

RFQ Injector for *PAMELA* FFAG

Matt Easton

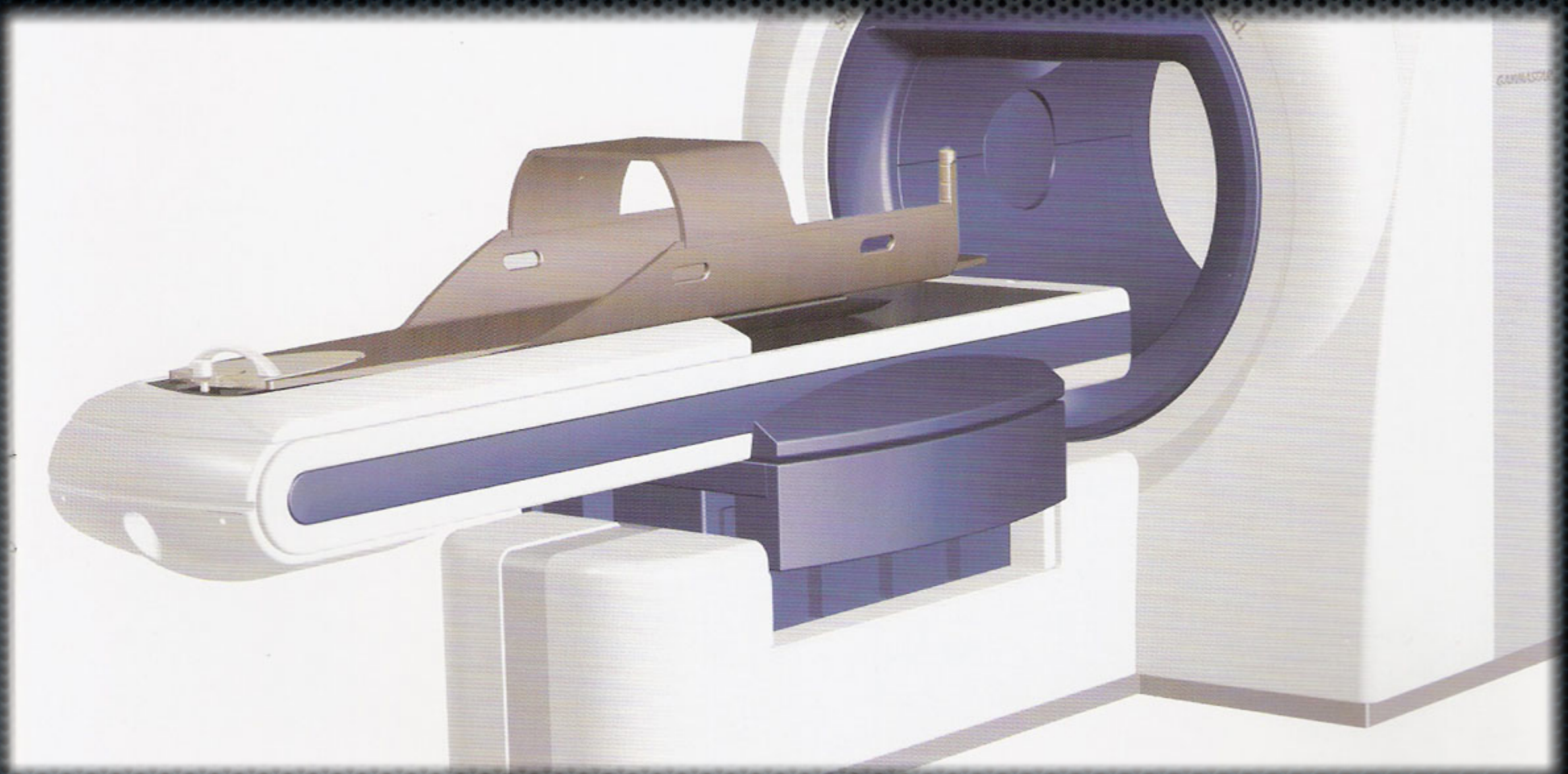
Imperial College London

PAMELA

FFAG for cancer therapy using protons and carbon ions

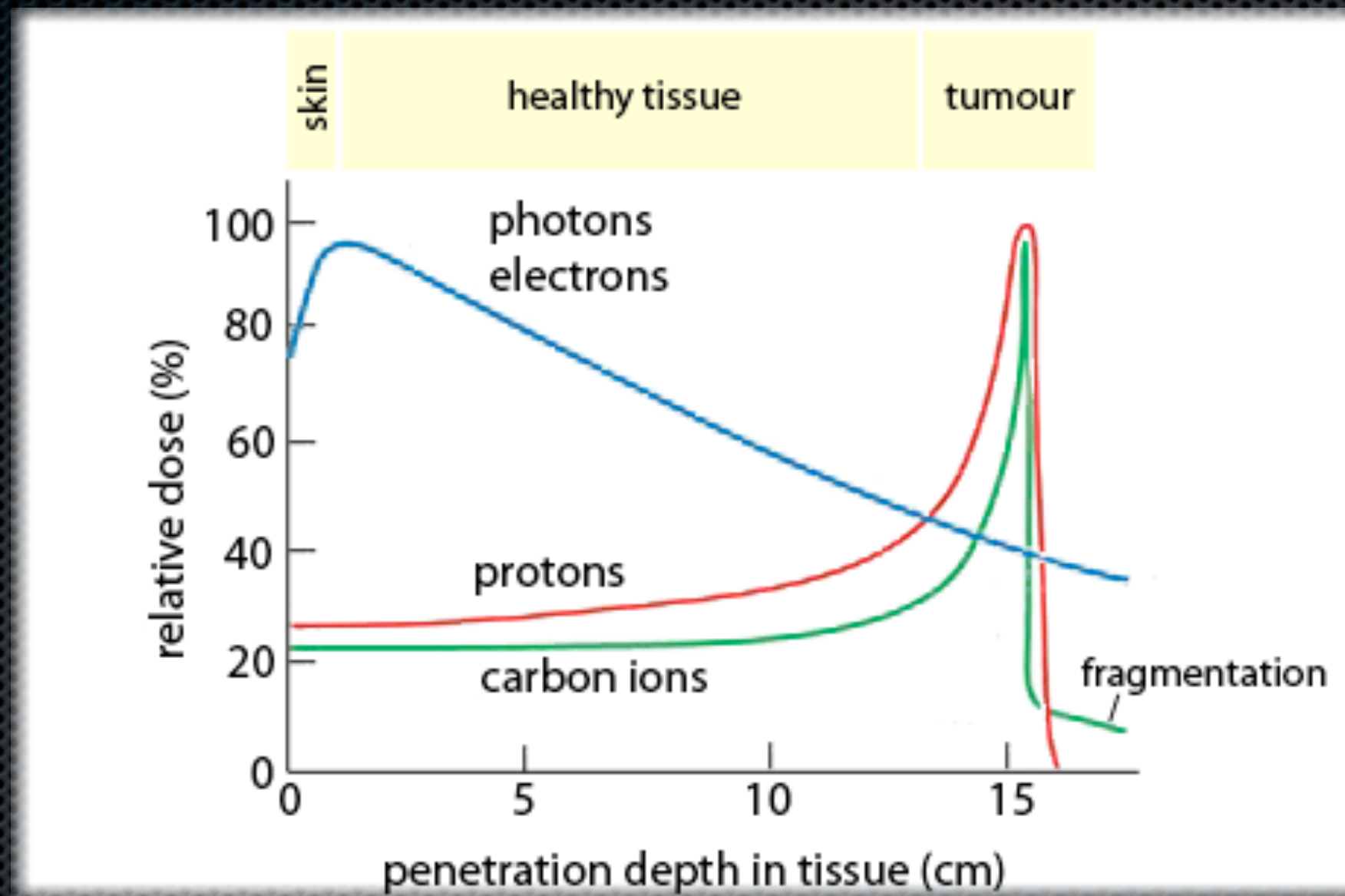
radiotherapy

treating cancer with particles



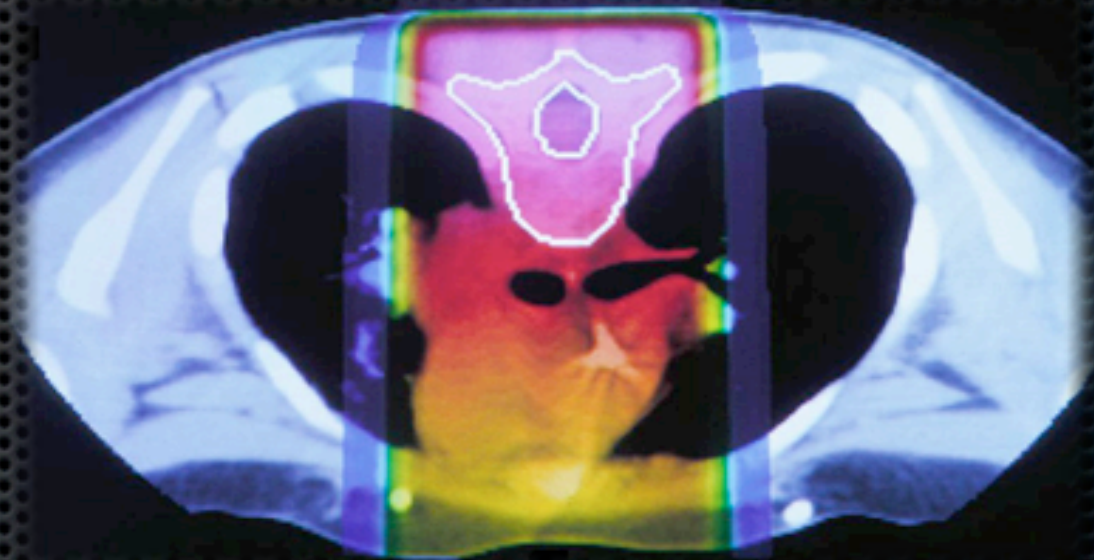
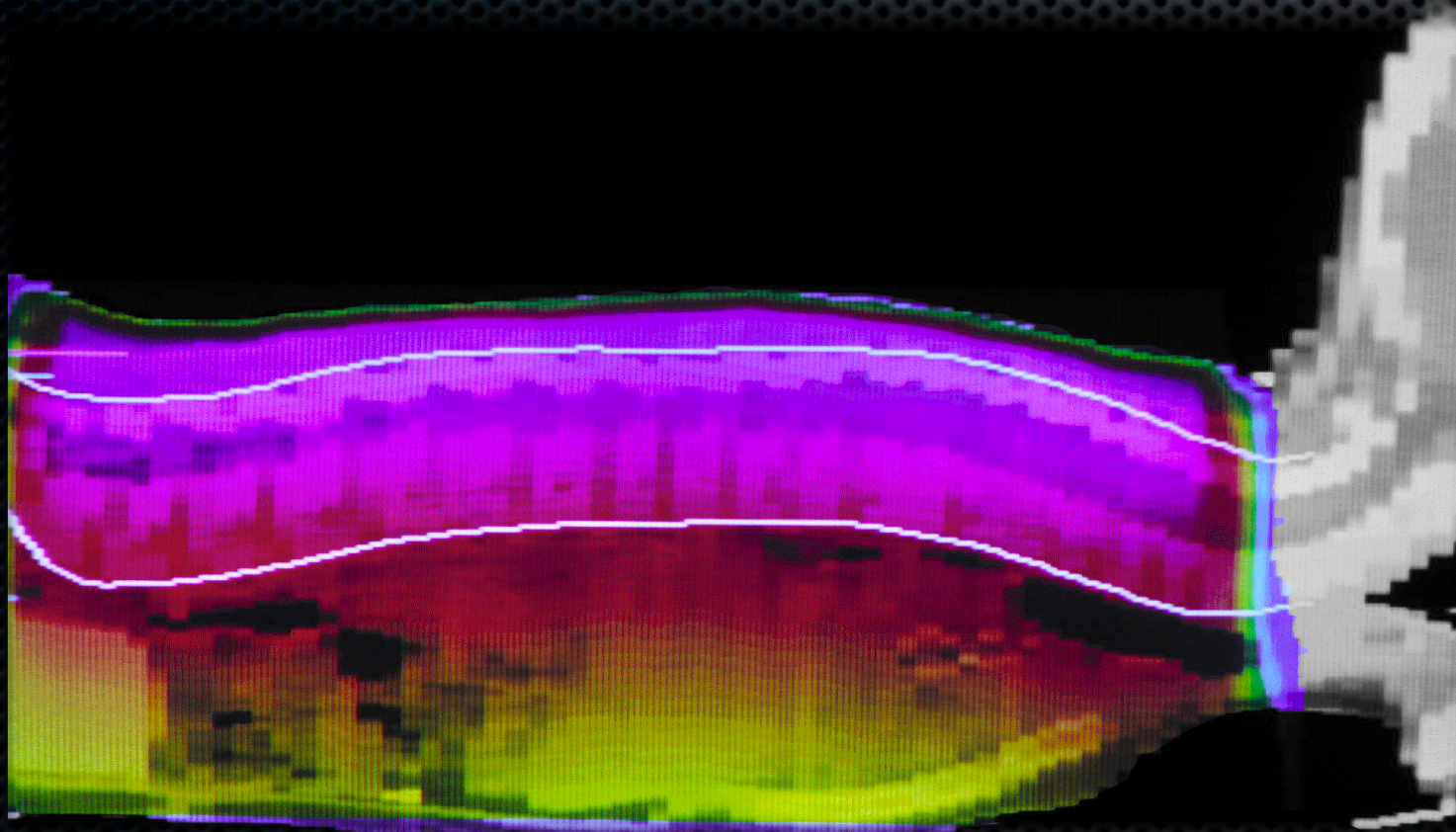
dose profile

showing relative dose to tissue at different depths



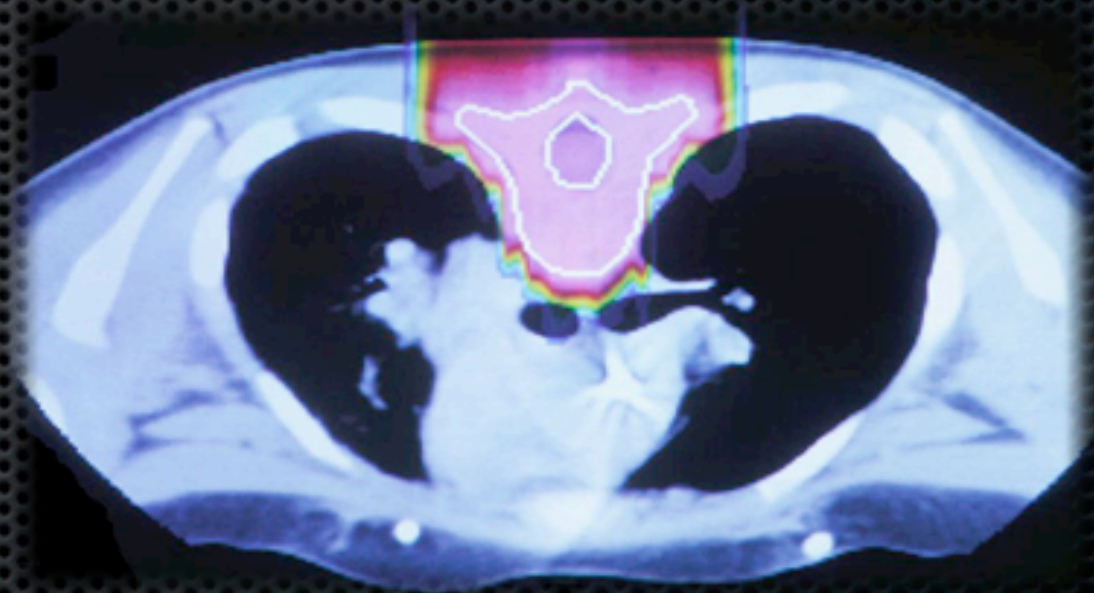
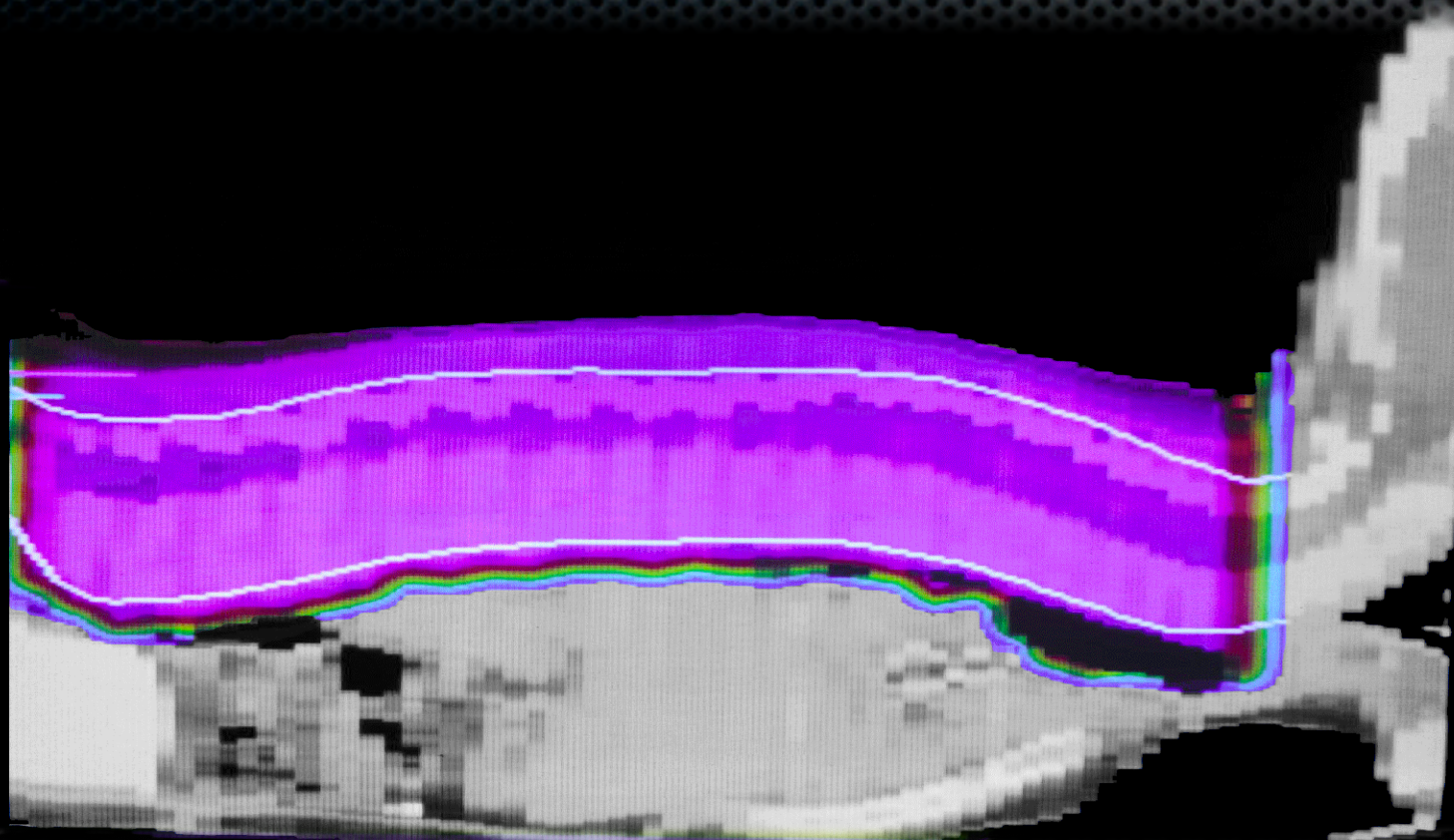
child medulloblastoma

conventional radiotherapy



child medulloblastoma

proton therapy





<http://basroc.rl.ac.uk>

- ✦ British Accelerator Science and Radiation Oncology Consortium
- ✦ academic, industrial and medical contributors
- ✦ aim:
“ the aim of BASROC is to build a complete hadron therapy facility using a novel accelerator technology called a non-scaling fixed field alternating gradient accelerator (ns-ffag).”

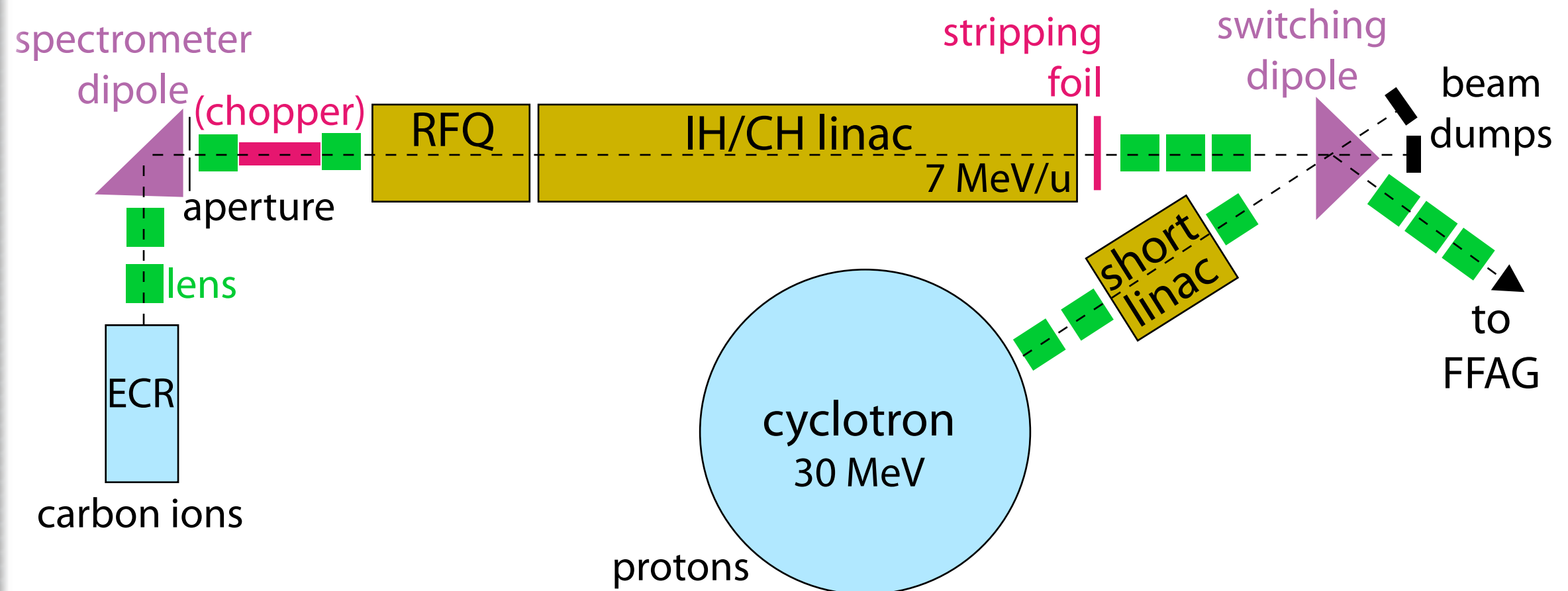


<http://basroc.rl.ac.uk>

- ✦ EMMA
Electron Model for Many Applications
- ✦ PAMELA
Particle Accelerator for MEdical Applications
- ✦ full clinical facility

pamela injector

carbon 6+ injector for ffag

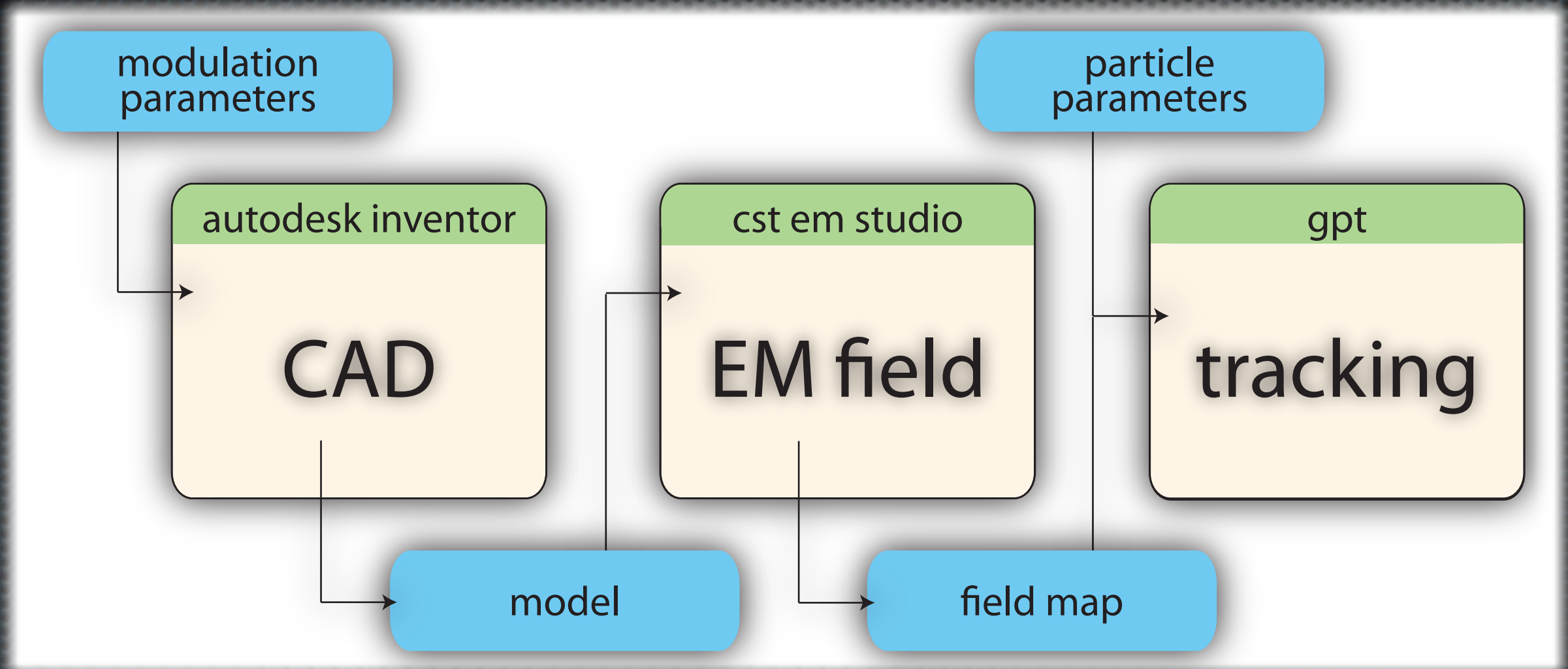


RFQ Design

CST ElectroMagnetic Studio

design model

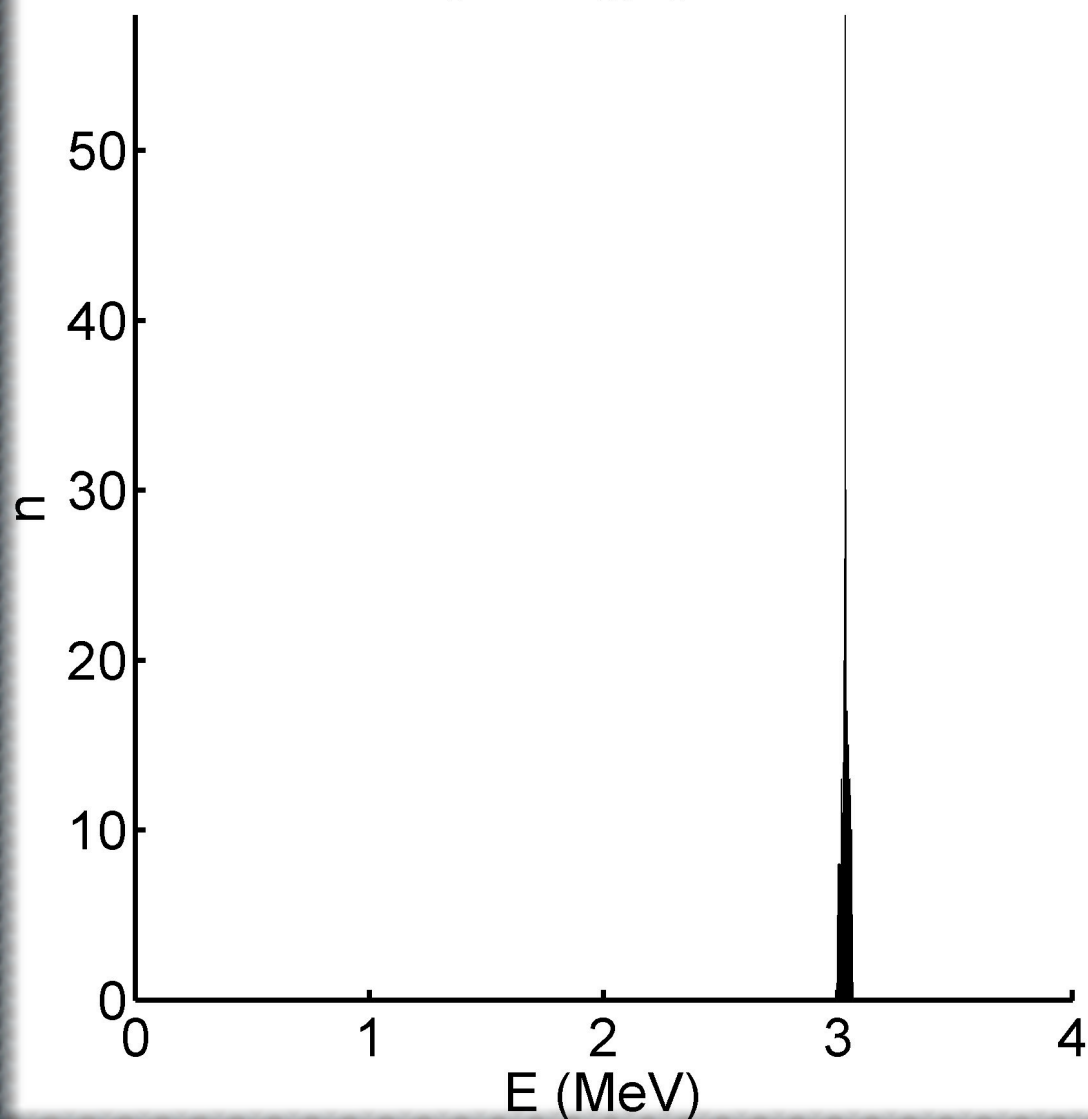
using *CST EM Studio*



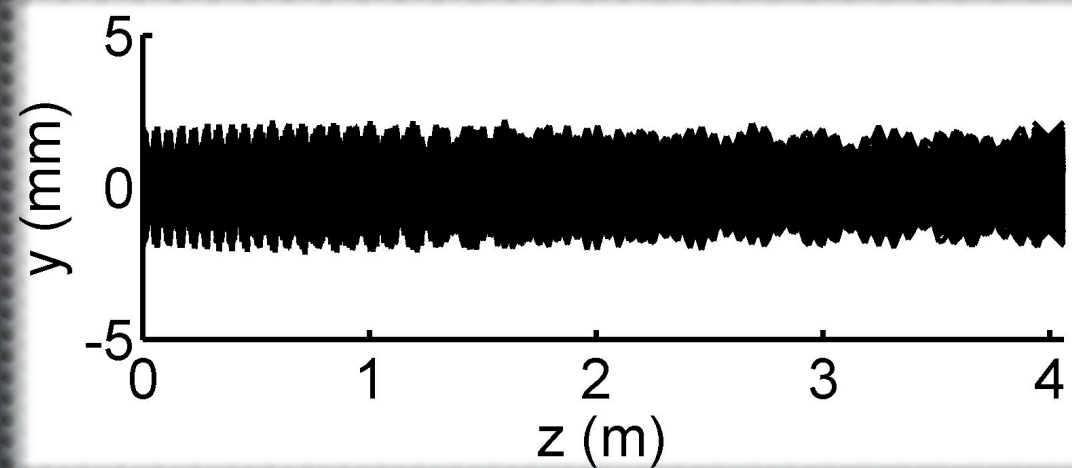
FETS field map

produced from *RFQSIM*, tracked with *GPT*

rfq energy profile



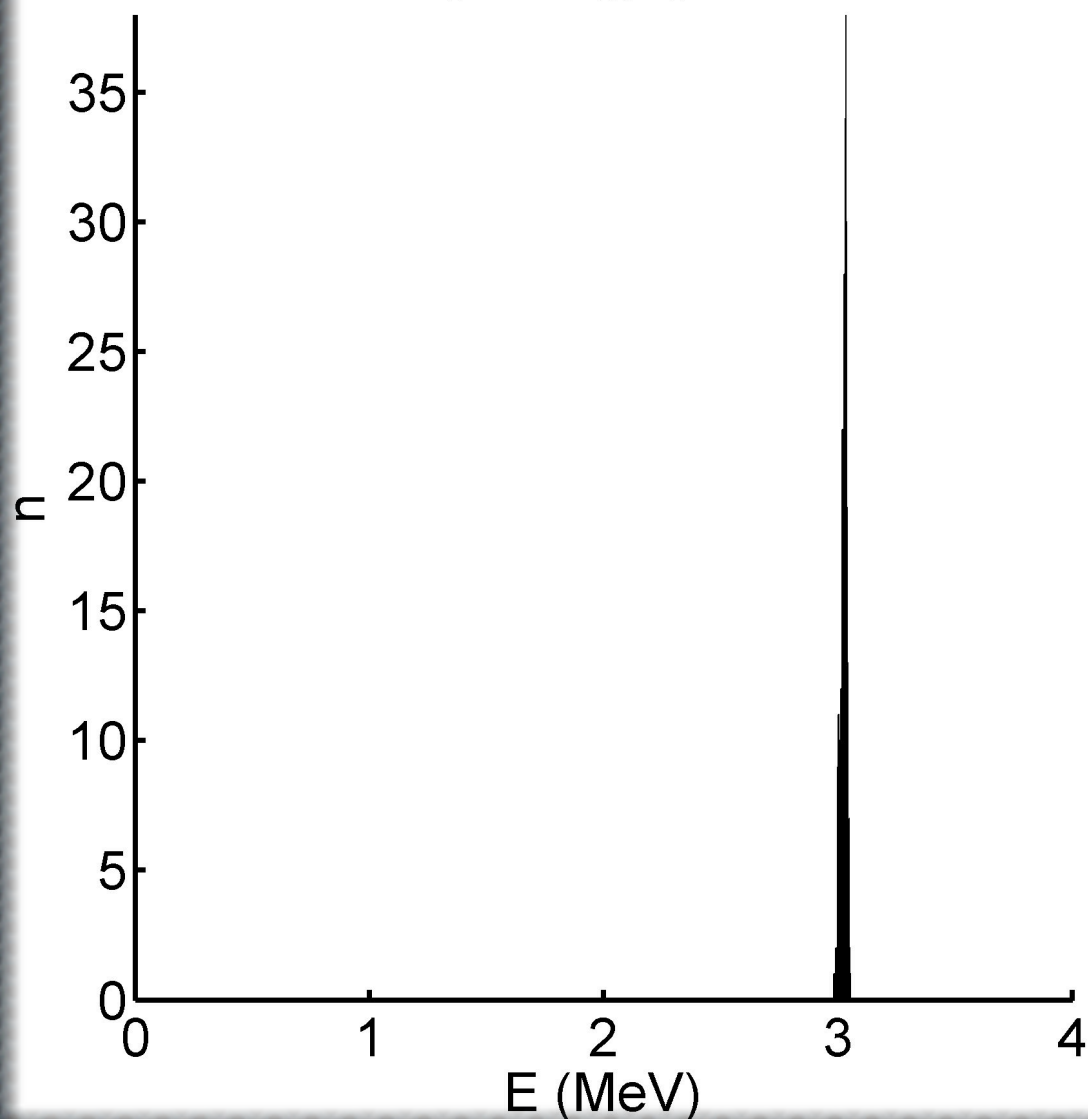
transmission = 100%
mean energy = 3.03 MeV
energy rms = 14 keV



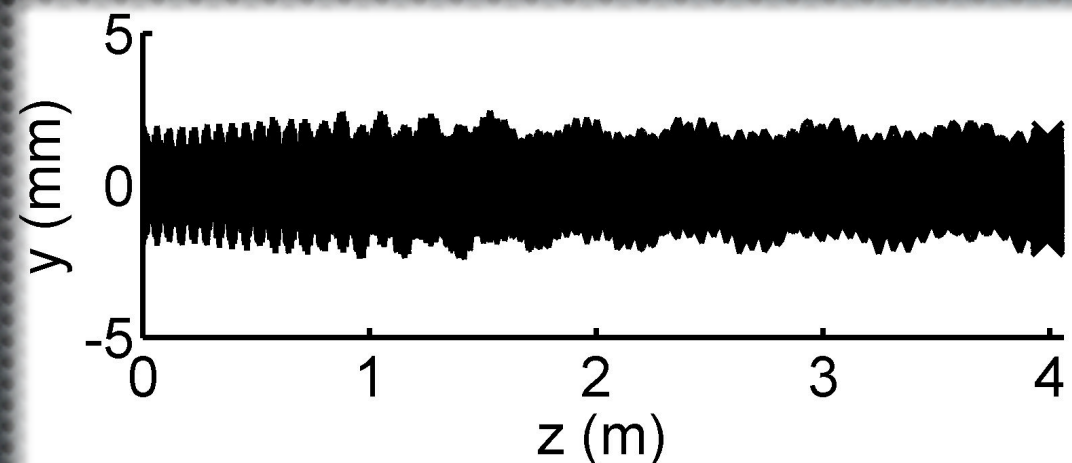
FETS field map in CST

based on *Inventor* CAD model in five sections

rfq energy profile



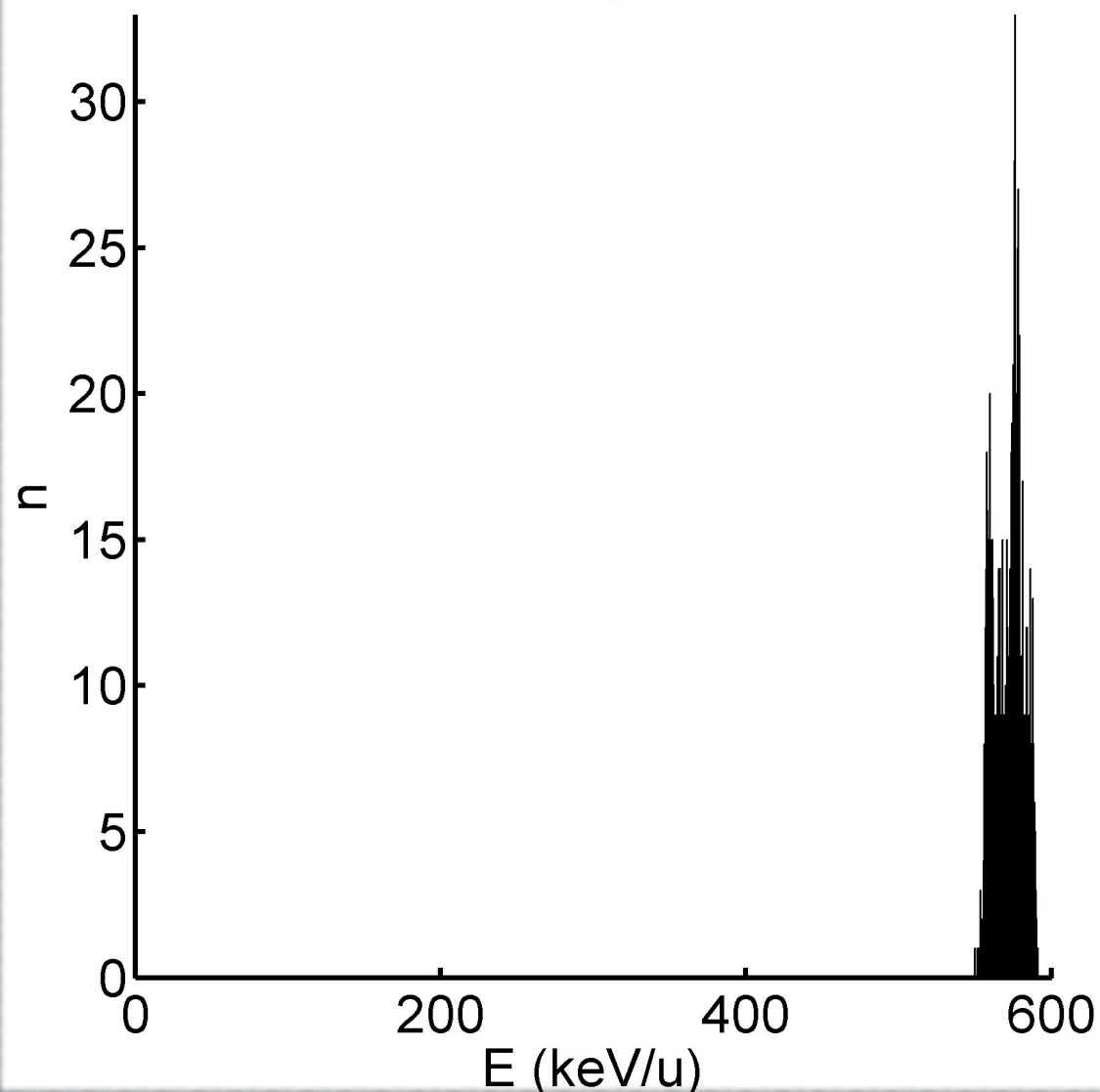
transmission = 100%
mean energy = 3.03 MeV
energy rms = 12 keV



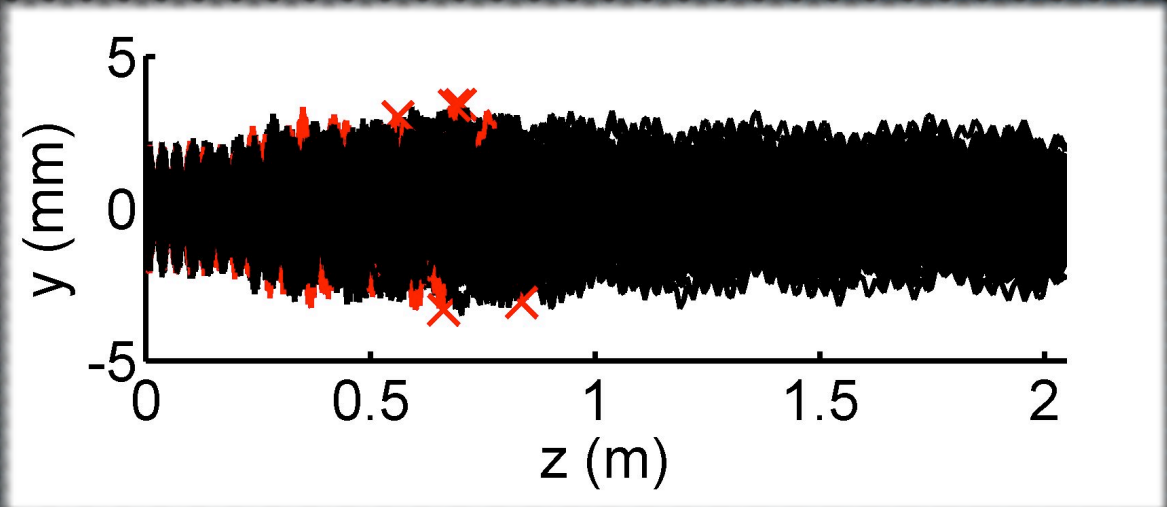
first *PAMELA* field map

based on a scaled version of the *FETS* RFQ field map

rfq energy profile



transmission = 99.1%
mean energy = 687 keV/u
energy rms = 11 keV/u



field scaling for *PAMELA*

- ✦ reduced input energy from 65 keV to 12 keV/u
 - ✦ velocity reduction by factor of 0.43
 - ✦ requires reduction in synchronous velocity of rfq

$$\beta_s = \frac{D\omega}{2\pi c}$$

field scaling for *PAMELA*

- ✦ reduce frequency from 324 MHz to 280 MHz
 - ✦ factor of 0.86
- ✦ reduce length from 4.1m to 2.0m
 - ✦ factor of 0.50
- ✦ total reduction of 0.43 as required

$$\beta_s = \frac{D\omega}{2\pi c}$$

field scaling for *PAMELA*

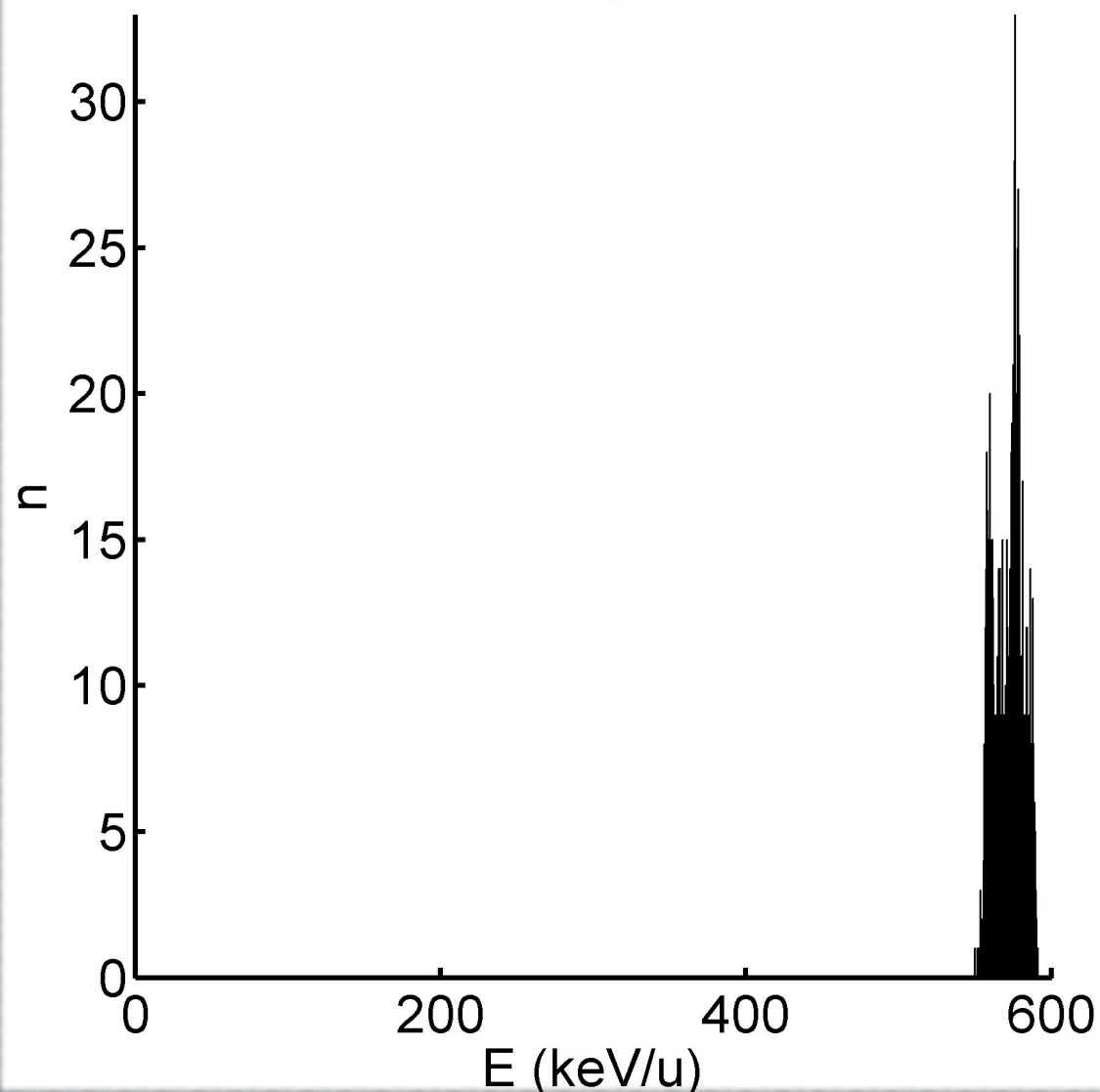
- ✦ lower charge to mass ratio for carbon 6+ means higher field magnitude required
- ✦ lower frequency of oscillation means lower field magnitude possible
- ✦ on balance a higher field magnitude is possible for pamela than for fets, allow a higher acceleration gradient

$$\epsilon \leq \frac{qE_0}{ma\omega^2 \cos \phi}$$

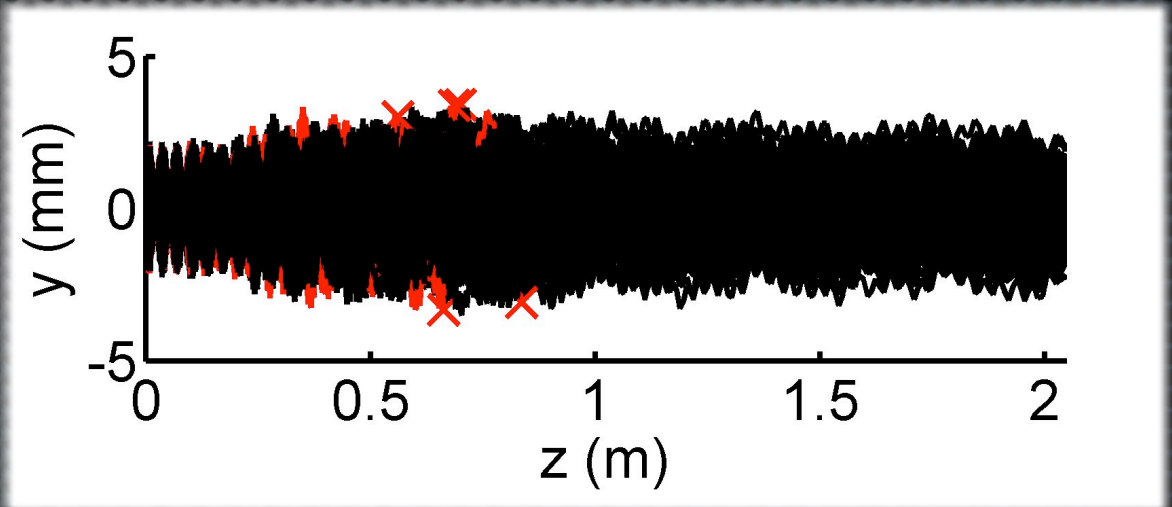
first *PAMELA* field map

based on a scaled version of the fets rfq field map

rfq energy profile



transmission = 99.1%
mean energy = 687 keV/u
energy rms = 11 keV/u



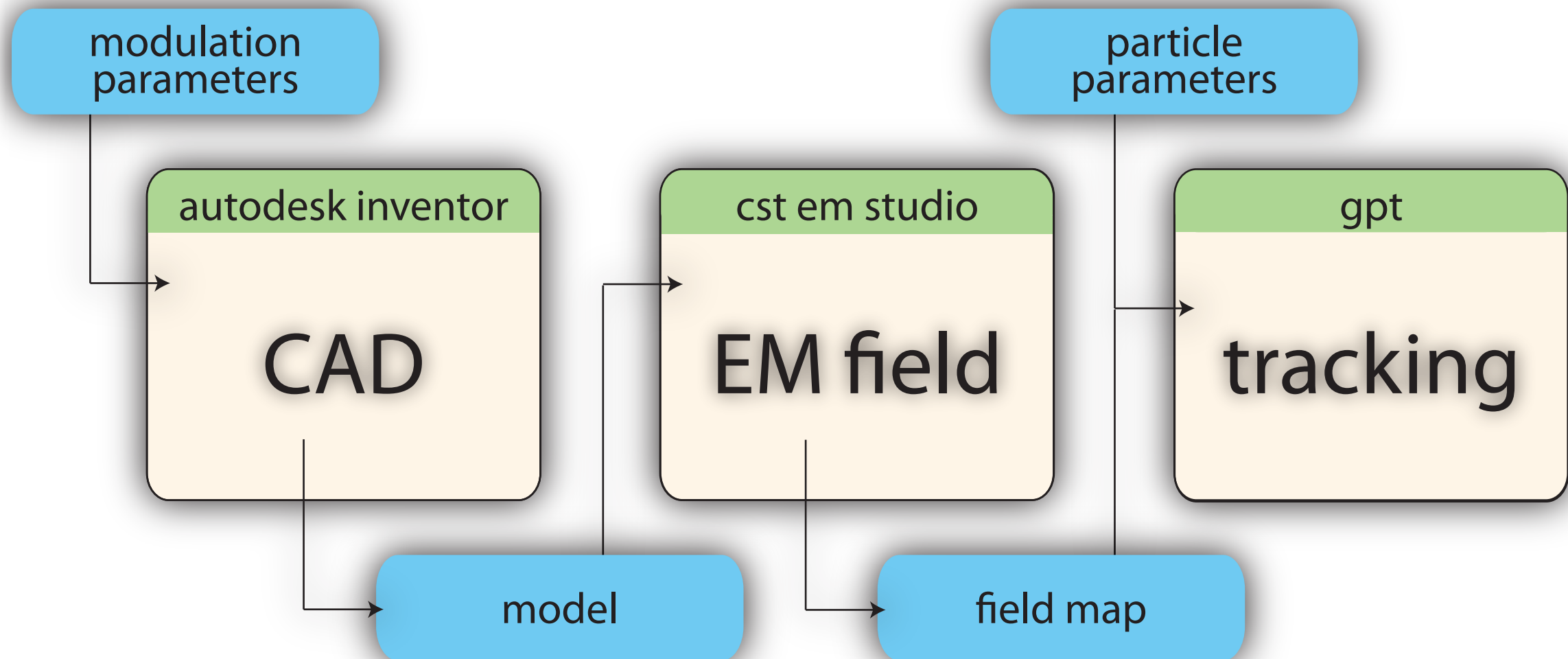
RFQ Design

Upgraded design model

Comsol and Matlab

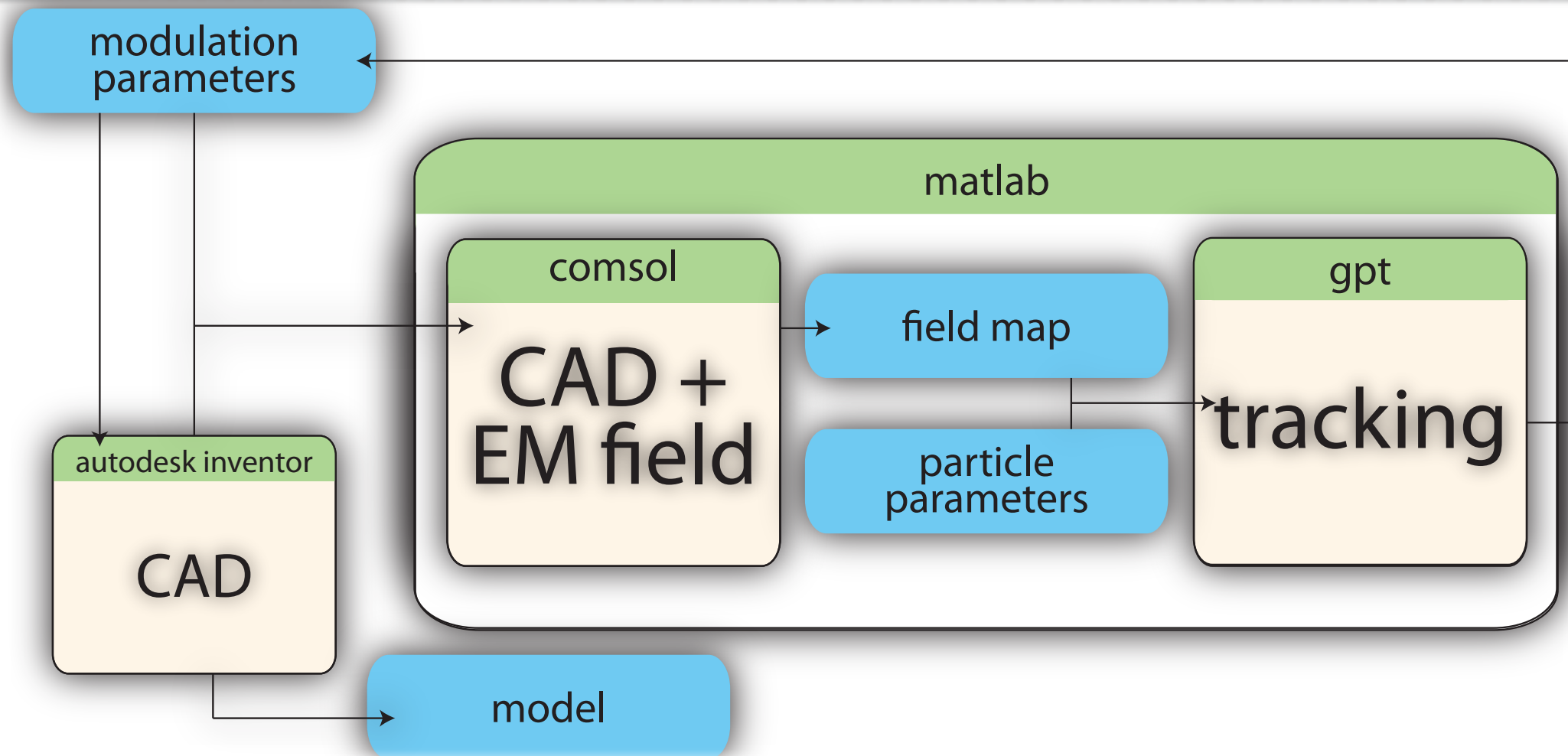
original design model

using *CST EM Studio*



upgraded design model

using *Comsol* and *Matlab*

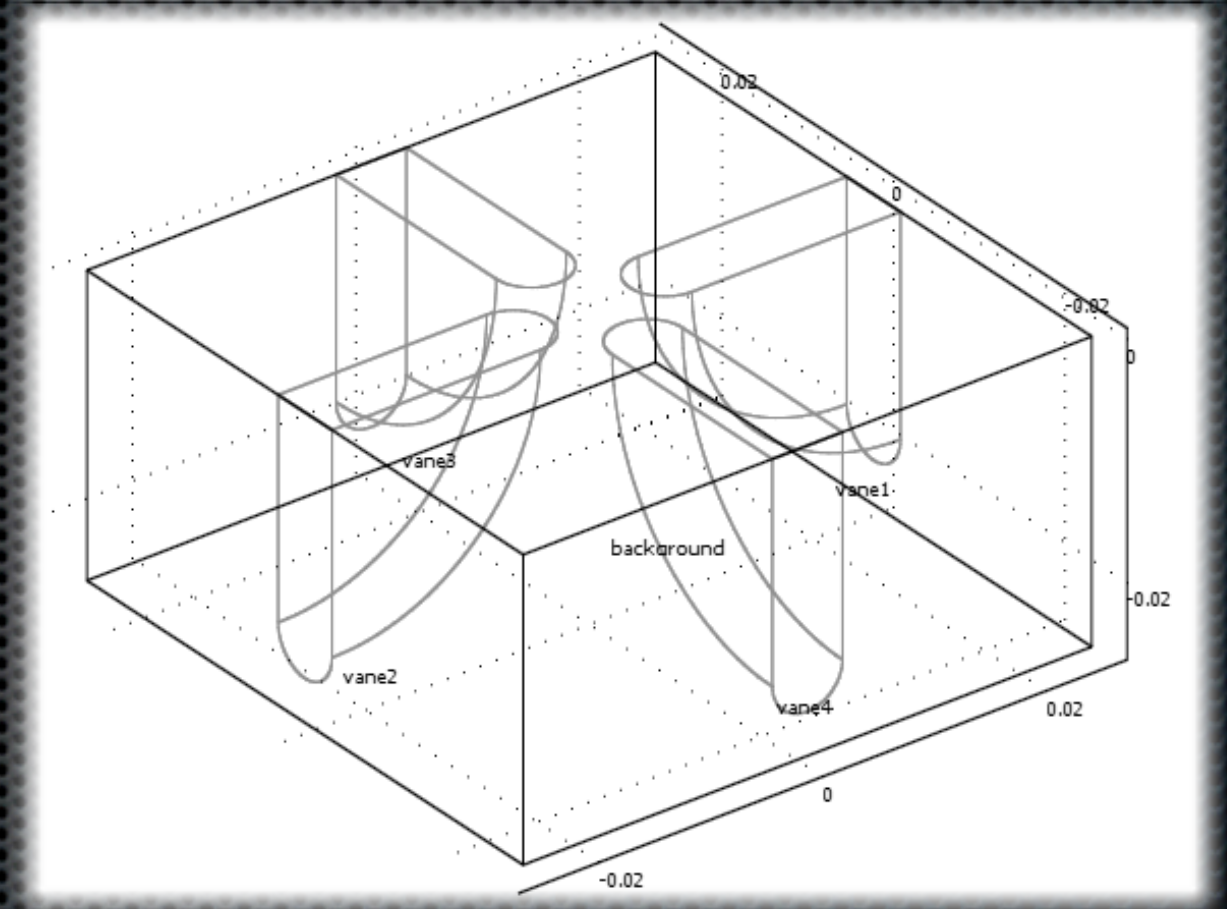
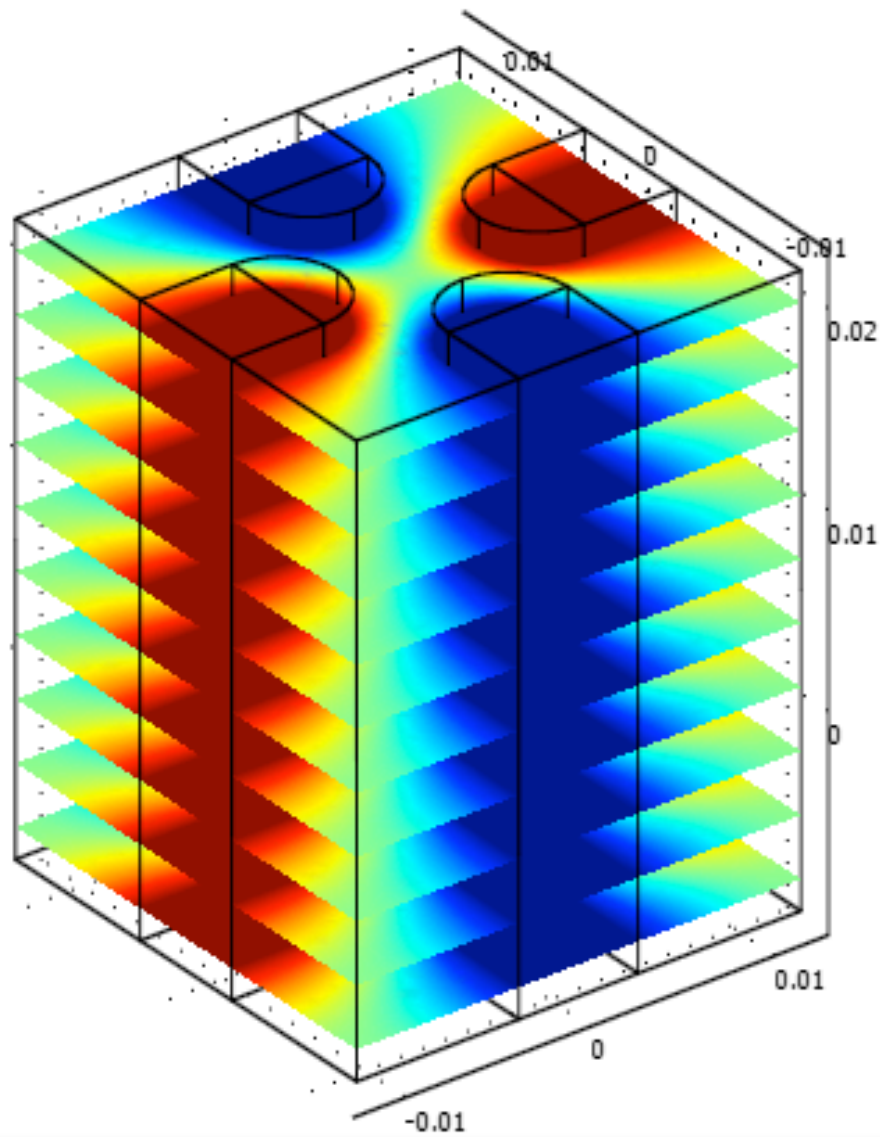


Matlab code

- ✦ three options for each run:
 - ✦ *FETS*
field map based on *FETS* RFQ modulation parameters
 - ✦ *FETS>PAMELA*
takes *FETS* field map and scales for *PAMELA*
 - ✦ *PAMELA*
field map based on new RFQ modulation parameters
- ✦ all other options set in parameter file

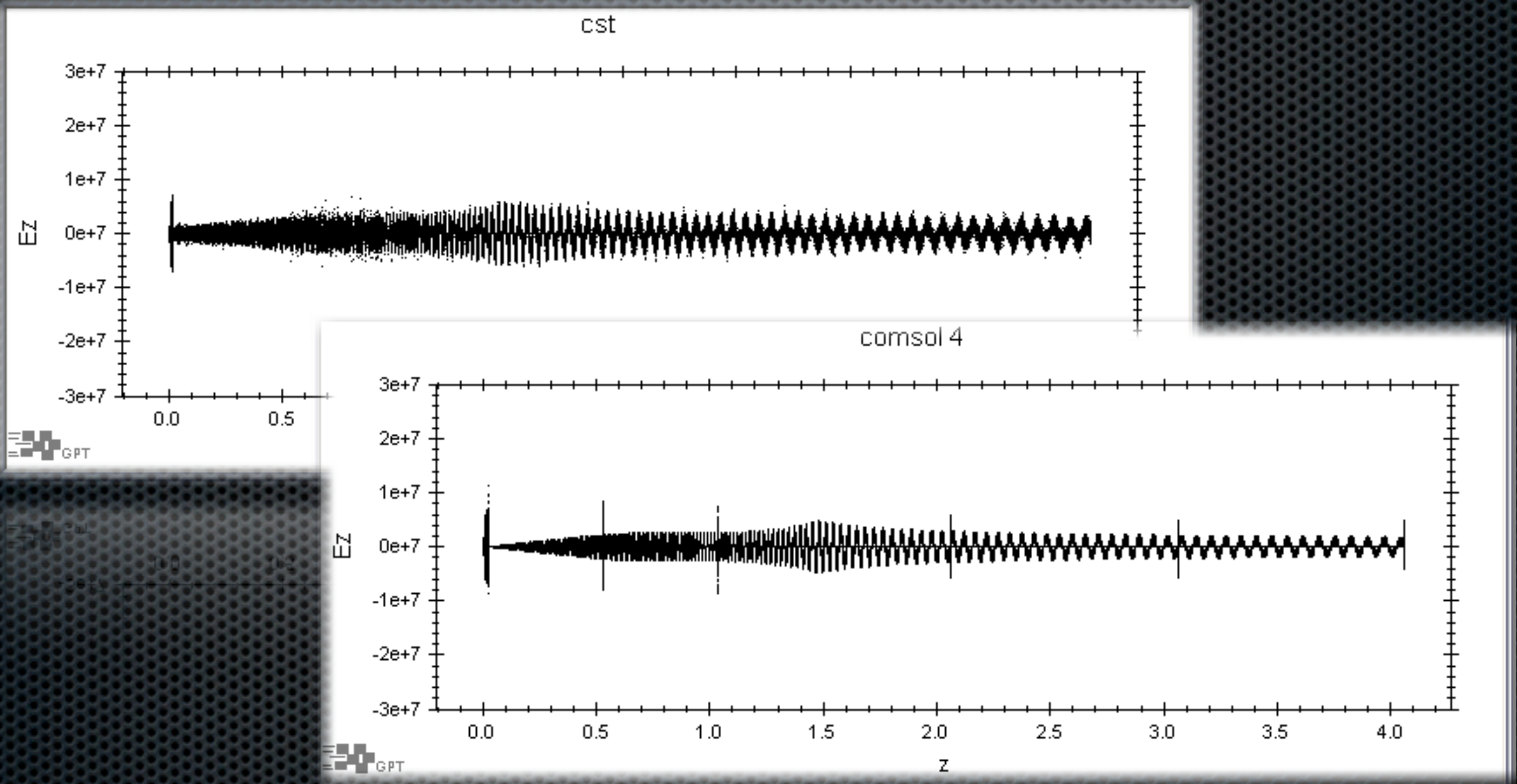
Comsol

FETS RFQ simulations



Comsol

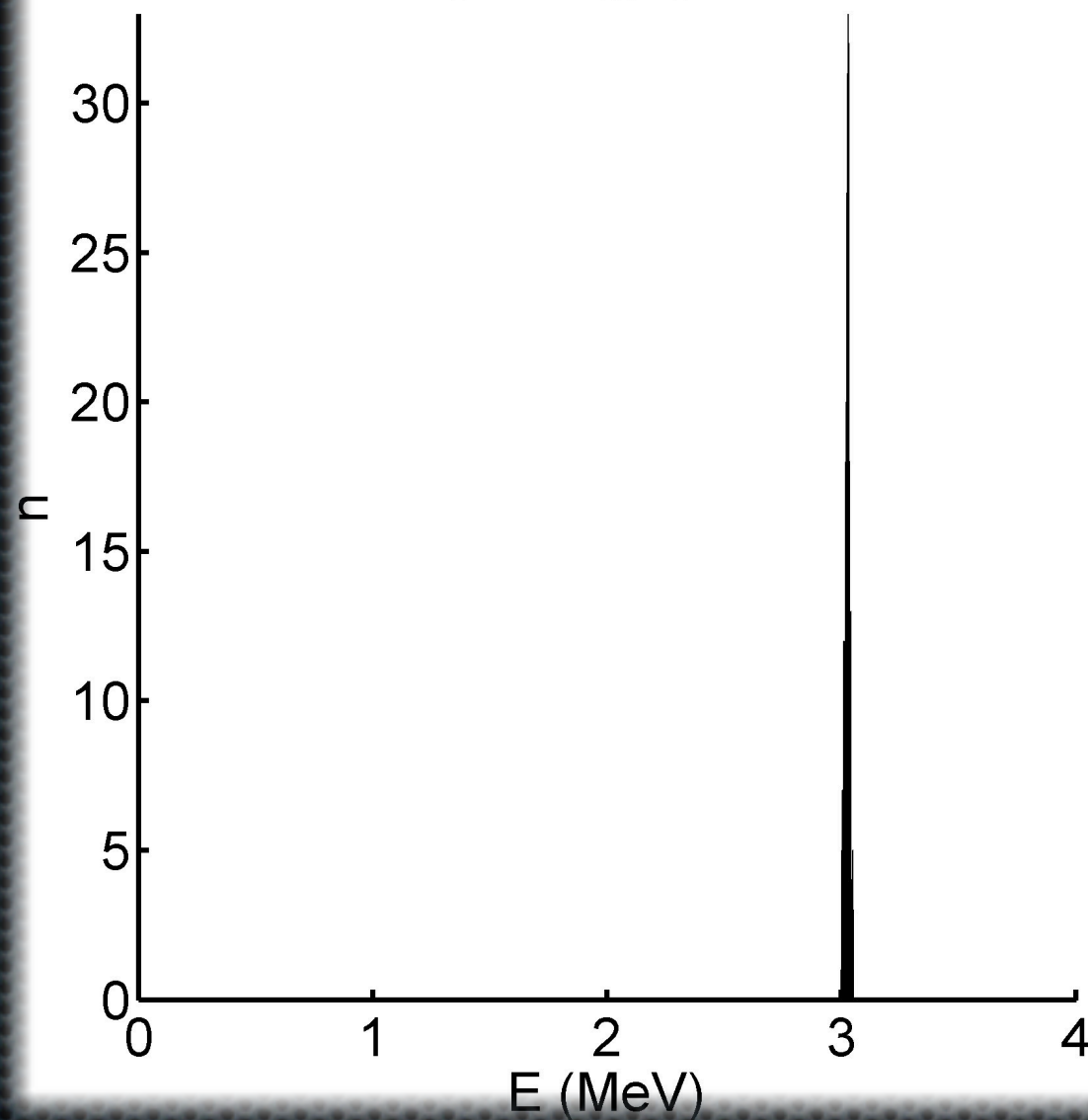
FETS RFQ simulations



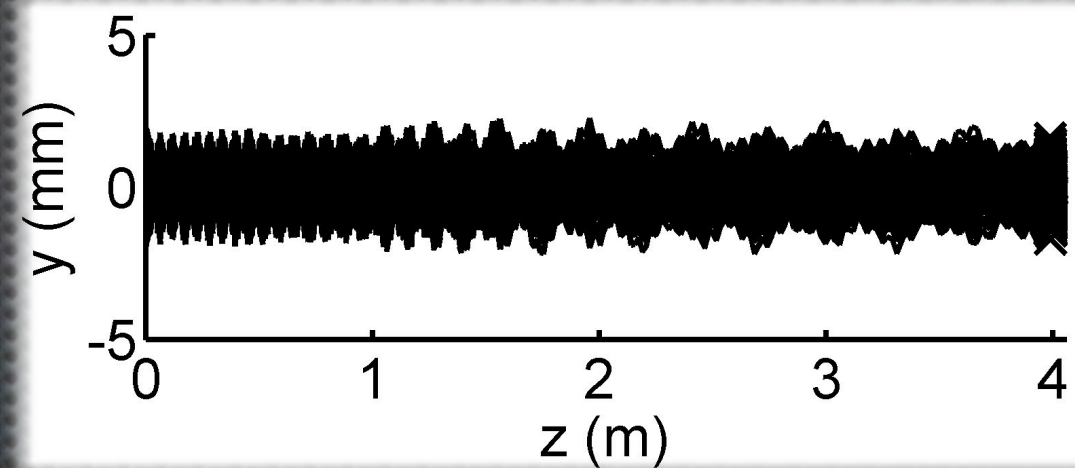
Comsol

FETS RFQ simulations

rfq energy profile



transmission = 100%
mean energy = 3.03 MeV
energy rms = 9 keV



to do:

- ✦ integrate *Comsol* with *Matlab* and *Inventor*
- ✦ build new *PAMELA* RFQ design
- ✦ optimise new design through iteration
- ✦ find the optimum point to switch from RFQ to Linac
- ✦ produce complete simulation from ion source to injection

RFQ Injector for *PAMELA* FFAG

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