Recent Developments on the Muon Non-Scaling FFAG for the Neutrino Factory and its Subsystems

J. Pasternak, Imperial College London / RAL STFC
Work in collaboration and with contributions from:
M. Aslaninejad (IC), J. Scott Berg (BNL),
N. Bliss (STFC/Technology/DL) C. Bontoiu (IC),
M. Cordwell (STFC/Technology/DL), D. Kelliher (ASTeC/STFC/RAL),
S. Machida (ASTeC/STFC/RAL), H. Witte (JAI-Oxford)

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Outline

- Introduction.
- Layout and optics.
- Magnet aperture studies.
- Kicker system design.
- Septum studies.
- Main magnet design.
- Conclusions and future plans.

Introduction

New IDS-NF baseline.	
Number of cells	67 m
Circumference	669 m
RF voltage	1.1956 GV
Max field in F magnet	4.4 T
Max field in D magnet	6.2 T
F magnet radius	16.1 cm
D magnet radius	13.1 cm
Muon decay	7.1 %
Injection energy	12.6 GeV
Extraction energy	25 GeV

Recent progress:

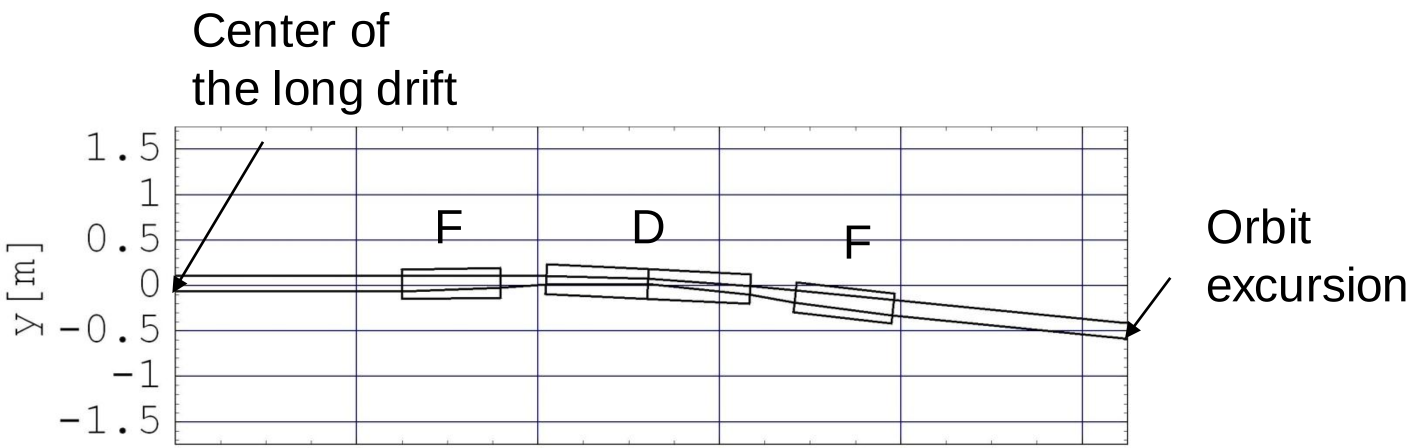
•Lattice update to incorporate 5m long drifts for symmetric injection/extraction.
•Injection/extraction geometries.
•Kicker/septum studies.
•Preliminary design of the main magnets

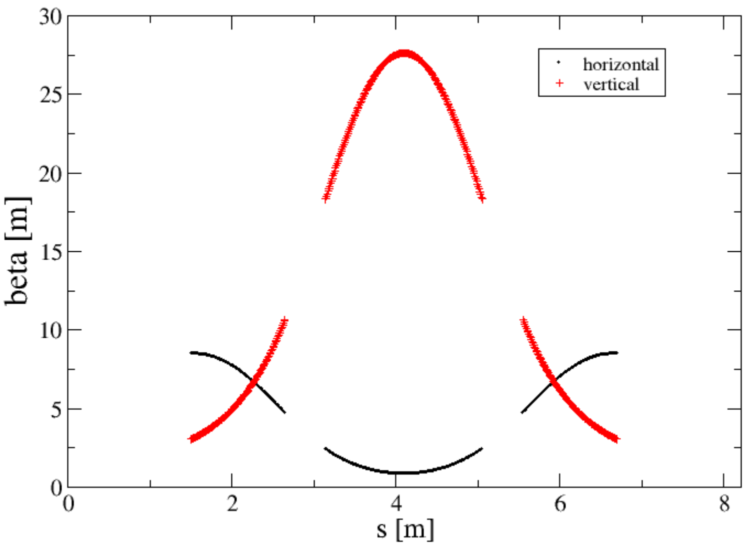
Non-scaling FFAG is selected for the final muon acceleration at the Neutrino Factory.

Advantages include:

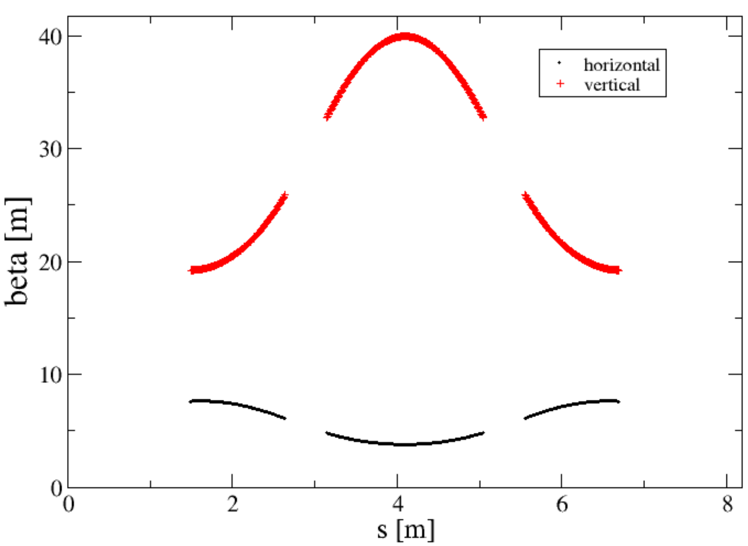
- Allows very fast acceleration (~12 turns).
- Large dynamic aperture due to linear magnets + high degree of symmetry.
- More turns than in RLA – more efficient use of RF – cost effective.
- Quasi-isochronous – allows fixed frequency RF system.
- Orbit excursion and hence magnet aperture smaller than in the case of a scaling FFAG – cost effective.
- Principles of NS-FFAG are now being tested during ongoing EMMA commissioning.

Layout and optics



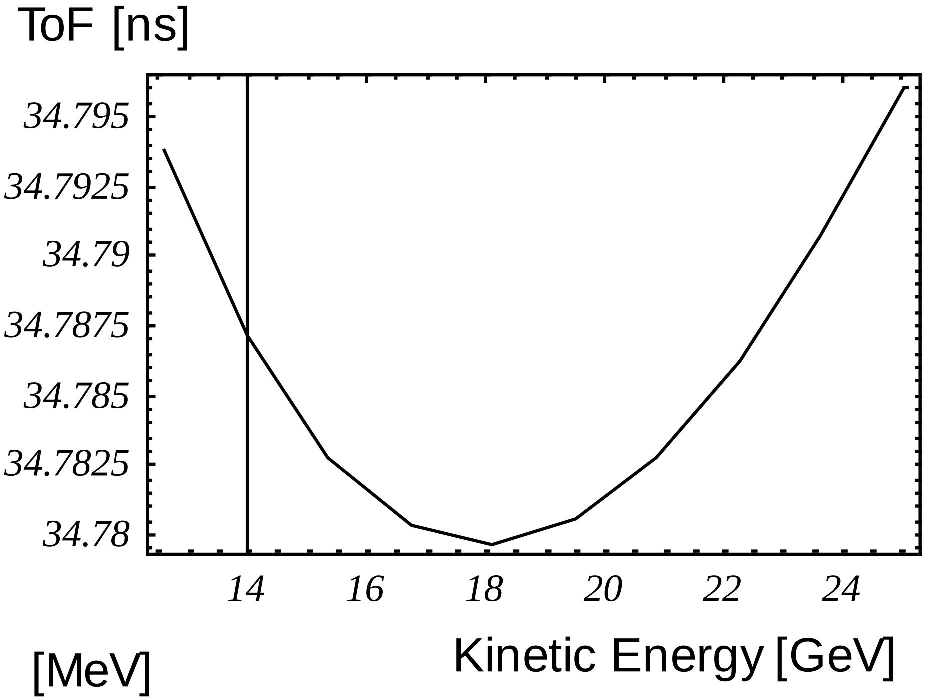


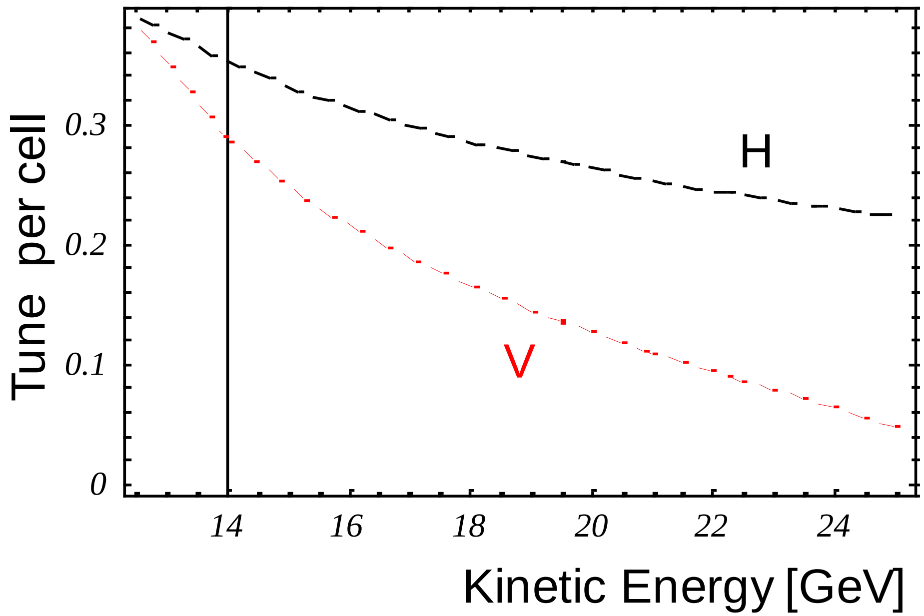
Beta functions at injection

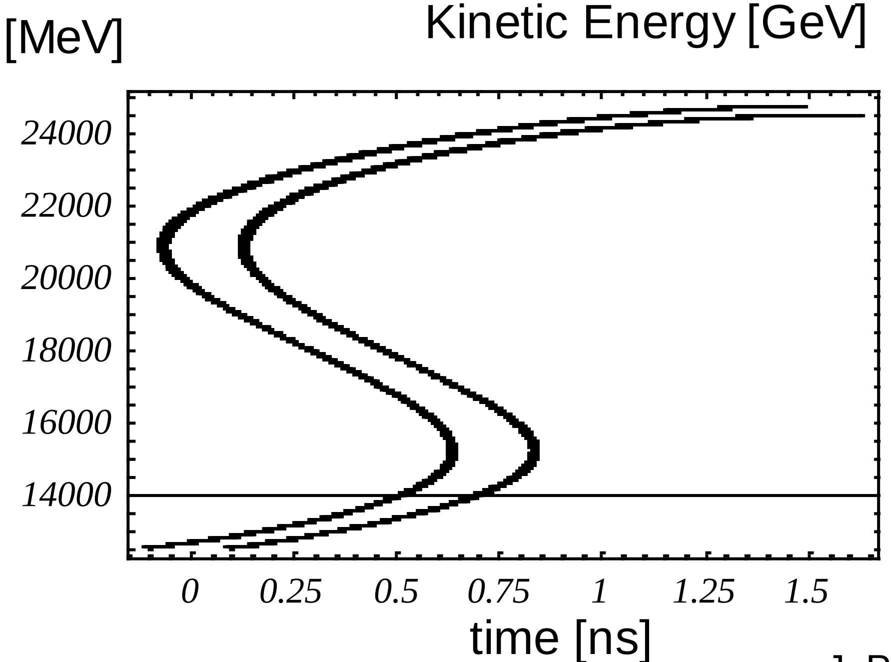


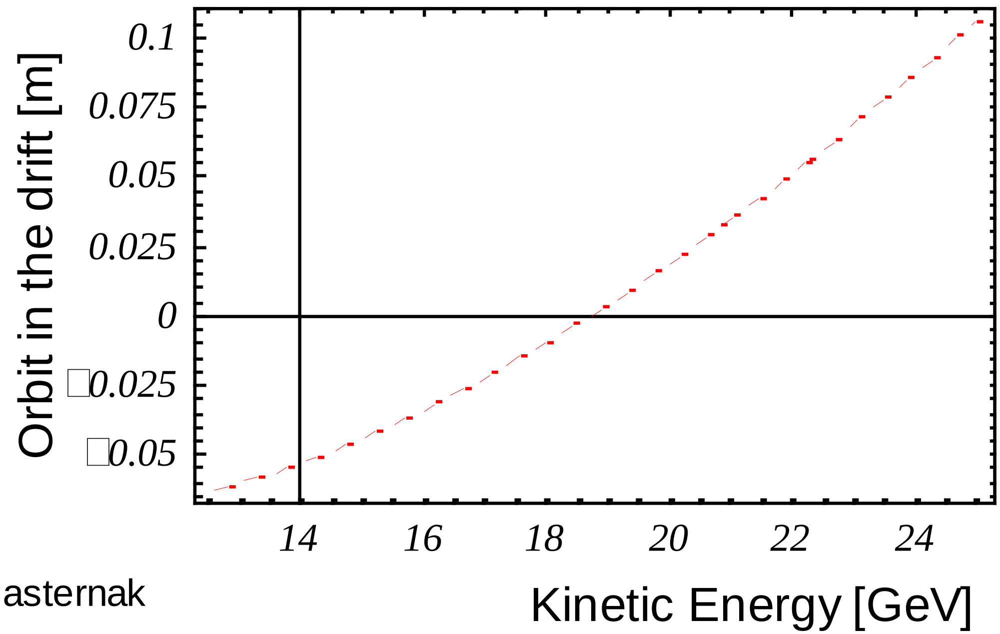
Beta functions at extraction

Beam Optics and Acceleration









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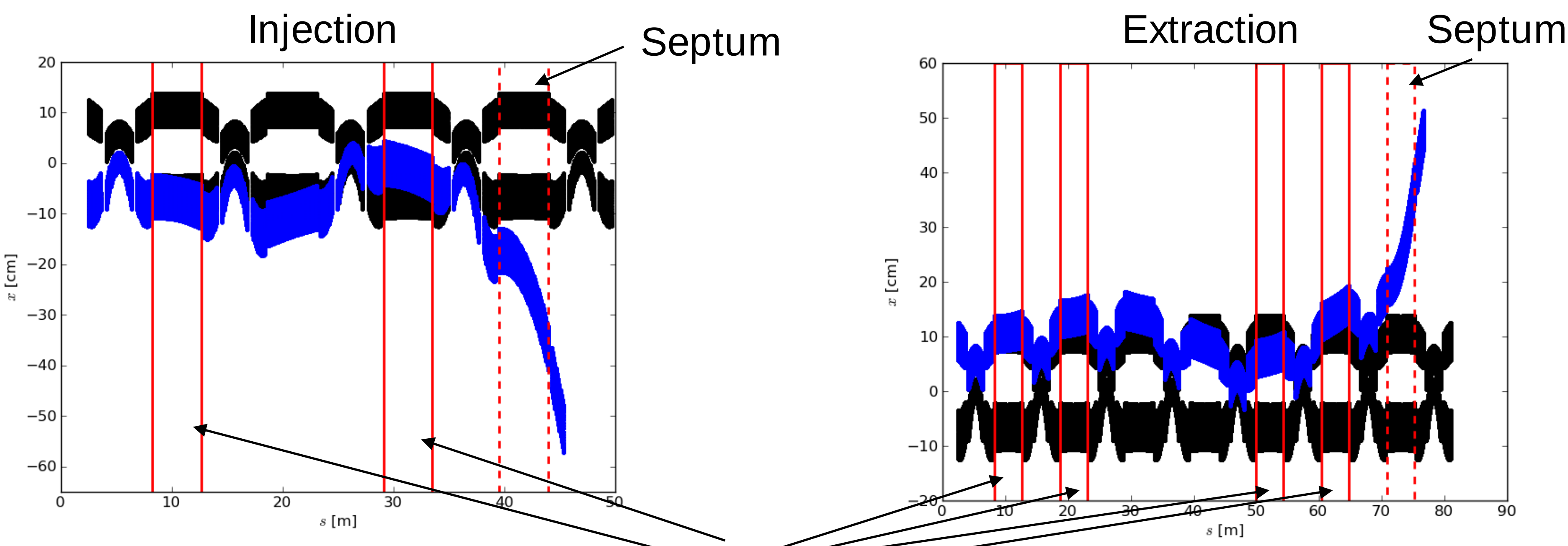
Injection/Extraction geometries

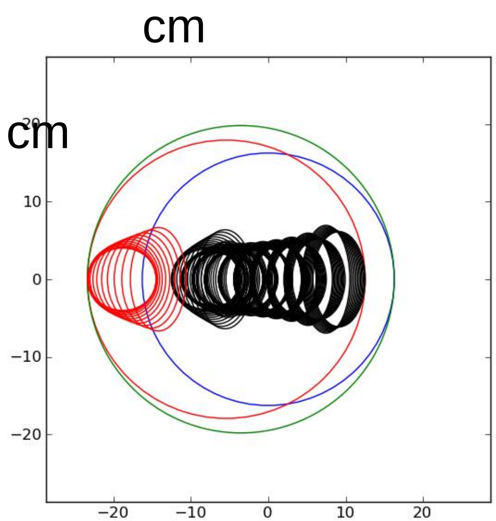


Injection	
Plane	Horizontal
No. Kickers	2
Kicker field (T)	0.089
Kicker Polarity	**+0+**
Septum field (T)	0.92

Extraction	
Plane	Horizontal
No. Kickers	4
Kicker field (T)	0.067
Polarity	**++00++**
Septum field (T)	1.76

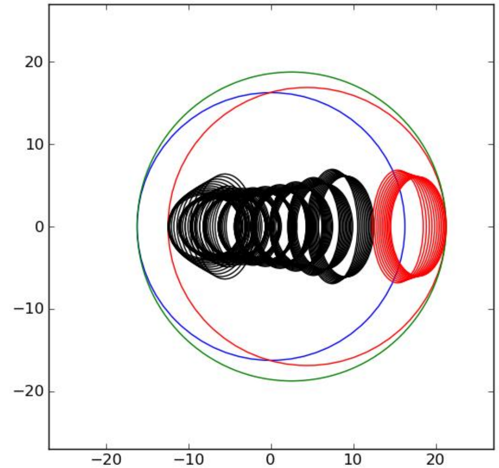
- Septum field was limited to 2 T by the stray fields studies (see next slides).
- Both injection and extraction are in the horizontal plane (minimal additional magnet aperture needed and no generation of the vertical dispersion).
- Larger apertures in the special magnets witch are needed have been calculated.

Magnet aperture studies

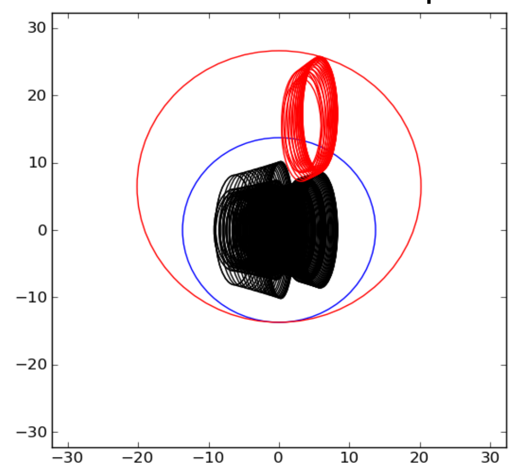


Magnet aperture in F magnet near the injection septum. Blue is the requirement for the circulating beam, red for kicked beam and green is the final special magnet aperture.

Magnet type	Number of magnets	Radius (cm)
Normal F	116	16.3
Normal D	58	13.7
Injection F	4	20.8
Injection D	4	16.1
Extraction F	8	19.8
Extraction D	2	15.5

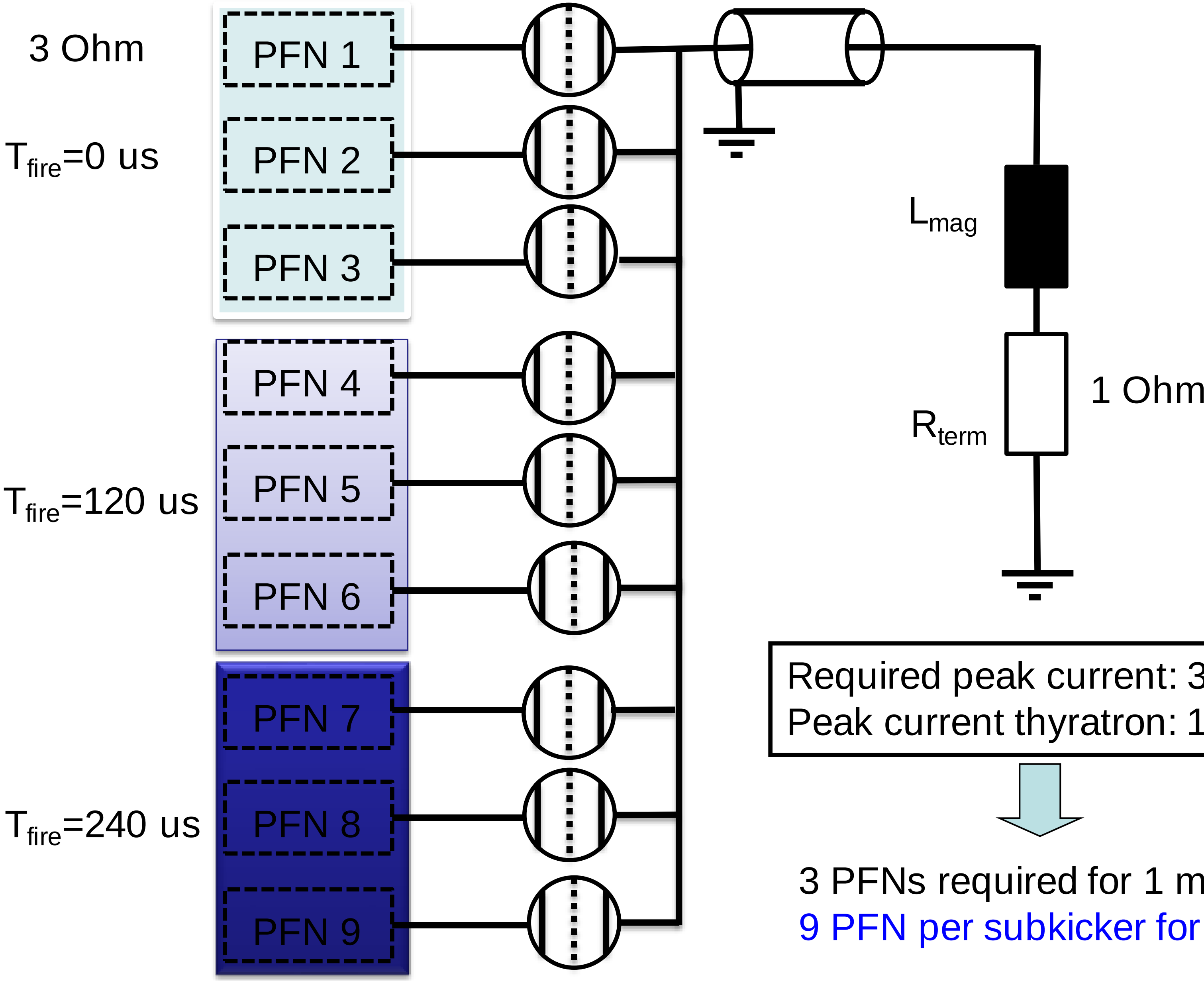


Magnet aperture in F magnet before the extraction septum.



Magnet aperture in D magnet rules out the vertical extraction.

IDS Kicker System

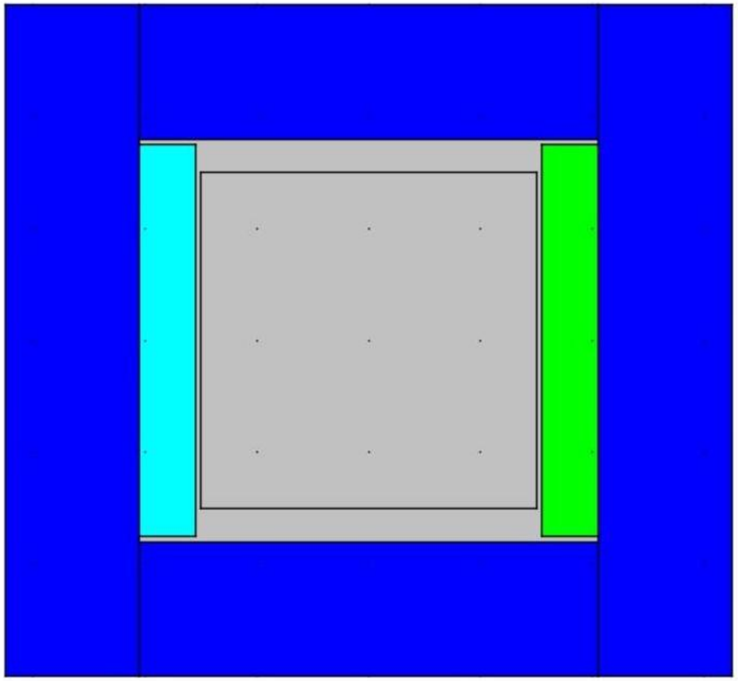


Required peak current: 30 kA
Peak current thyratron: 10 kA

3 PFNs required for 1 muon bunch train.
9 PFN per subkicker for 3 trains!

Kicker magnet

- Travelling wave type.
- Geometry
  - Aperture: 0.3x0.3 m^2 (recent update ~0.32x0.22)
  - Yoke: 120 mm
  - Length: 4.4 m
- Field: 100 mT (to add margins)
- Current: 29 kA
- Voltage 60 kV
- Magnetic energy: 1700 J
- Inductance (single turn): 5.1 uH
- Subdivided into 4 smaller kickers (36=9x4 PFNs and switches per magnet).
- Rise/fall time 2.2 us.
- Impedance matching
  - Add capacitors

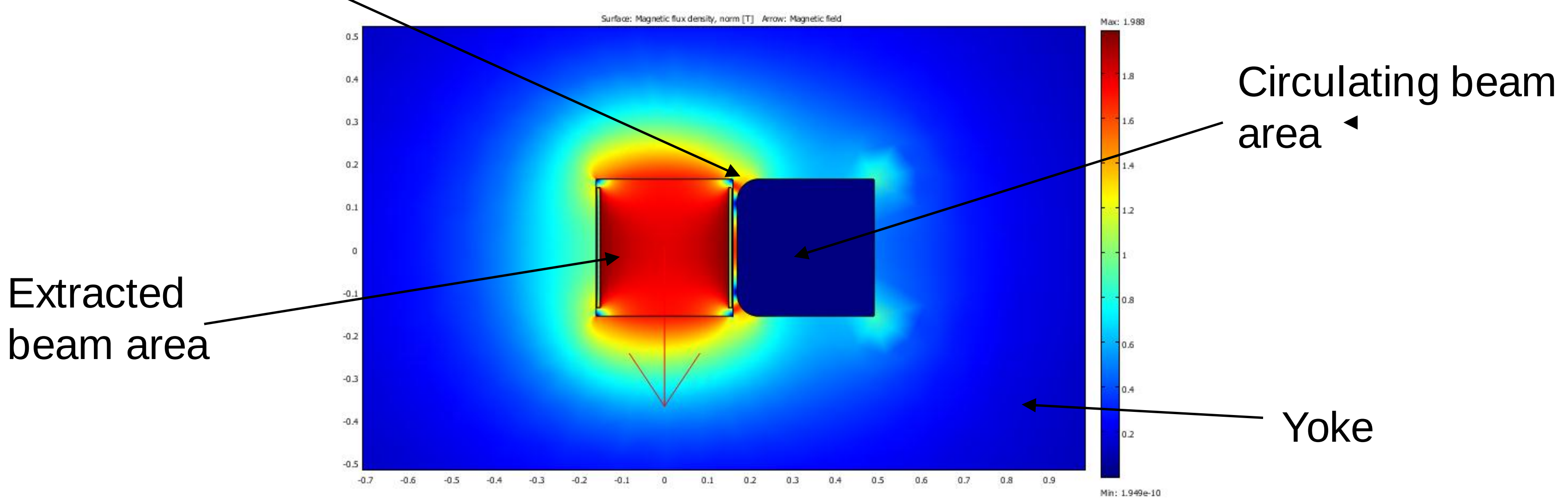


Current pulses in 3 kicker sections – „travelling wave" using PSPice

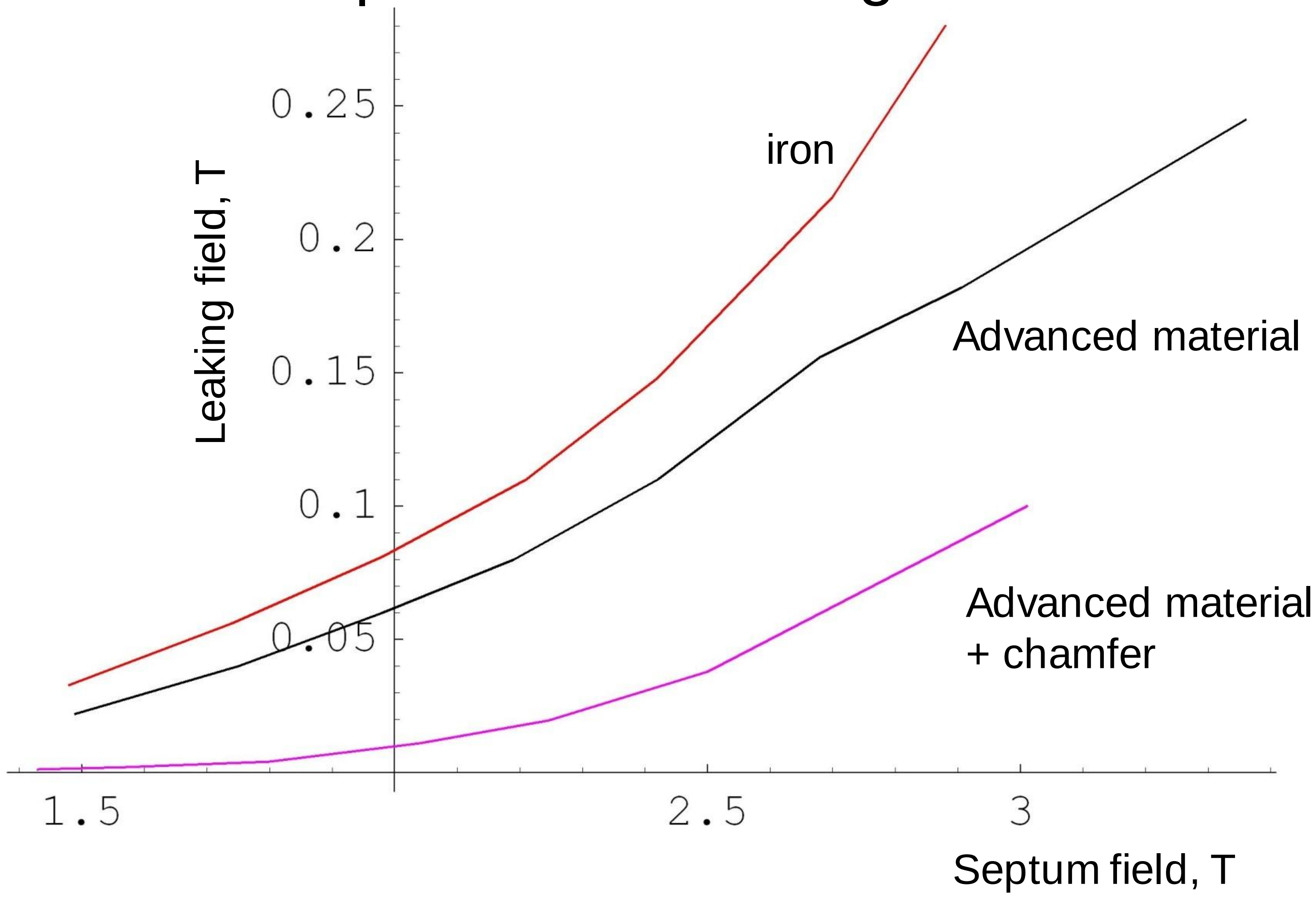
Update needed to match the new short muon train.

Septum geometry

- The goal of the study was to limit the field leakage from the septum to the circulating beam region.
- We were using COMSOL and performed 2D simulations.
- Starting point was a basic „C-shape” septum magnet.
- Iron was introduced all around the circulating beam.
- Iron was replaced by the soft magnetic cobalt-iron-alloy with high saturation limit.
- Chamfer was introduced.



Septum Field Leakage

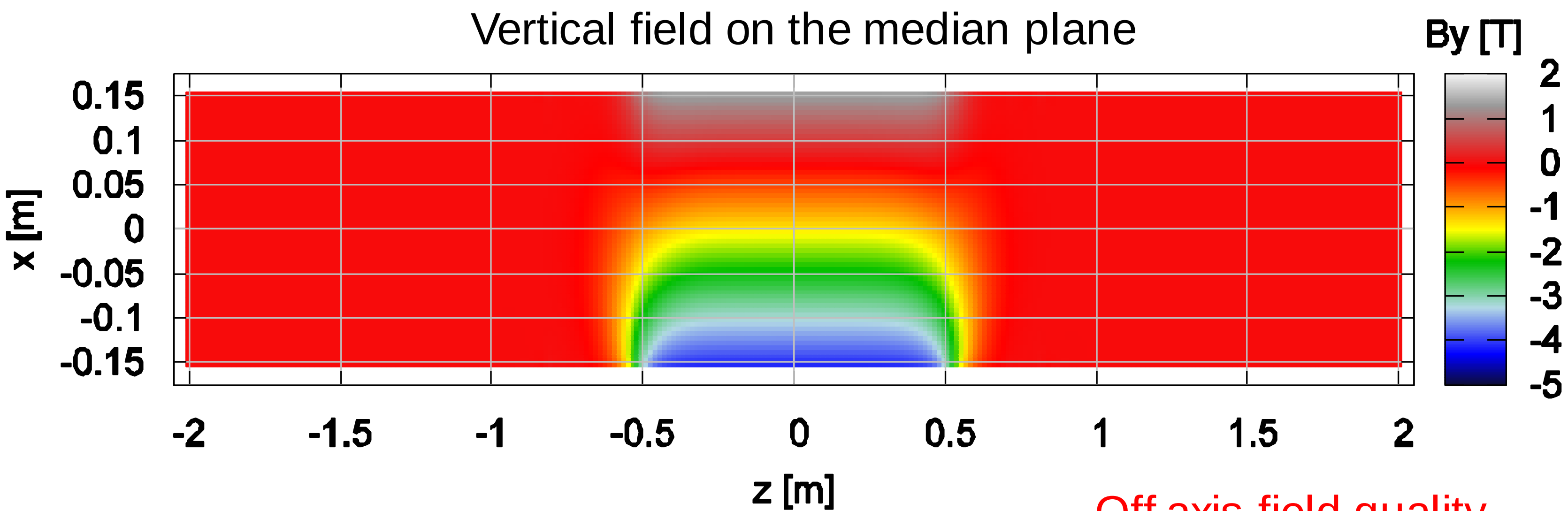


- The advanced material is the soft magnetic cobalt-iron-alloy (VACOFLUX 50 from www.vacuumschmelze.de)
- We may still look for more advanced materials.

Main magnet design

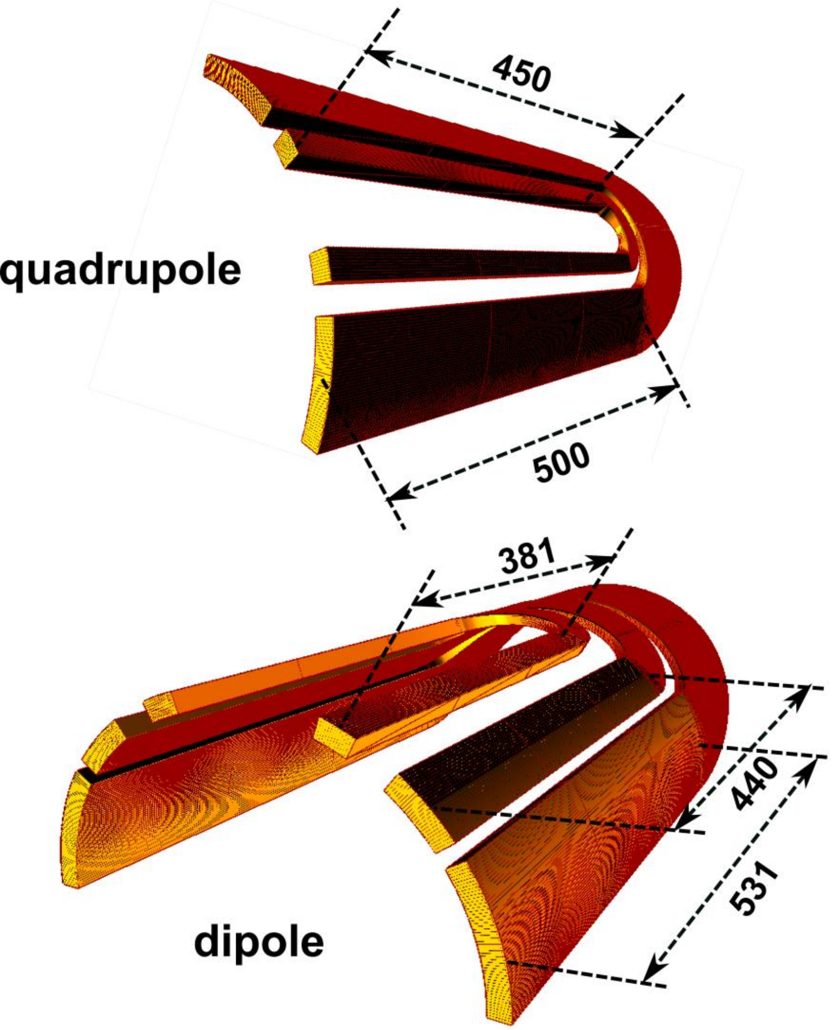
The current design effort:

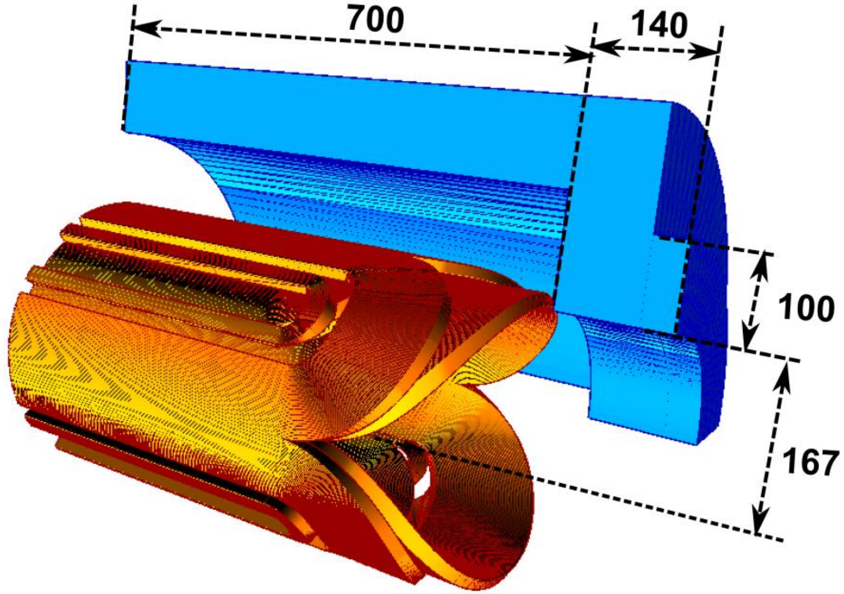
- Focuses on the conventional „Cos-Theta" with separate layers for dipole and quadrupole components.
- This is motivated by simplicity and in addition a possibility of a flexible optics tuning.
- Design is performed using the CERN ROXIE code.
- Work on F magnet is more advanced (included in the IDR).



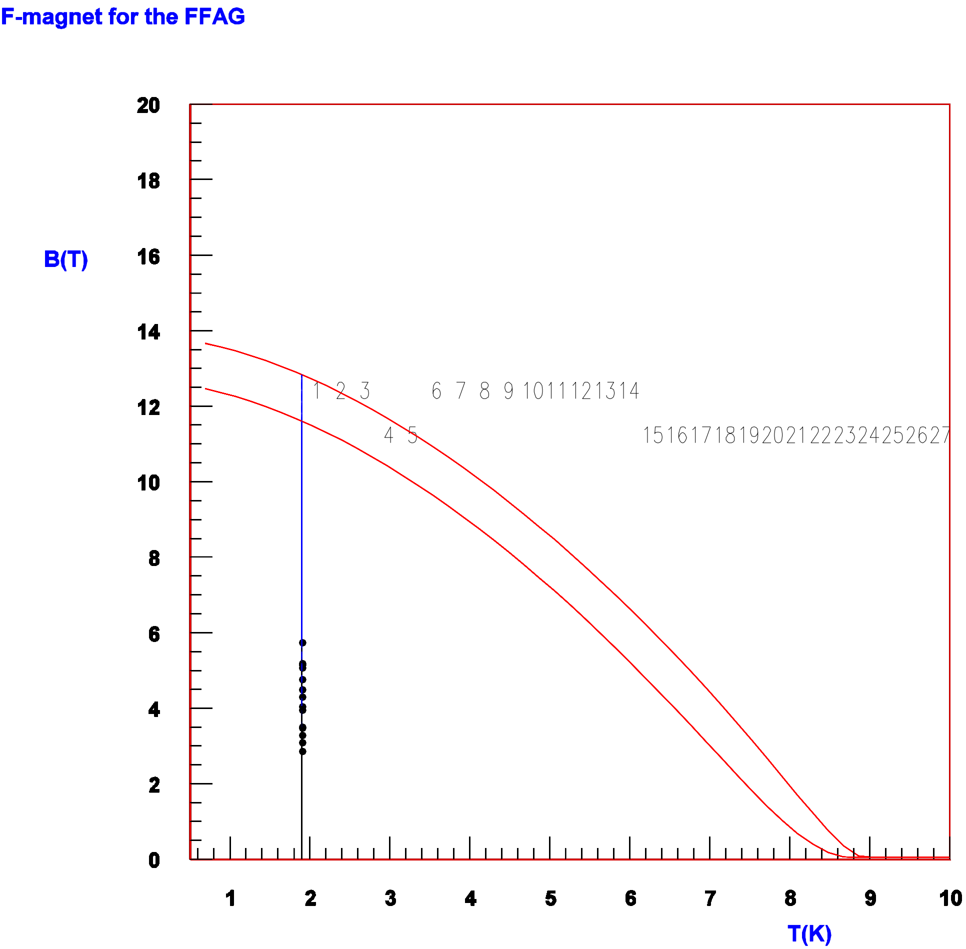
Off axis field quality needs to improved!

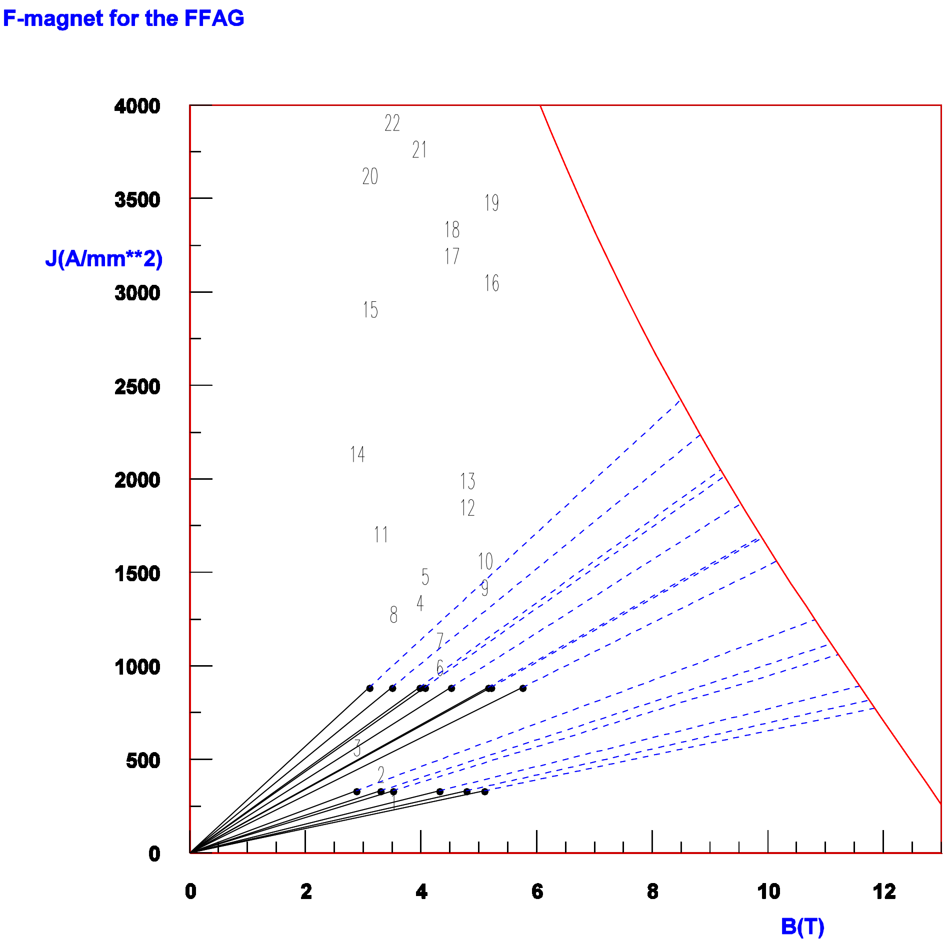
F magnet geometry





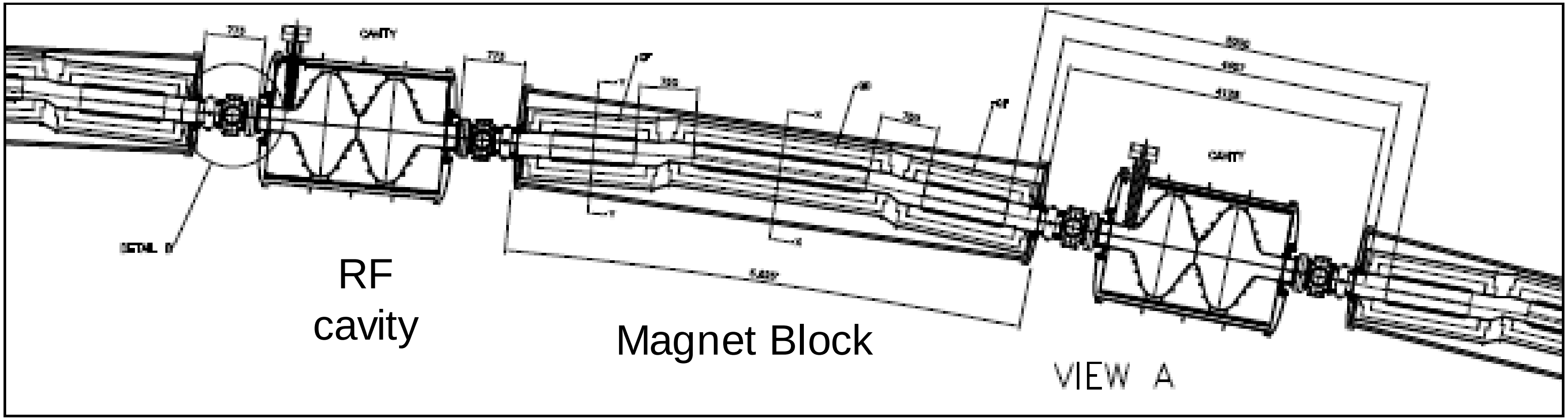
Quench calculations for the F main magnet

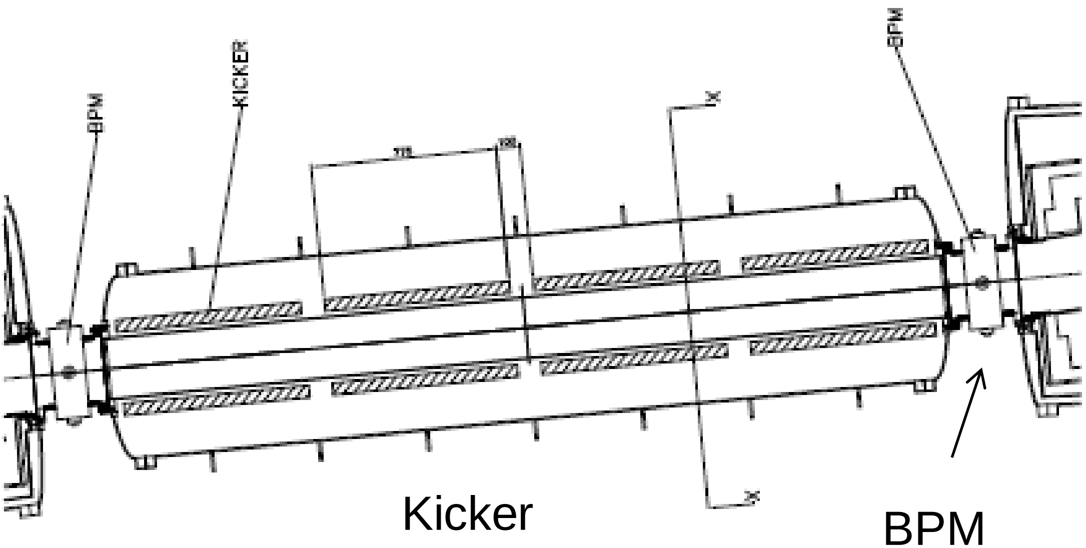




ROXIE calculations shows good margins with respect to quench!

Towards engineering design





- Start of the engineering effort
- Effective drift length reduced to 4m (due to space for the cryostat and flanges).
- Kicker field increased 0.106 T
- Extraction septum field to 1.94 T
- Injection/extraction still feasible!

Summary

- The IDS baseline was updated in order to allow for realistic and symmetric injection/extraction.

- Horizontal injection/extraction schemes were produced and kicker and septum parameters were defined.

- The kicker system was designed and looks feasible, but the hardware tests would be needed to demonstrate the life-time of critical components (switches, capacitors etc.).

- Field leakage from the septum limits the magnetic field to 2 T, which dictates the length of the drift.

- The preliminary design for the main F magnets was produced.

Future plans -> next slide!

Future plans

- Beam dynamics studies (chromacity correction, error study, estiamtion of magnet tolerances etc.).
- Design of the transfer lines.
- The realistic kicker design.
- 3D septum simulations.
- Feasibility of the cryogenic design of the septum and its quench calculations (including beam loss).
- Update of the main magnets geometry with the good field quality (possibly including sextupoles for chromaticity correction).
- Cryogenics for the main magnets.
- Costing.