 = Empty drift

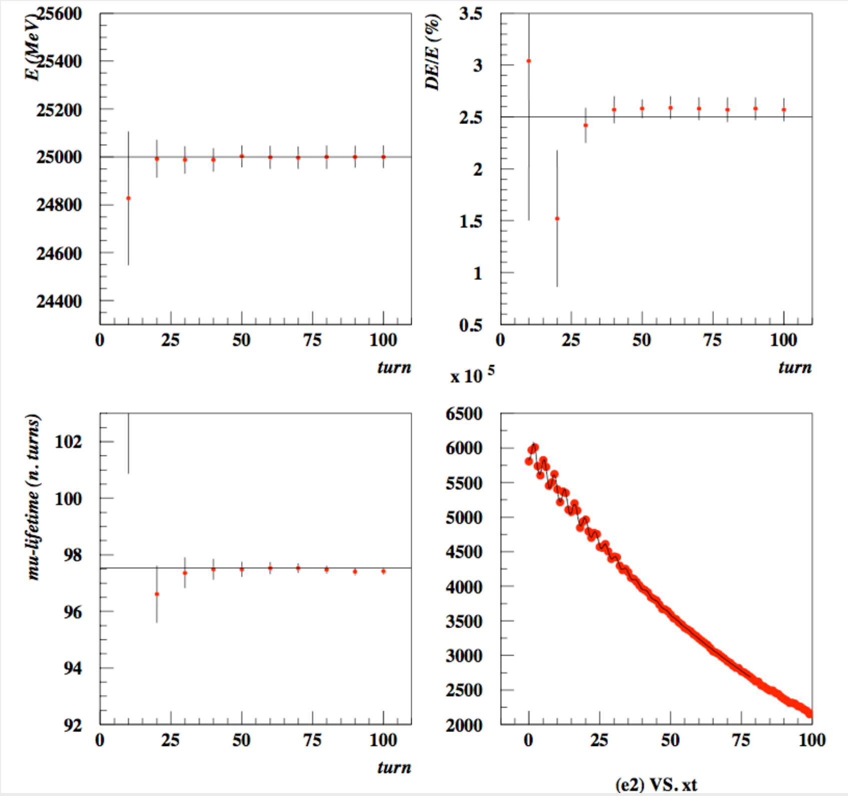
Preferred option

			4m	4.5m	5.0m
Plane (H/V)	H	H	H	H	H
No. Kickers	6	6	4	4	4
Kicker field (T)	0.088	0.075	0.087	0.078	0.067
Polarity	**++--++**	**++--++**	**++00++**	**++00++**	**++00++**
Septum field (T)	5.1	3.64	2.77	2.16	1.76

Preferred option

Decay rings

- Decay ring lattice design (25 GeV) available, design for LENF in preparation
- Longitudinal particle dynamics studies show that no RF is required for shorter bunchtrains
- Instrumentation for decay rings (together with near detector) under investigation



Costing

- First costing workshop spring 2010 at CERN
- Costing session at IDR plenary meetings 5 & 6
- Costing group established (EUROν)
- Costing tool available at CERN (used for ILC)
- Work breakdown structure defined
- Several questions concerning different costing methods, currency and inflation issues have been discussed.
- For IDS “mixed” costing approach according to readiness of the hardware design is planned

- IDS costing will be within the uncertainty range (50-70%) but should be rather seen as exercise for RDR

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Component count for costing (Linac & RLA's)

beamline	RF cavities		solenoids	dipoles	quads	sext
	1-cell	2-cell				
pre-accelerator	6	62	25			
inj-chic I				8+3	16	3
RLA I						
linac		24			26	
arc1				35	43	
arc2				49	57	8
arc3				63	71	8
arc4				77	85	8
inj-chic II				8+3	16	3
RLA II						
linac		80			42	
arc1				35	43	
arc2				49	57	8
arc3				63	71	8
arc4				77	85	8
Lambertson				1		

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IDR and summary

- Sub groups present detailed plans for IDR.
- Baseline document updated for writing of IDR
- Responsibility for chapters defined
- Contents of each chapter defined
- Risk mitigation and fall back options defined
- For IDS "mixed" costing approach according to readiness of the hardware design (global to detailed) is planned

Timetable :

30Oct10: Deadline for first drafts of principal sections to conveners;

30Nov10: Sections from conveners to IDR editor (KL);

06-10Dec10: IDR 'writing workshop' #1

06-10Jan11: IDR 'writing workshop' #2

Presentation of IDR at IDS meeting in January @ RAL