Geant4 Simulations of Conventional Positron Source

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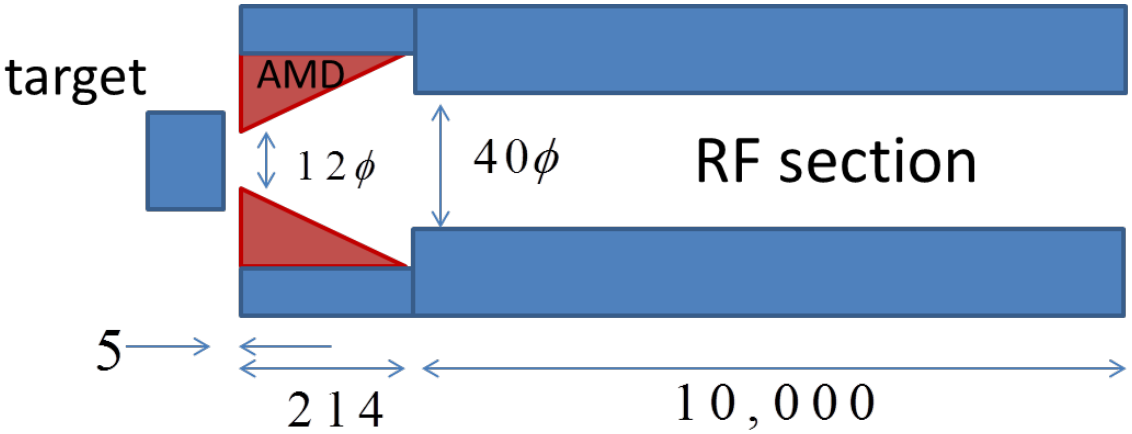
Outline

- Conventional e^+ source parameters
- Geant4 model of conventional e^+ source
- e^+ yield simulation results
  - E-field phase
  - e^- spot size on target
  - FC max. field
  - FC aperture size
  - Space between target and FC
  - E-field amplitude
- PEDD in target, FC and RF structure
- Summary

Source Parameters: Primary Beam, Geometry, Fields

Starting set of parameters that have been chosen for simulations



- Primary beam: 6 GeV e^-, 4 mm rms radius (Gaussian distribution)
- Target: W25Re, $4X_0$ thickness (1.36 cm), 5 mm space to FC
- AMD (FC): 214 mm long, 12 mm entry aperture diameter, 7 T max B-field, taper parameter = 60 m^{-1}
- RF section embedded into 0.5 T solenoid: 10 m long, 40 mm aperture diameter, 25 MV/m max E-field
- DR acceptance: $\Delta z < 34$ mm, $\Delta E < 1.5\%$, $\epsilon_{nx} + \epsilon_{ny} < 0.07$ rad·m

Simulation Tools

e^+ generation and capture have been calculated in Geant4 application (PPS-Sim).

Geant4 ver. 9.4.p03 has been used*.

*There is some problems with scoring of deposited energy (time goes back?!). FLUKA has been used to estimate an average energy deposition and PEDD. E-field is not implemented in FLUKA.

Simplifications in PPS-Sim

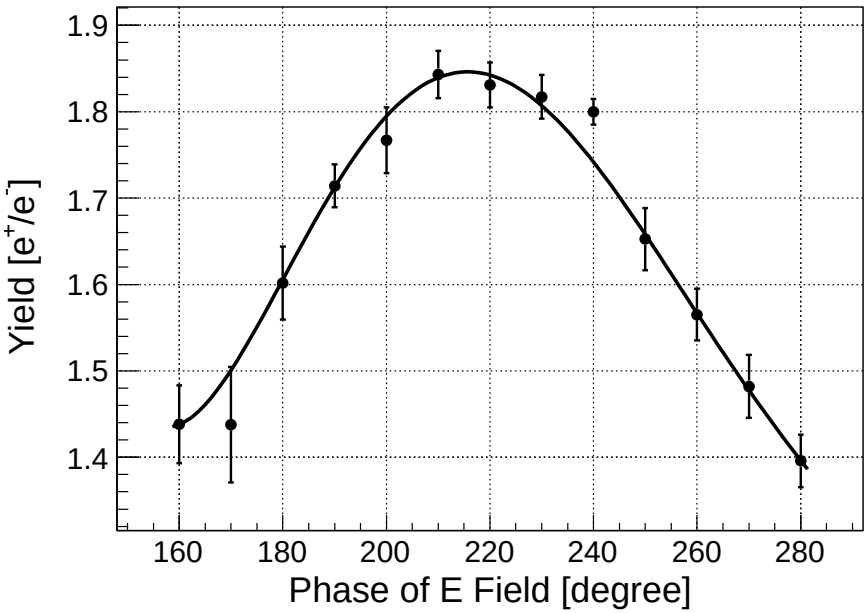
- Ideal B-field profile with max. at the beginning of FC
- Linear decreasing B-field in space between FC and target
- Ideal E-field (harmonic function in space and time)
- Single long RF structure
- DR acceptance was emulated as a series of cuts at 125 MeV

E-Field Phase

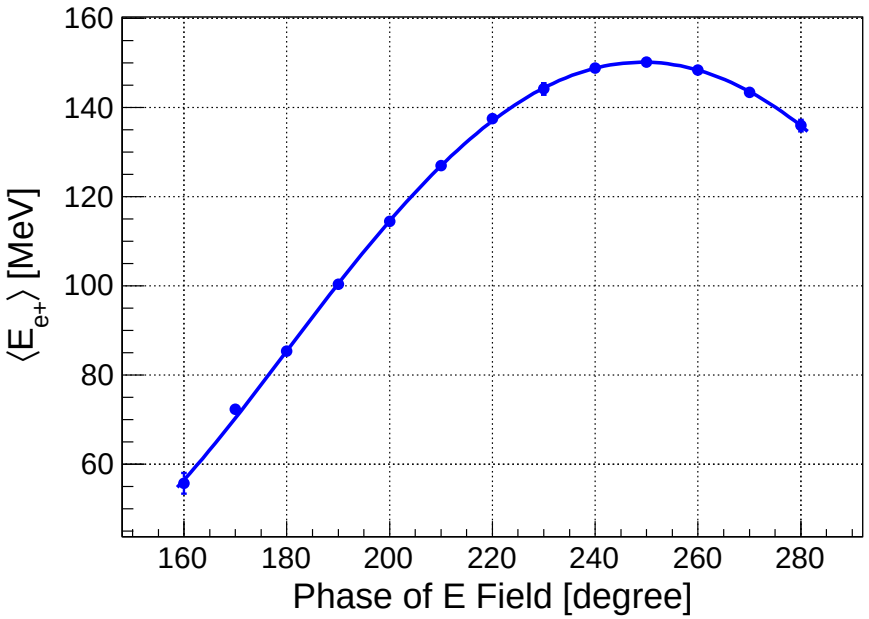
e^+ source with "base" parameters (see slide 3)

After target: $Y \approx 15\ e^+/e^-$, $\langle E_{e^+} \rangle \approx 57$ MeV. At RF end: $Y \approx 2.75\ e^+/e^-$

Captured e^+ Yield vs Phase of E-Field



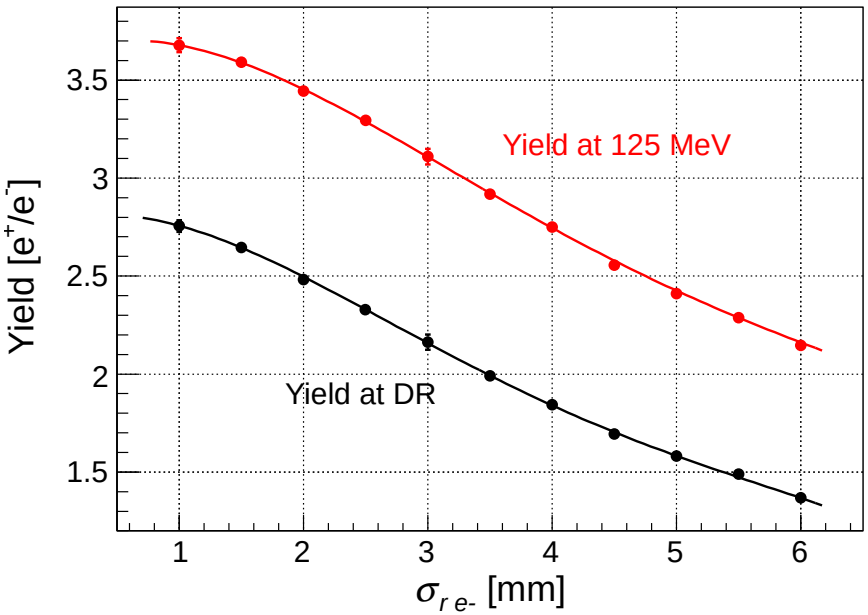
Average e^+ Energy at the End of Capture RF



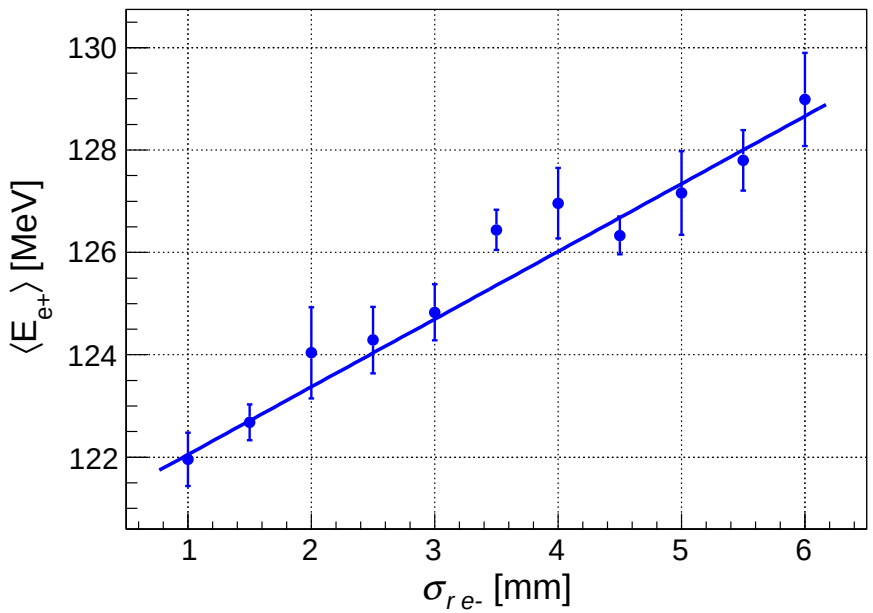
Spot Size of e^- Beam on Target

E phase = 210 degree

Yield at "125 MeV" and "DR" vs RMS Radius of e^- Beam



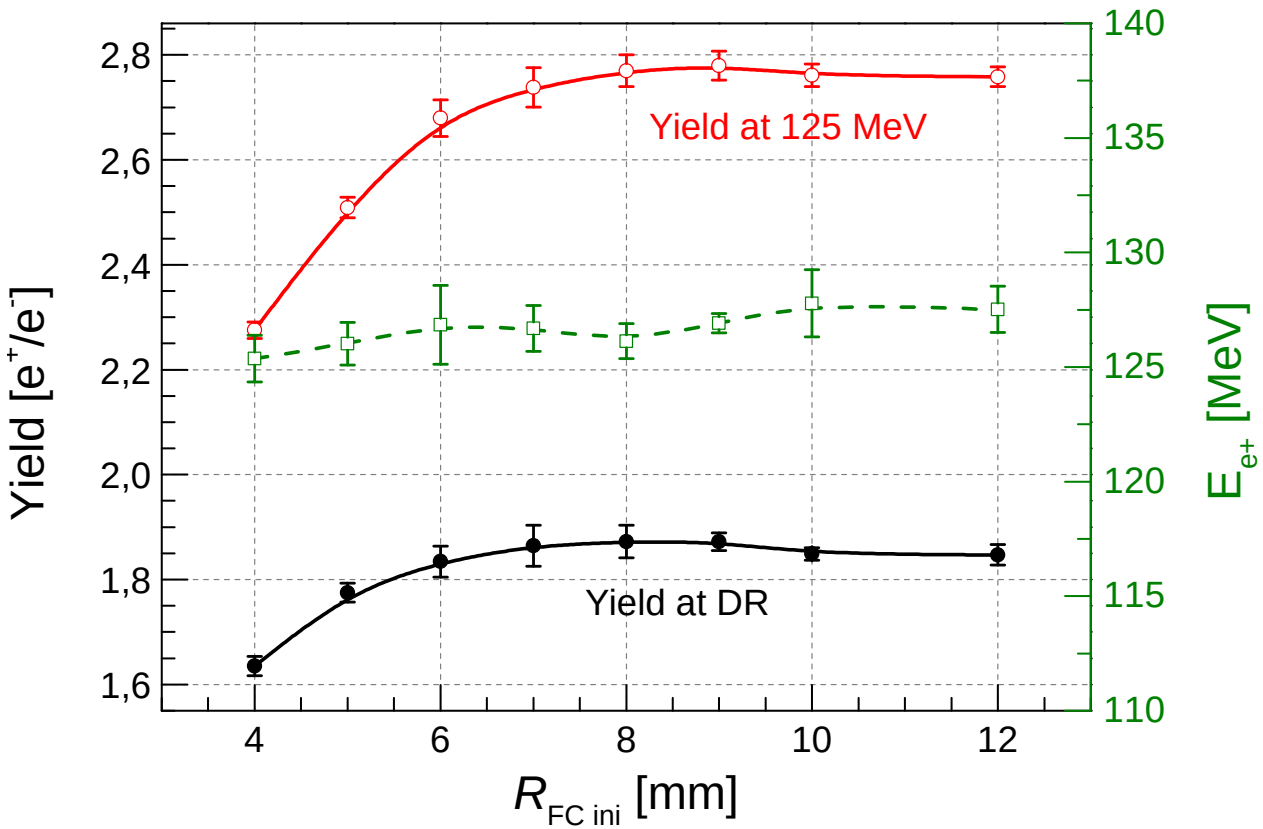
Average e^+ Energy vs RMS Radius of e^- Beam



Aperture Size of FC

e^- beam rms radius = 4 mm

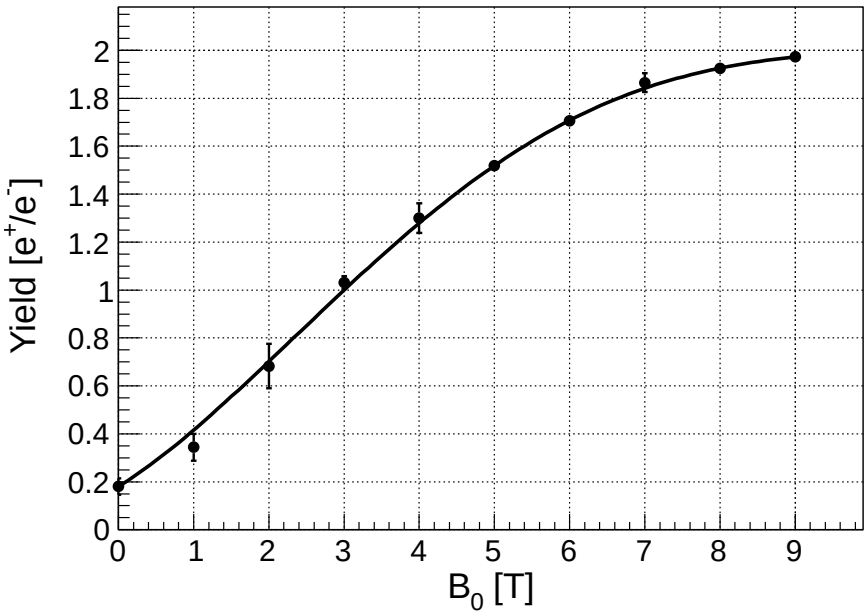
e^+ Yield and Mean Energy vs Entry Aperture Radius of FC



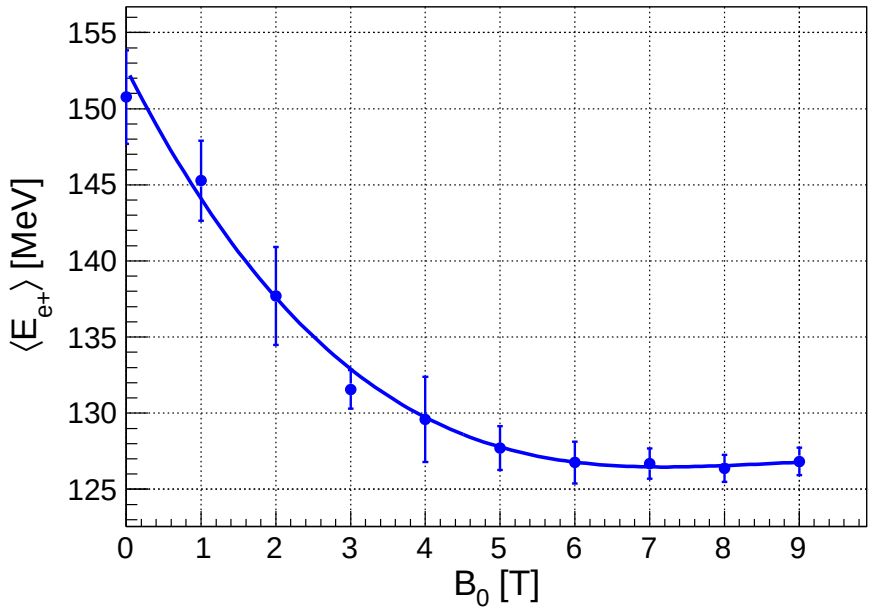
Peak Field of FC

$$R_{FC\,ini} = 6 \text{ mm}$$

Yield vs Peak B-Field



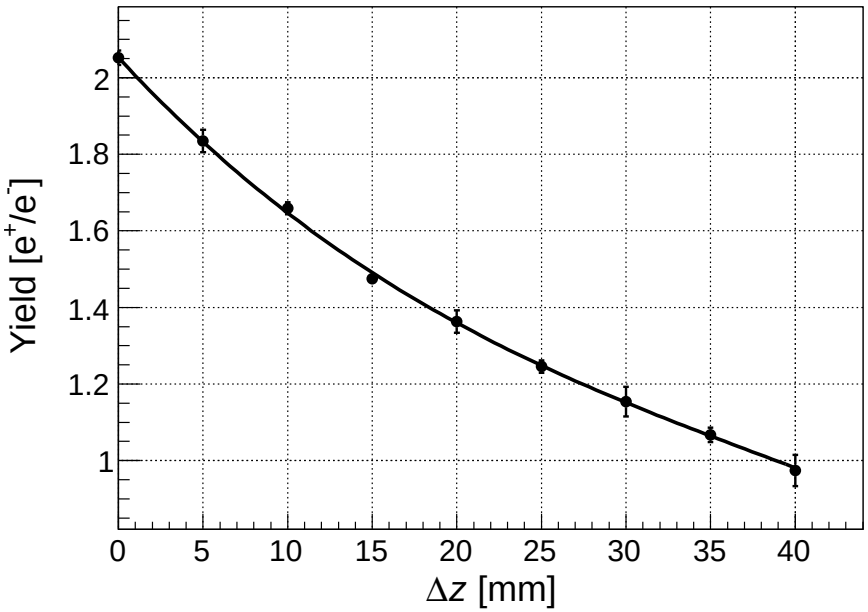
e$^+$ Energy vs Peak B-Field



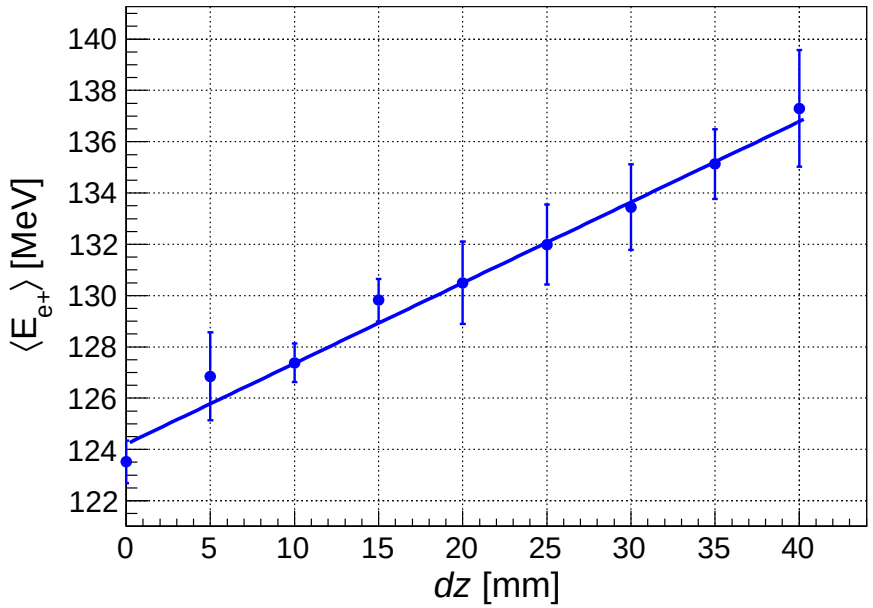
Distance between Target and FC

$$B_{max} = 7\ \mathrm{T}$$

Yield vs Distance between Target and FC



e^+ Energy vs Distance between Target and FC

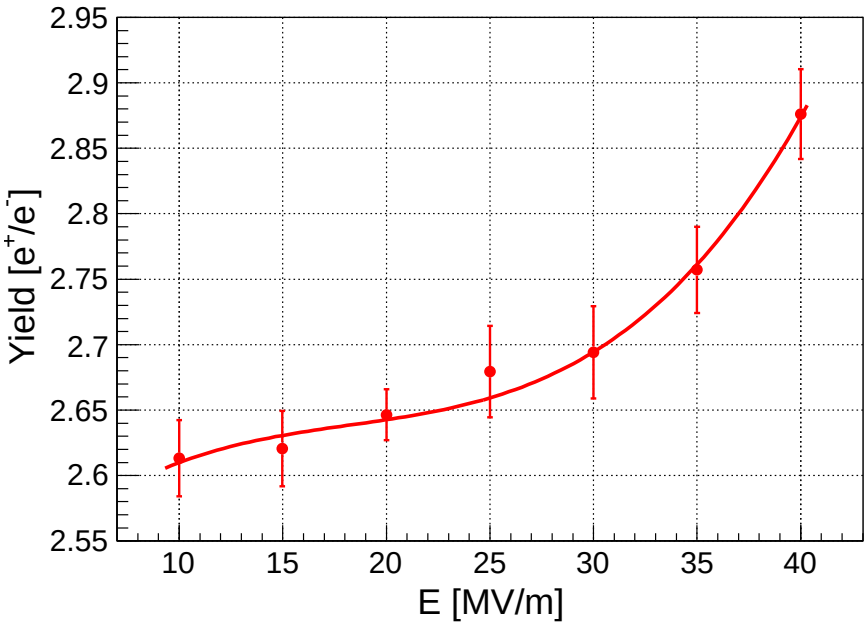


Amplitude of E-Field

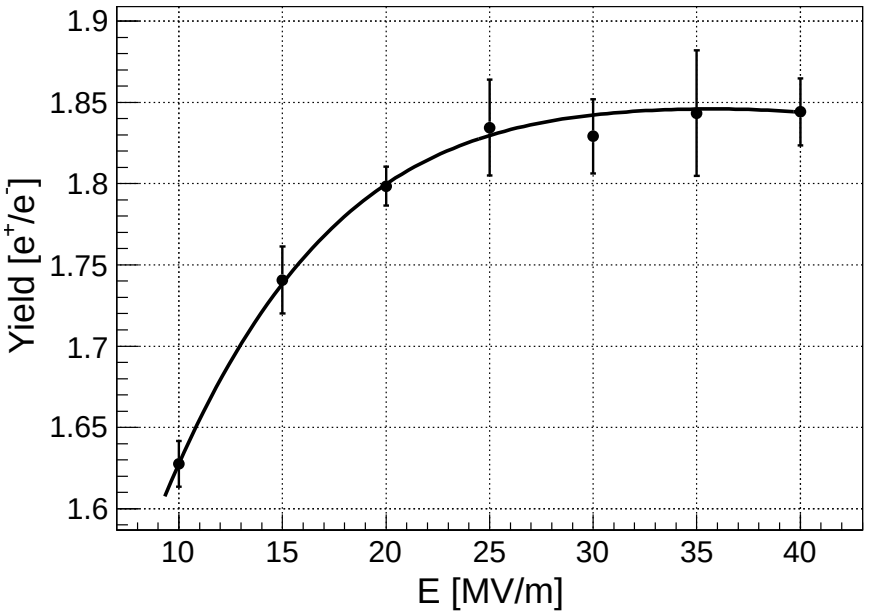
Length of RF structure has been adjusted (inverse) proportionally to change of E-field

$\Delta z = 5$ mm

Yield at End of Capture RF vs Amplitude of E-Field



Yield at DR vs Amplitude of E-Field

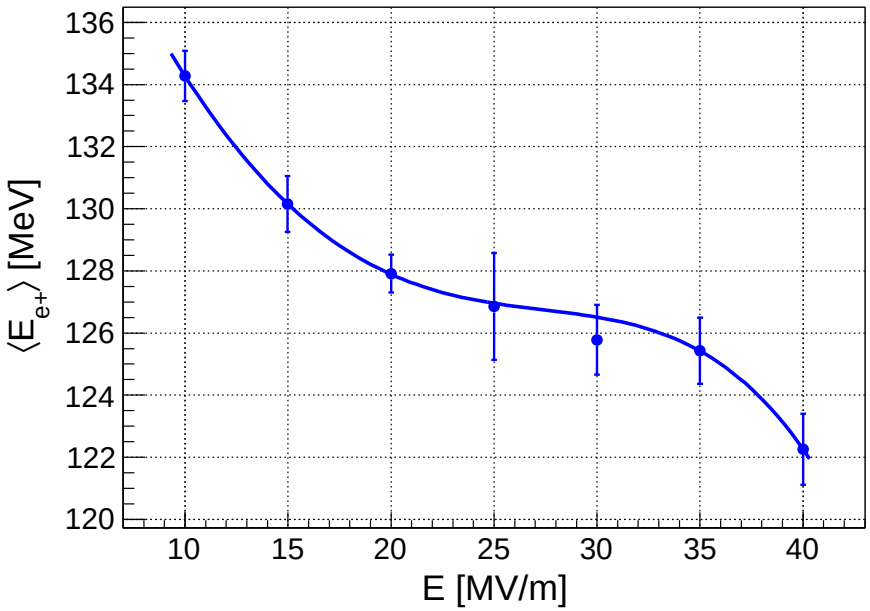


Amplitude of E-Field

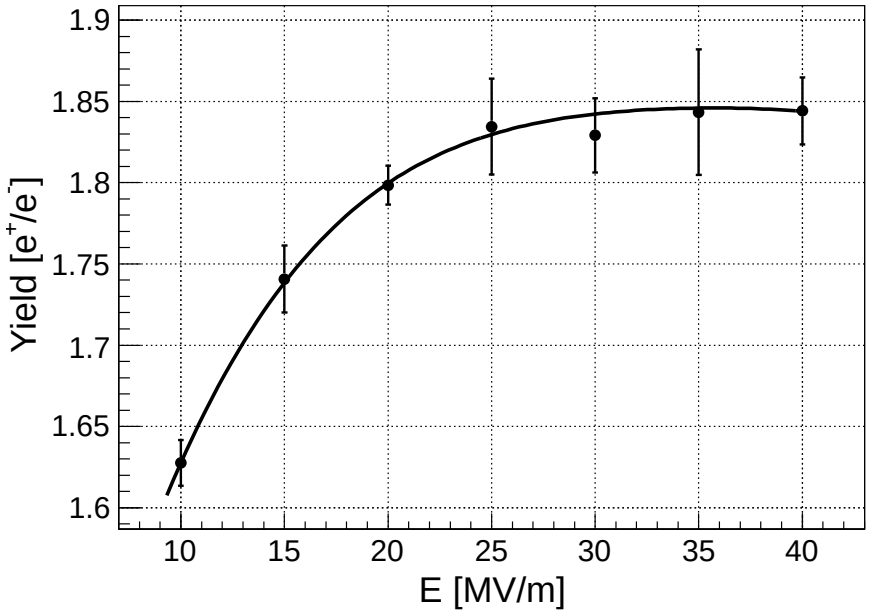
Length of RF structure has been adjusted (inverse) proportionally to change of E-field

$\Delta z = 5$ mm

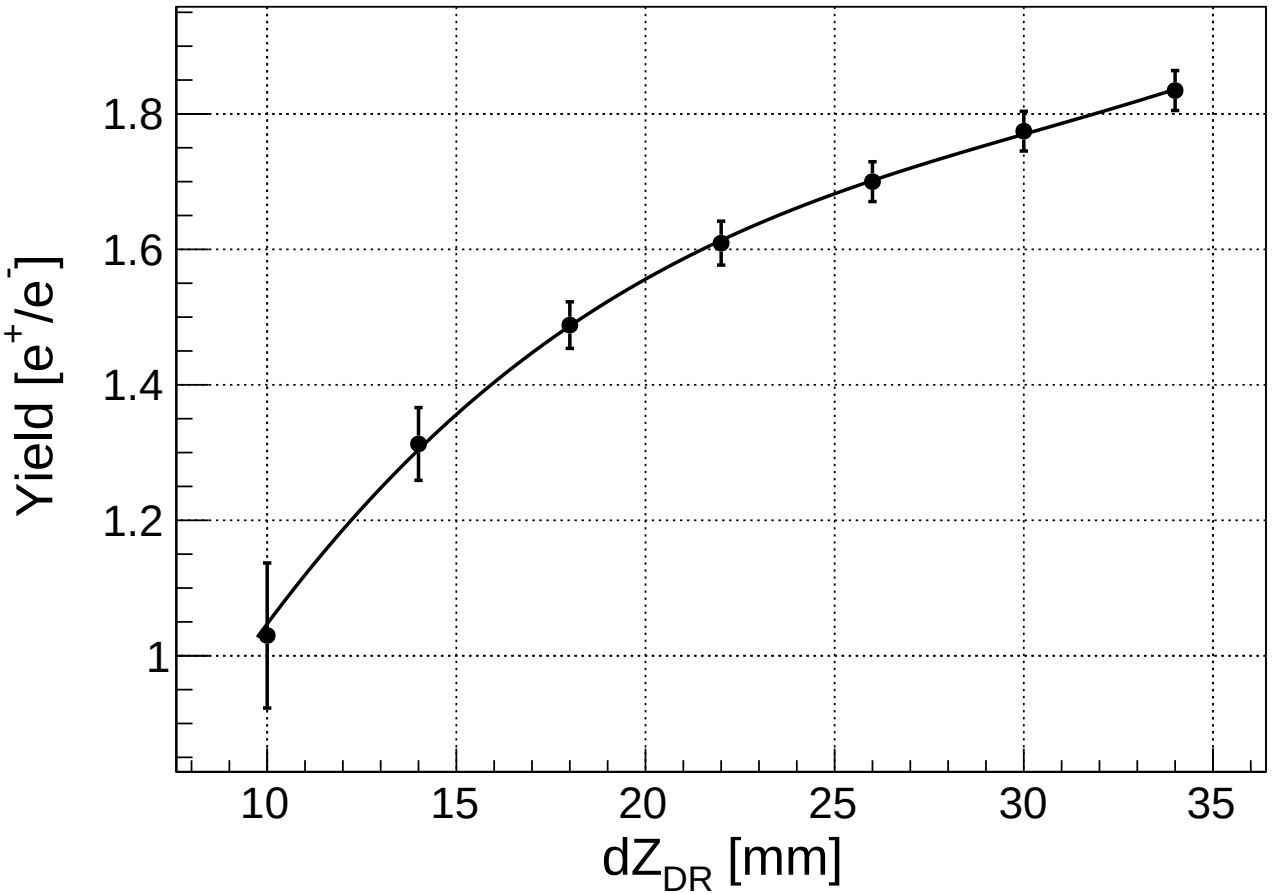
e^+ Energy vs Amplitude of E-Field



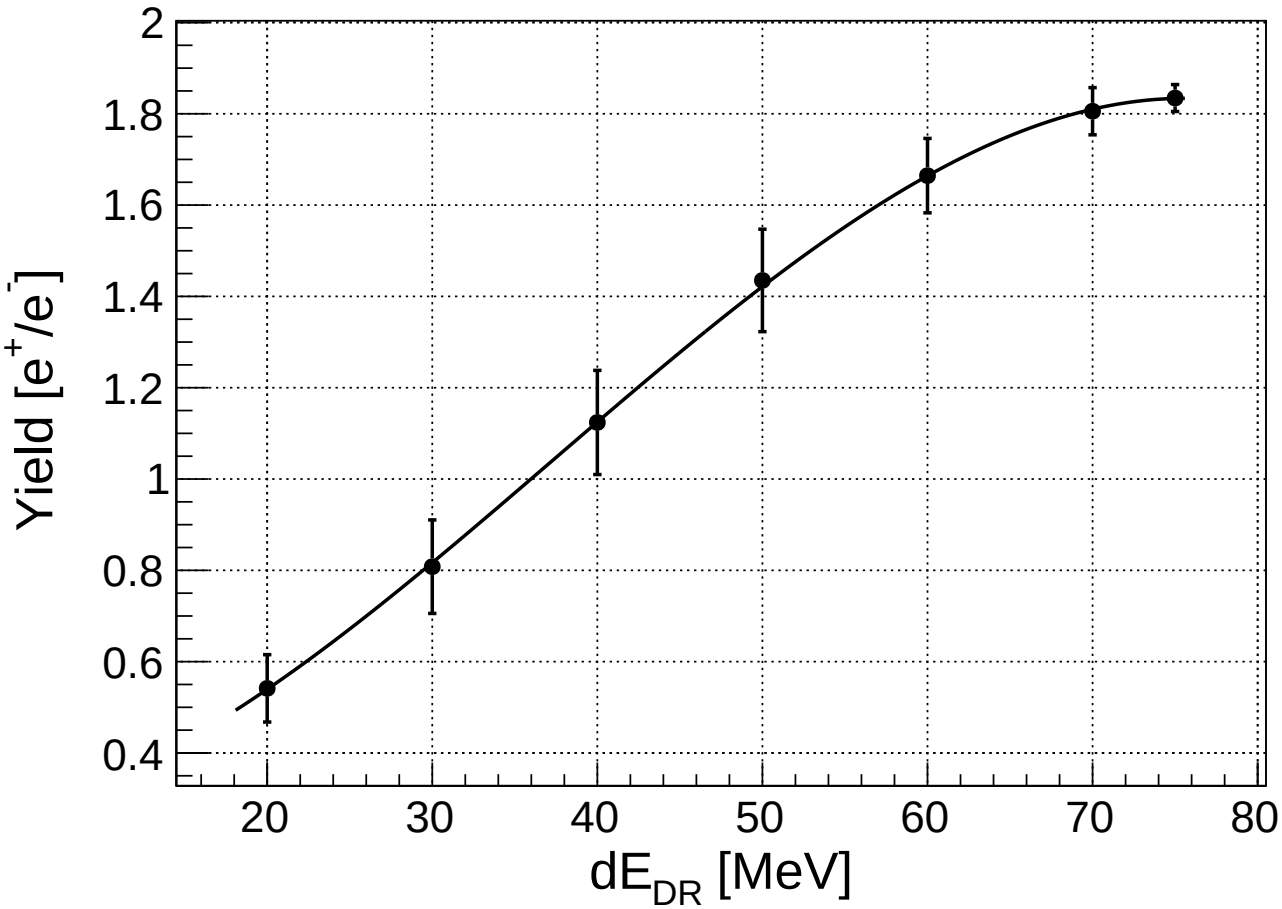
Yield at DR vs Amplitude of E-Field



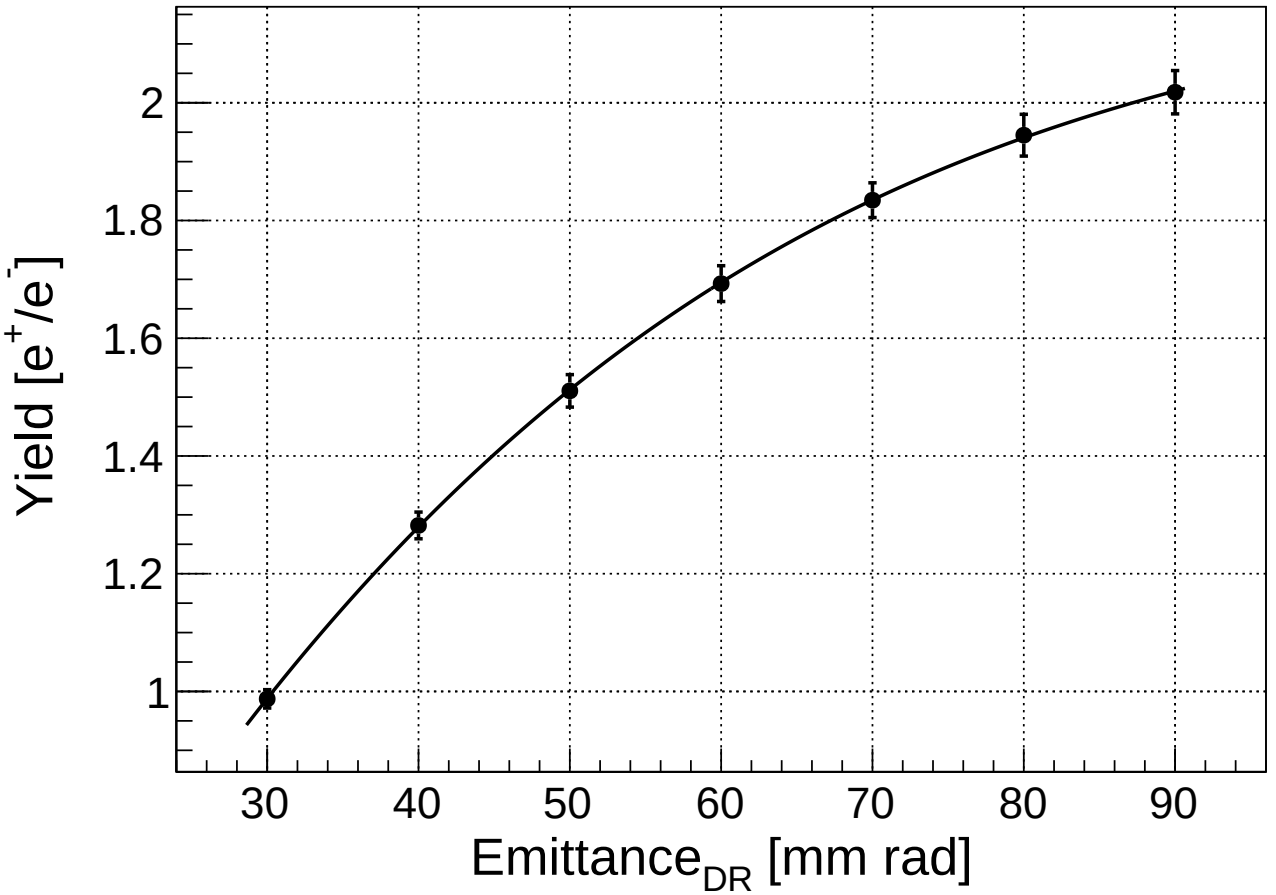
DR Acceptance: Bunch Length



DR Acceptance: Energy Spread



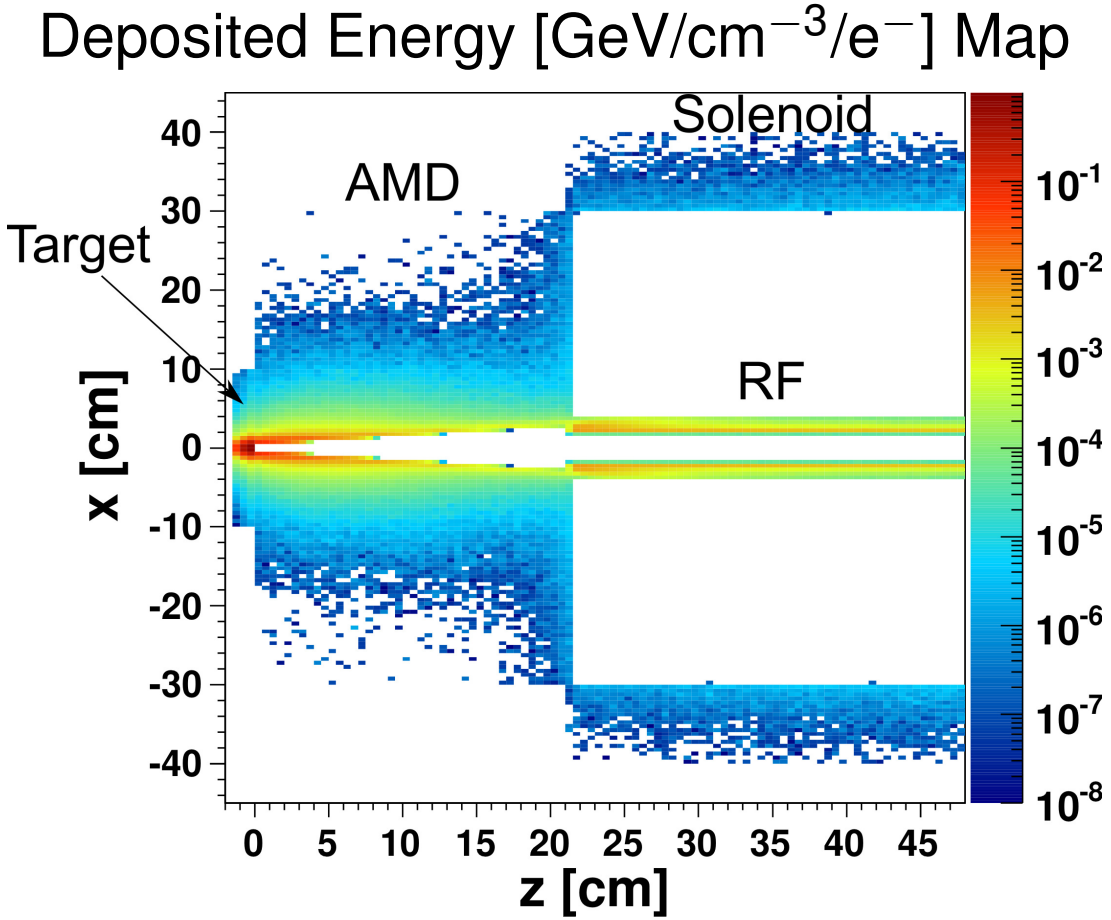
DR Acceptance: Transverse Emittance (Sum X and Y)



Energy Deposition Overview (FLUKA)

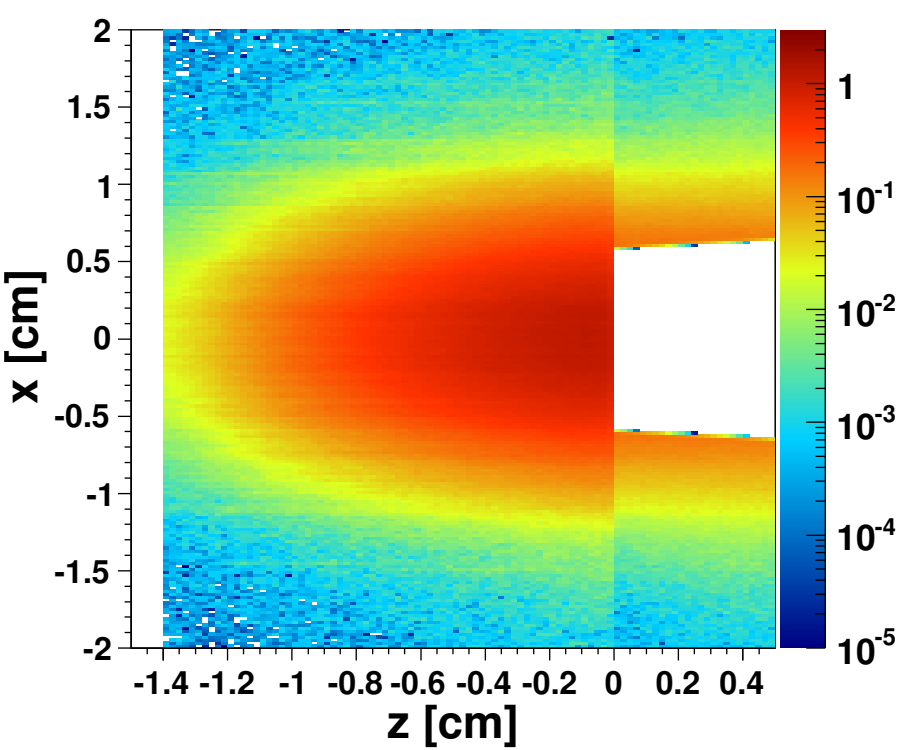
FLUKA simulation (May 2011)

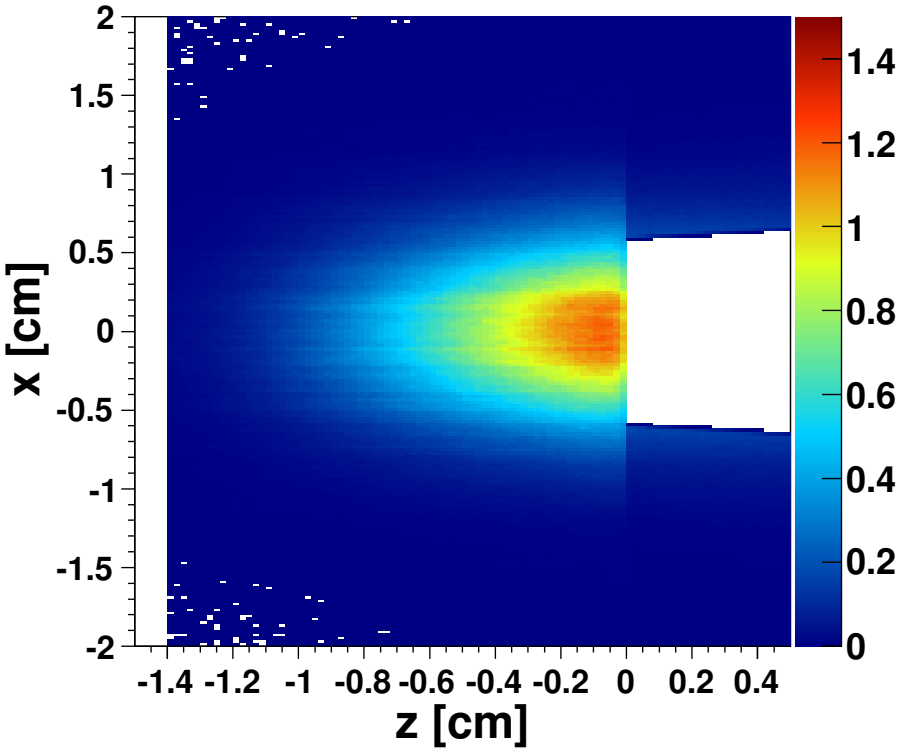
- e^- beam size: $\sigma_x = \sigma_y = 4$ mm
- Pure tungsten target
- 1.4 cm target thickness
- No space between target and FC



Energy Deposition in Target and FC

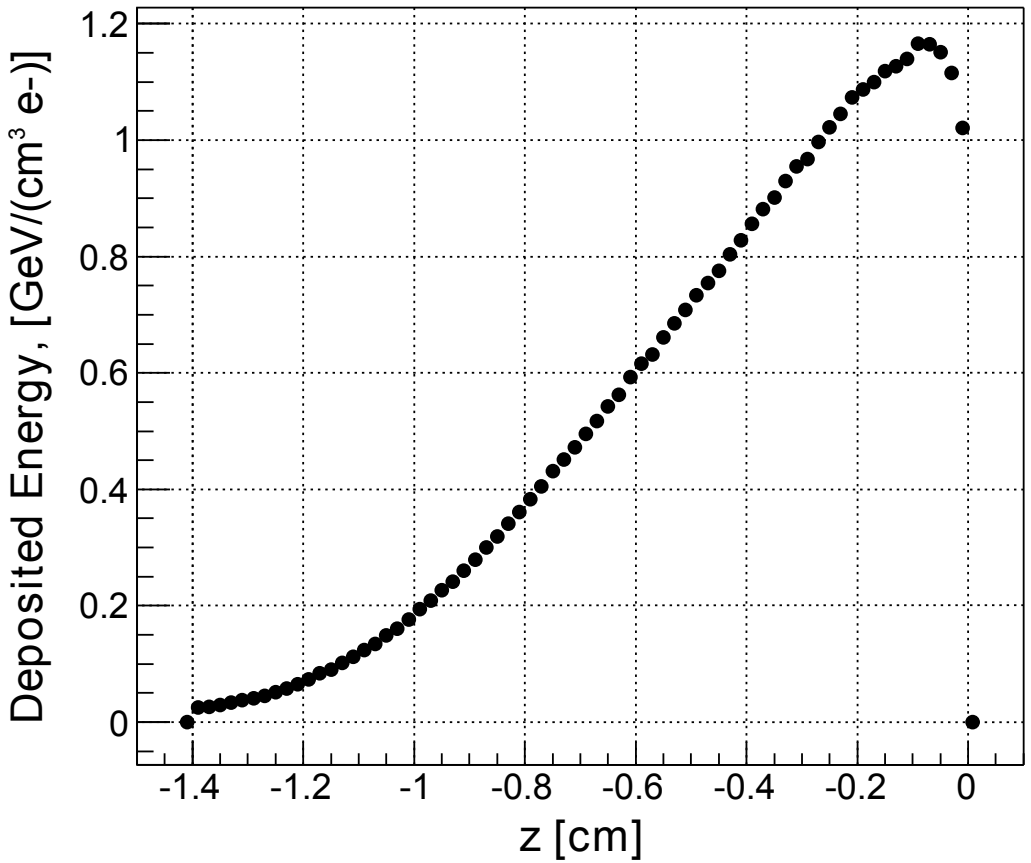
Map of Deposited Energy [GeV/(cm^{-3} e^{-})]
in Target and FC





Peak Energy Deposition in Target

Deposited Energy Density in Target (along Beam Axis)

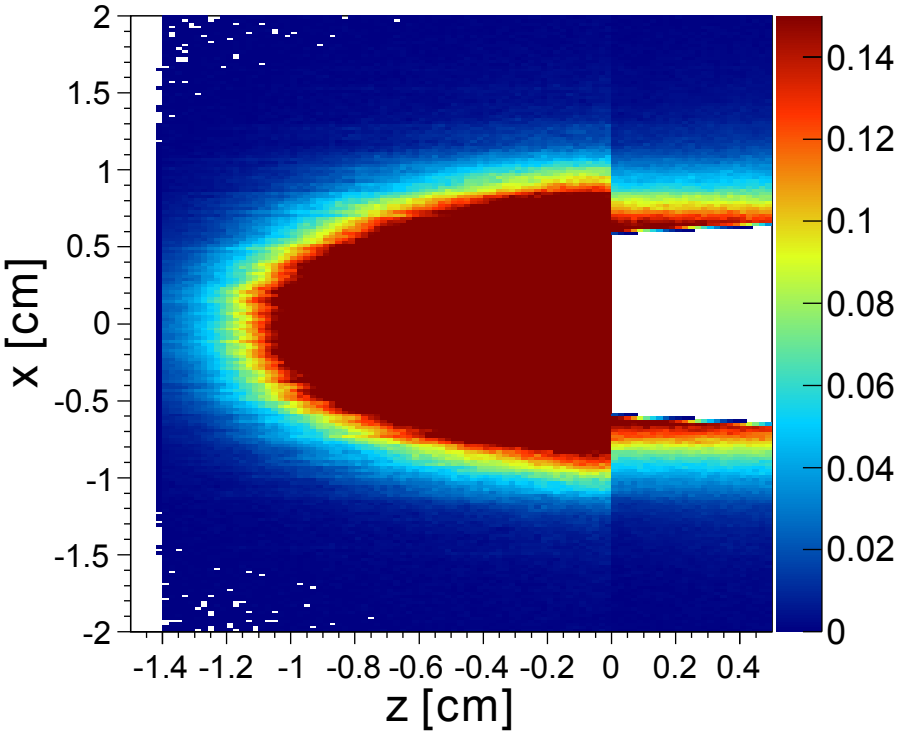


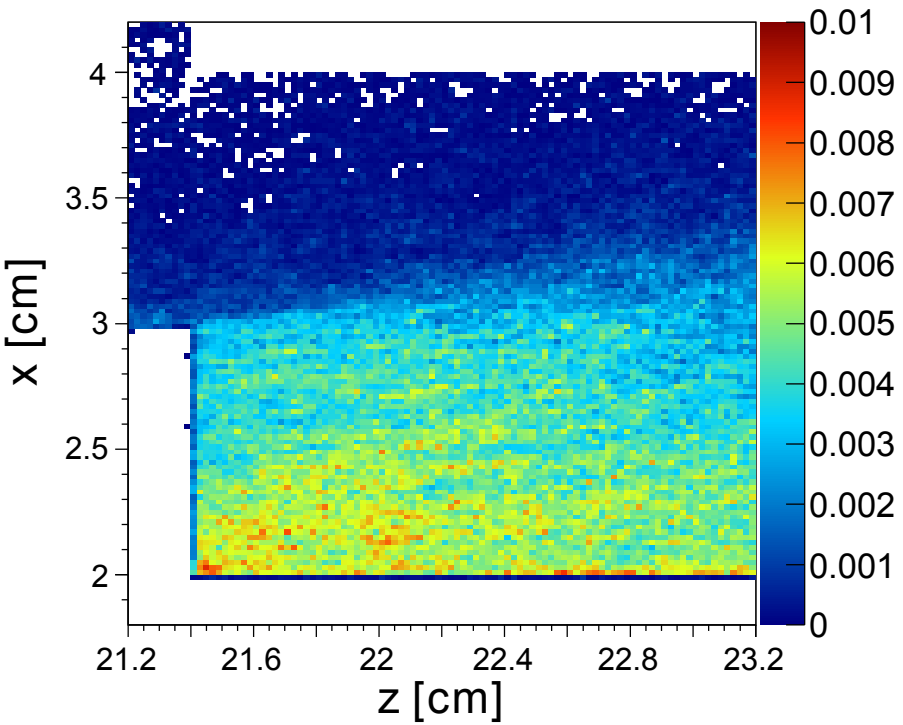
$2 \cdot 10^{10}$ e^-/bunch, 132 bunches/triplet

PEDD: 25.5 J/g per triplet

Energy Deposition in FC and RF Cavity

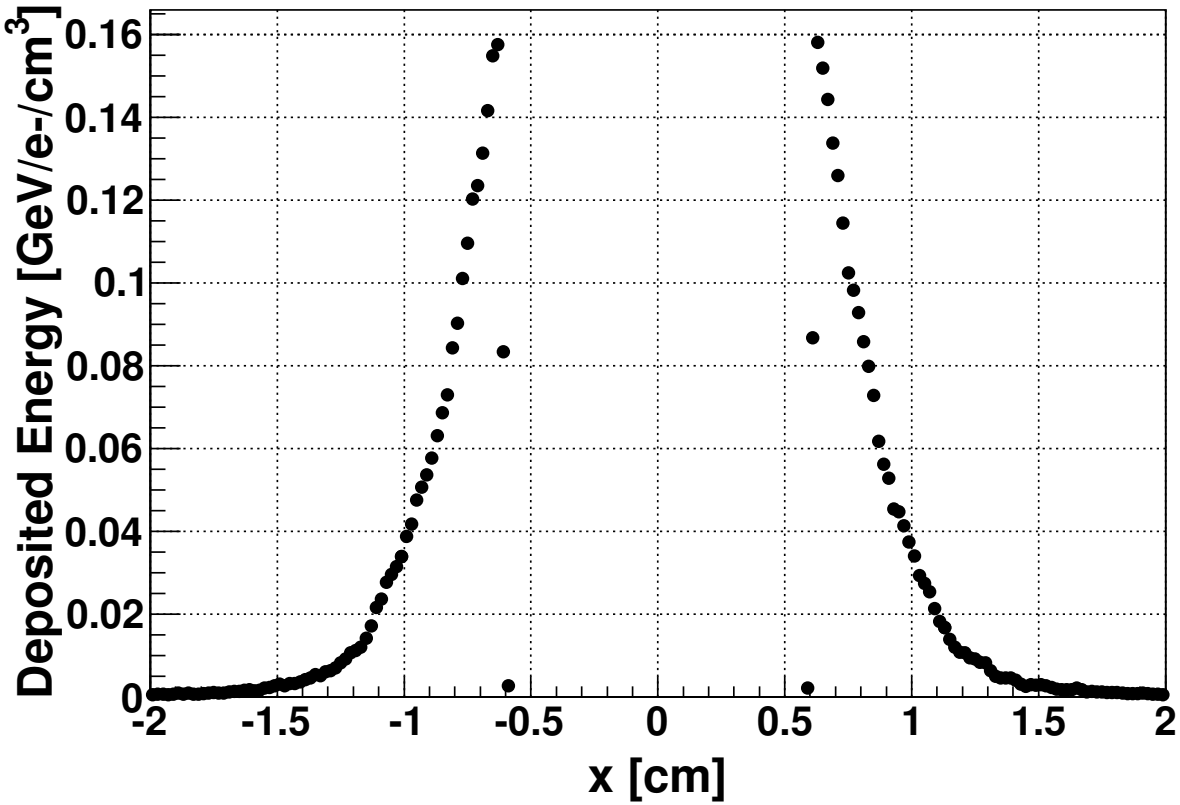
Deposited Energy Density [GeV/(cm^3 e$^-$)] in Transition Regions:
Target-FC (left), FC-RF Cavity (right)





Energy Deposition in FC

Deposited Energy Density in FC vs X (close to target)



PEDD: **7.6 J/g** per triplet (132 bunches). $\Delta T = 19.6$ K

PEDD: **151.2 J/g** per pulse (2640 bunches)

Max. Average Power: **6.75 kW**

Summary and Outlook

- Dependencies of e^+ yield on different source parameters (e.g. aperture size of FC, peak **B** and **E** fields, etc.) have been calculated
- PEDD in target and FC have been estimated

- Extend implementation of B-field in Geant4 model of FC (read field map from external file)
- Add more RF structures (study effect of deceleration on e+ yield)

- Simulate thermal stress and radiation damage of FC. Do we need any protection (absorber in space between target and FC)?

Backup Slides

Results Published in NIM paper

Yield	1.6 e+/e-	
Total E_{dep} in target	823 MeV/e-	35 kW
PEDD in target	1.04 GeV/cm^3/e-	22.7 J/g
Total E_{dep} in AMD	780 MeV/e-	33 kW
PEDD in AMD	? GeV/cm^3/e-	? J/g
Total E_{dep} in RF cavity	470 MeV/e-	20 kW
PEDD in RF cavity	? GeV/cm^3/e-	? J/g