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Gamma-to-Electron Magnetic Spectrometer (GEMS) Update

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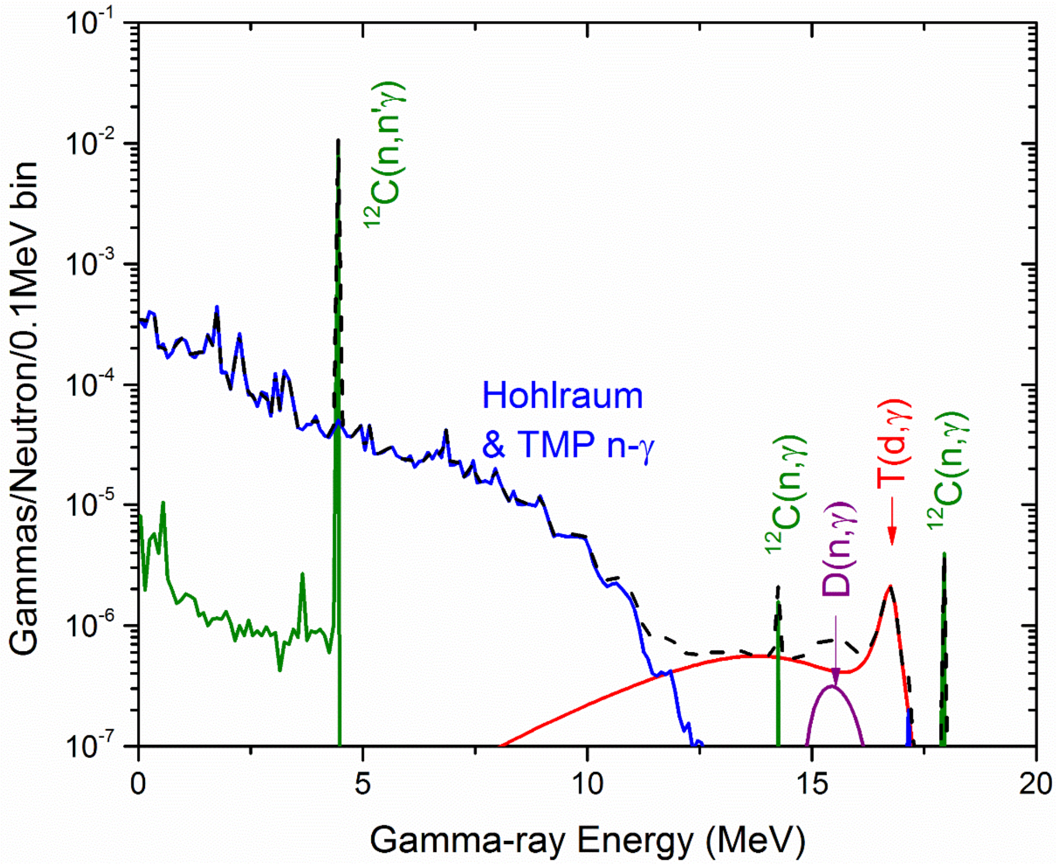
Outline

- Motivation for GEMS
- Review of Conceptual Design of GEMS
- Detector Simulation Benchmarking (in progress)

The ICF γ-ray Energy Spectrum provides 'burn-averaged' observables, providing a global reference for the line-of-sight-specific measurements



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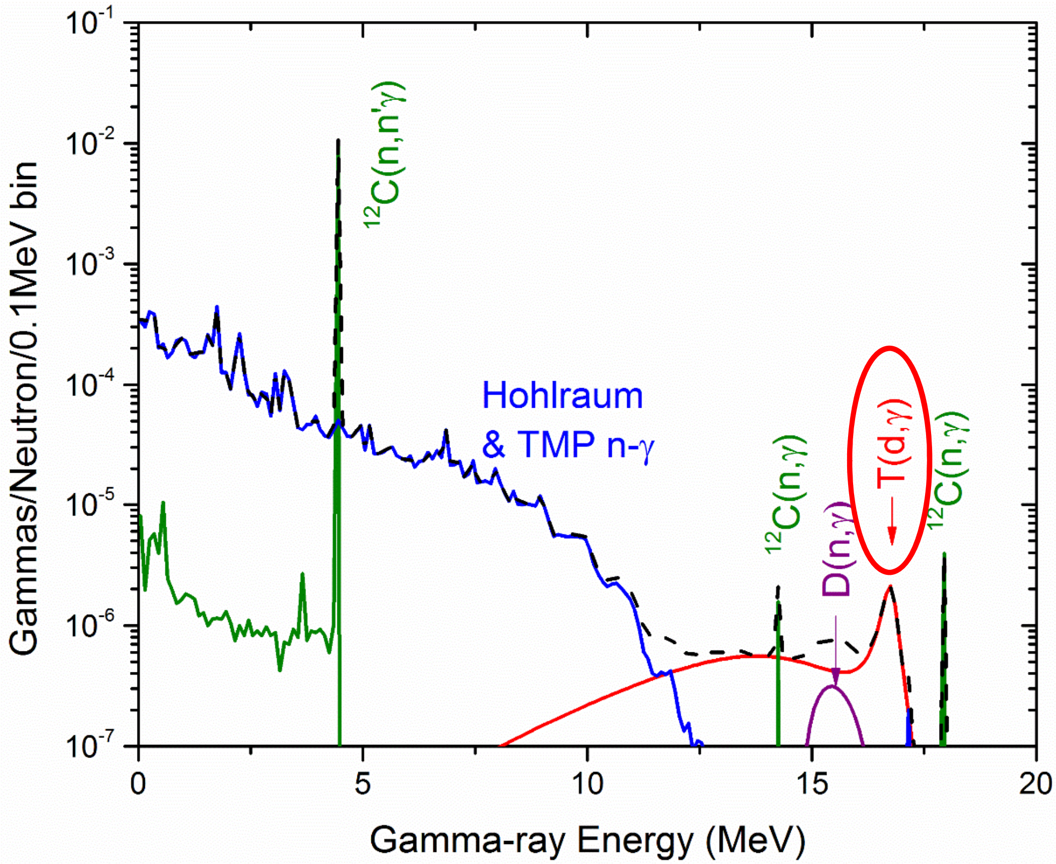

Burn-averaged observables

- **Total Y_{DT}**
  - $Y_{DT} = B_{\gamma/n}\ Y_{DT\gamma}$
- **Total Down Scattering Fraction (TDSF)**
  - $TDSF = 1 - (Y_{n(13\text{-}15)}/Y_{DT\text{-}\gamma})$
- Existing yield measurements compromised by:
  - Yn: neutron downscattering
  - GRH: interfered by D(n,γ) and $^{12}C(n,\gamma)$
- $DT\gamma_0$-rays could provide Total DT yield
  - Negligible DT-γ down-scattering (unlike DT-n)
  - in-situ calibrations using DT Expl Pshr (ρR ≈ 0)

GEMS total DSF will provide additional ρR data independent of line of sight

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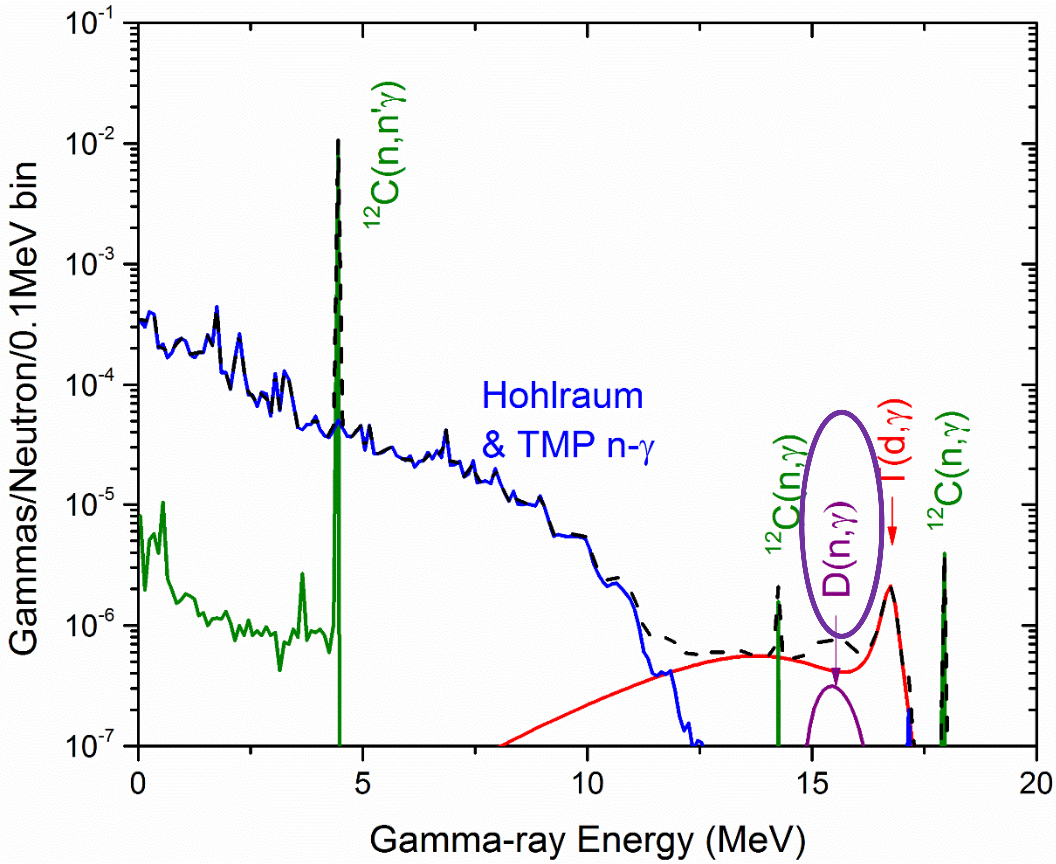

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- **Cold fuel ρR**
  - D(n,γ)

$$\frac{Y_{D(n,\gamma)}}{Y_{D(t,n)}} = \sigma_{D(n,\gamma)} \cdot \frac{N_a}{(MW_D + MW_T)} \cdot <\rho R>_{DT}$$

$$\sim 1.44 \times 10^{-6} \quad [\gamma / n / (g / cm^2)]$$

Direct measurement of Fuel ρR

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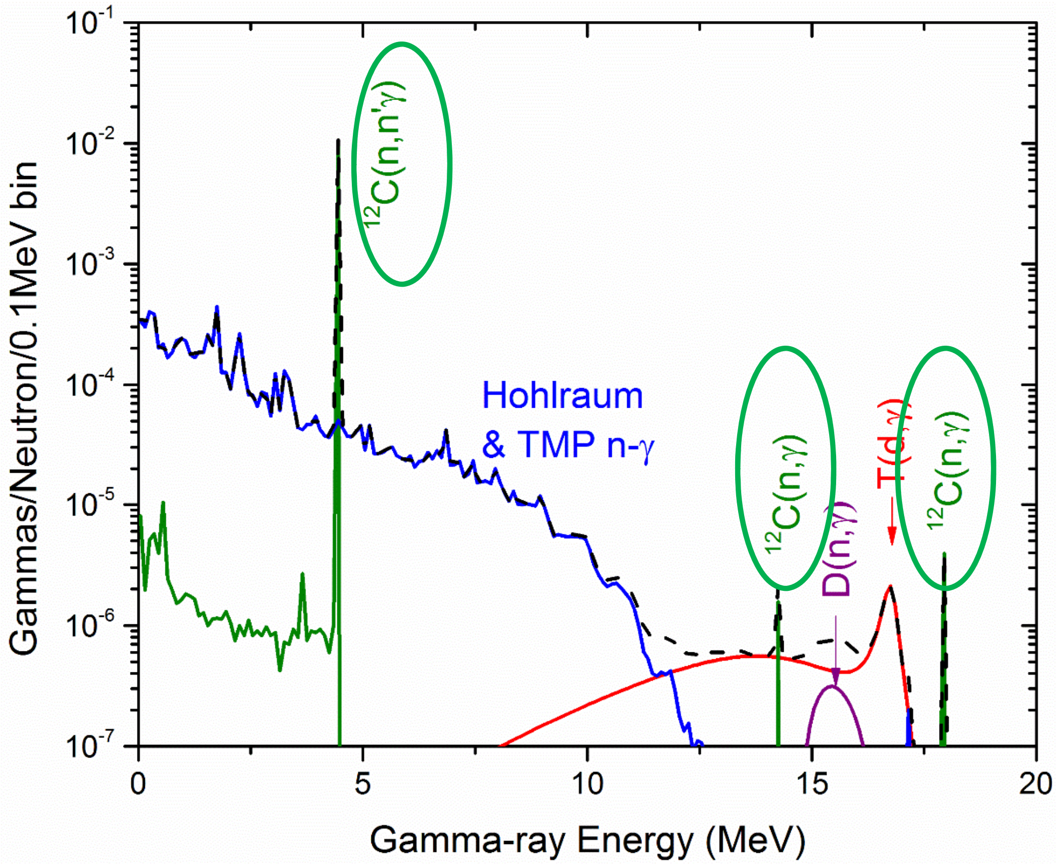

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- **Total Down Scattering Fraction (TDSF)**
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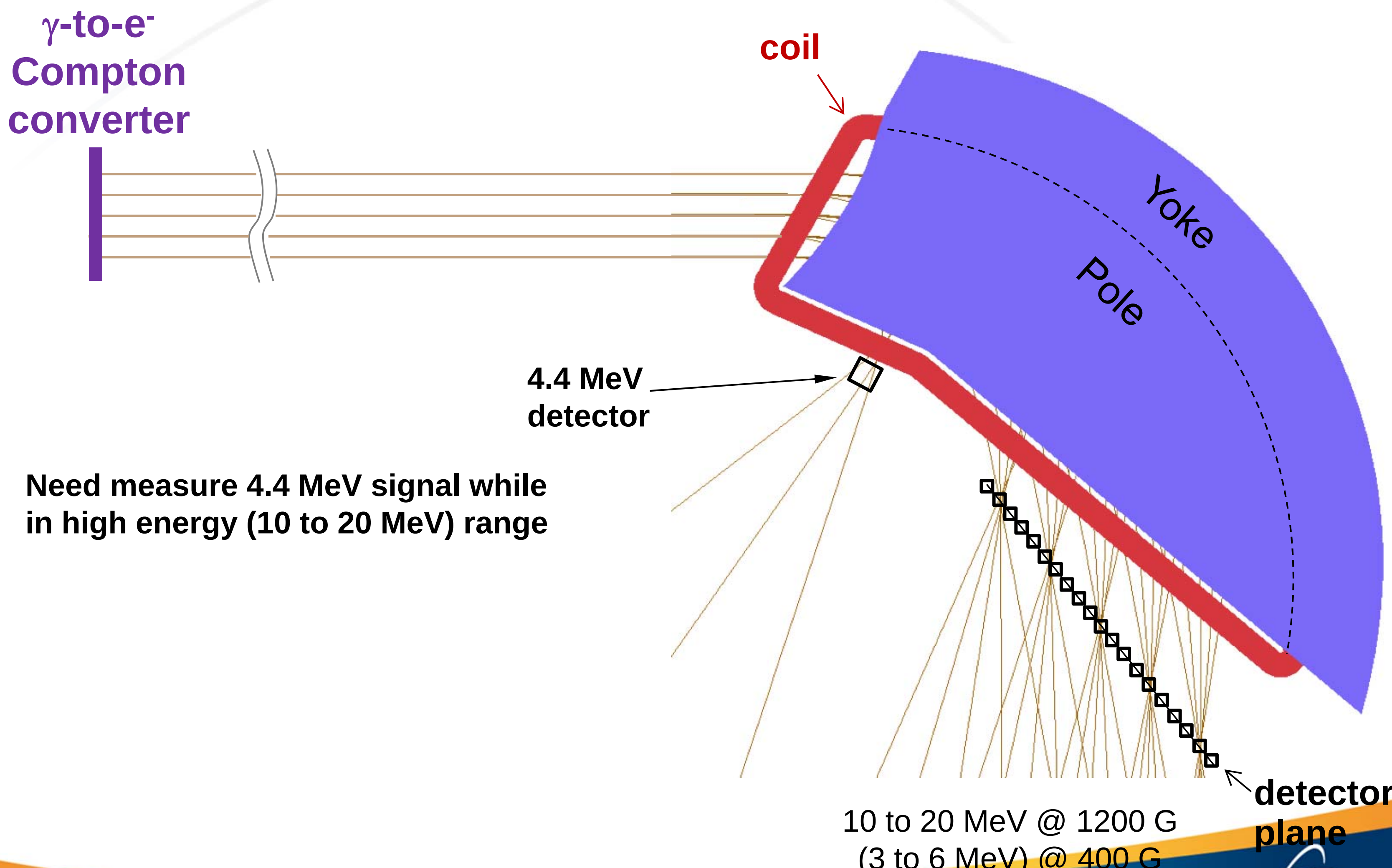
- **Cold fuel ρR**
  - D(n,γ)
- **Ablator ρR**
  - 12C(n,n'γ)
  - 12C(n,γ)

GEMS can improve Ablator ρR accuracy (GRH ~ 20 %) even at today's NIF yield

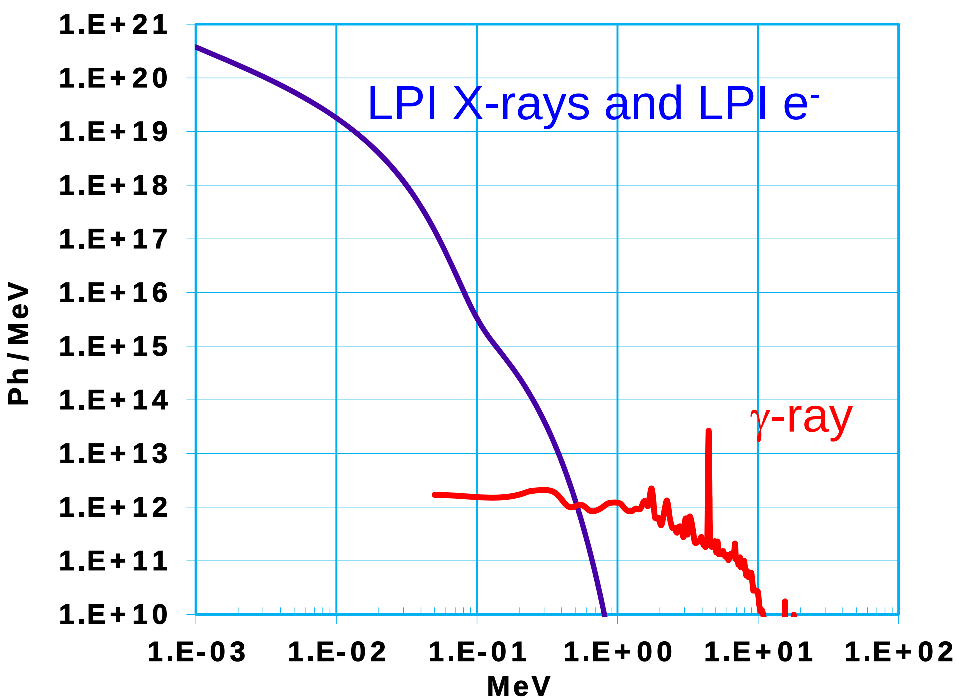
Gamma-to-Electron Magnetic Spectrometer (GEMS) concept has been proposed to measure the ICF γ spectrum



Slide 7

GEMS Design Challenges at NIF

~10^5x more LPI X-ray than the DT fusion gamma-ray (looking at stars on sunny day!)



- To minimize NIF background radiation
  - X-ray filter + Background e-filter
  - Locating magnet & detector array outside NIF chamber
  - Fast electron detector (< 1.5ns)
  - Quartz Cherenkov radiator (> 175 keV)
- To improve sensitivity
  - Large gap electromagnet
  - *Locating Compton converter inside NIF chamber*

GEMS detection efficiency (η) was also calculated by Monte-Carlo simulations with constant magnet efficiency assumed

$$\eta \approx \Omega_\gamma \times \int_{\Omega_e} \frac{d\sigma}{d\Omega} d\Omega \times \eta_{\mathrm{magnet}}$$

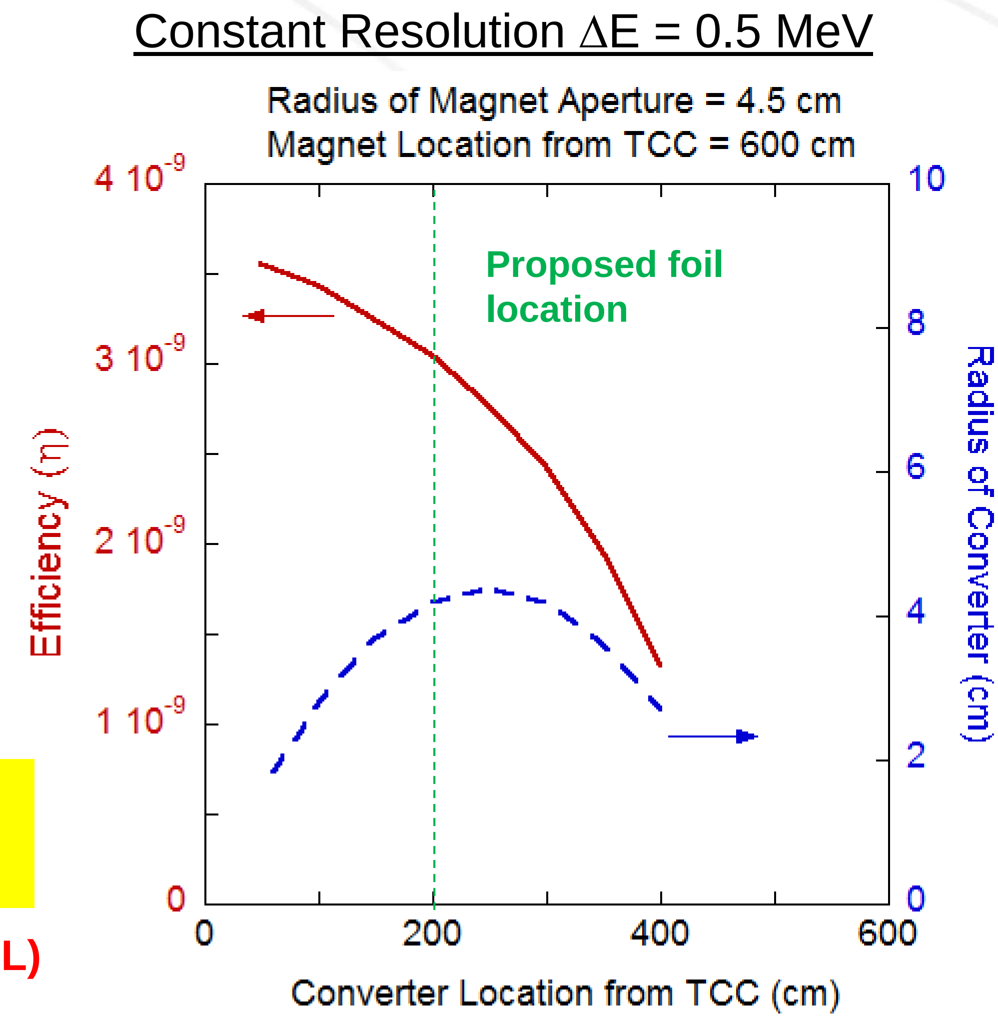
Magnet focusing

Compton conversion

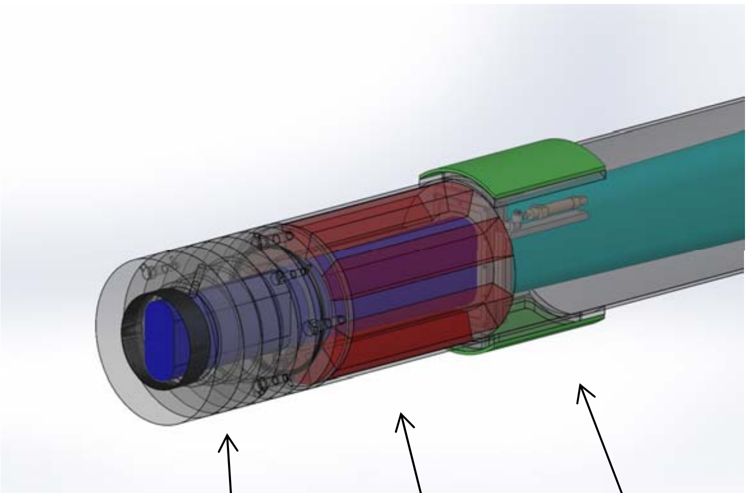
Kinematic (converter & magnet aperture size and location)

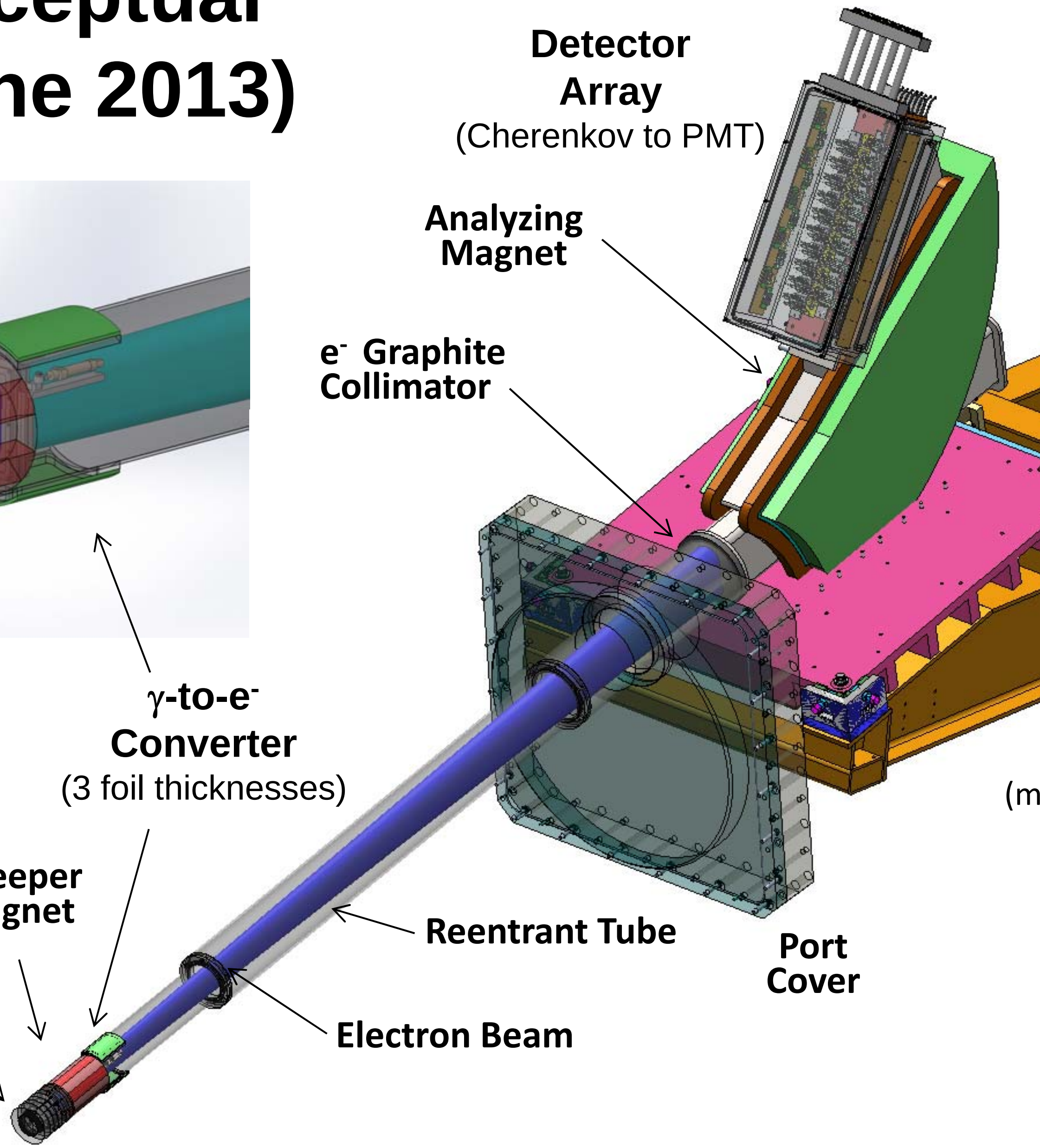
Sensitivity constrained by ΔE/E and foil distance from TCC

Geant4 (GA), CYLTRAN (LANL)



GEMS Conceptual Design (June 2013)





Physics-based Performance Goals (June 2013)

Topic	Requirement	
Energy Resolution	$\Delta E/E$ = 3-5% (e.g., 0.5 MeV @ 16.7 MeV, 0.2 MeV @ 4 MeV)	
Energy Range	Total: 2-25 MeV Single Shot: $E_0 \pm 33\%$ (e.g., 10-20, 3-6 MeV) Separate 4.4 MeV channel when operating in 10-20 MeV mode	
Binning	$\geq$ 20 energy bins (+1 for 4.4 MeV when tuned to 10-20 MeV)	
Temporal Response (fwhm)	< 1.5 ns (discriminate against LPI x-rays ~2 ns early and Chamber wall n-γ 100 ns later)	
SNR	> 5 for 100 γ	
Dynamic range	> 100	
Accuracy	Statistical <11%; Systematic < 10%; Total <15%	
Sensitivity	**CH ablator ρR**	Y>5e14 for ρR_{CH} >200 mg/cm^2
	Total DT yield	Y>2e15 for γ_0
	Fuel ρR	Y>1e16 for ρR_{fuel} >1 g/cm^2

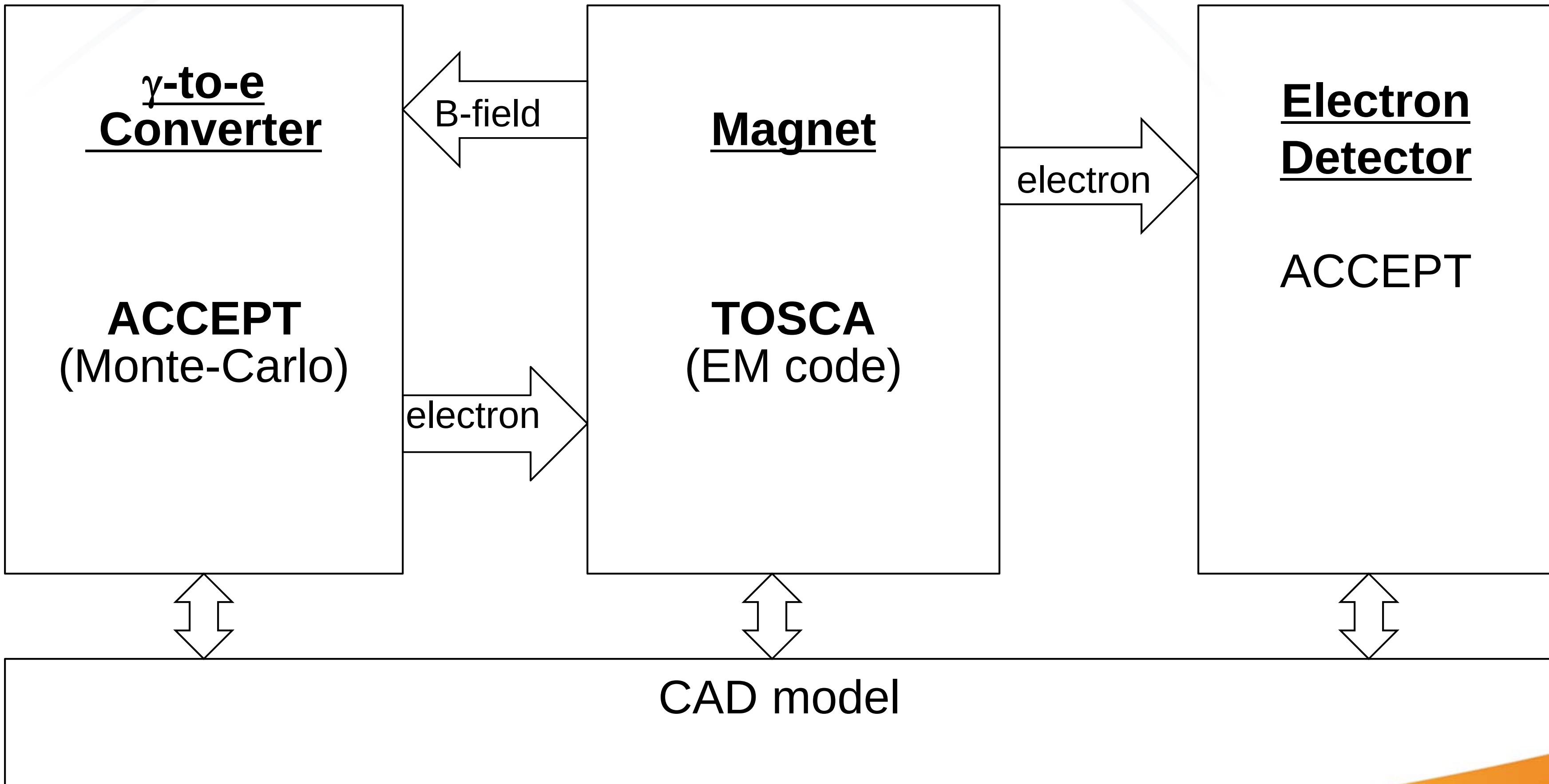
Outline

- Motivation of GEMS
- Review of Conceptual Design of GEMS
- Detector Simulation Benchmarking (in progress)

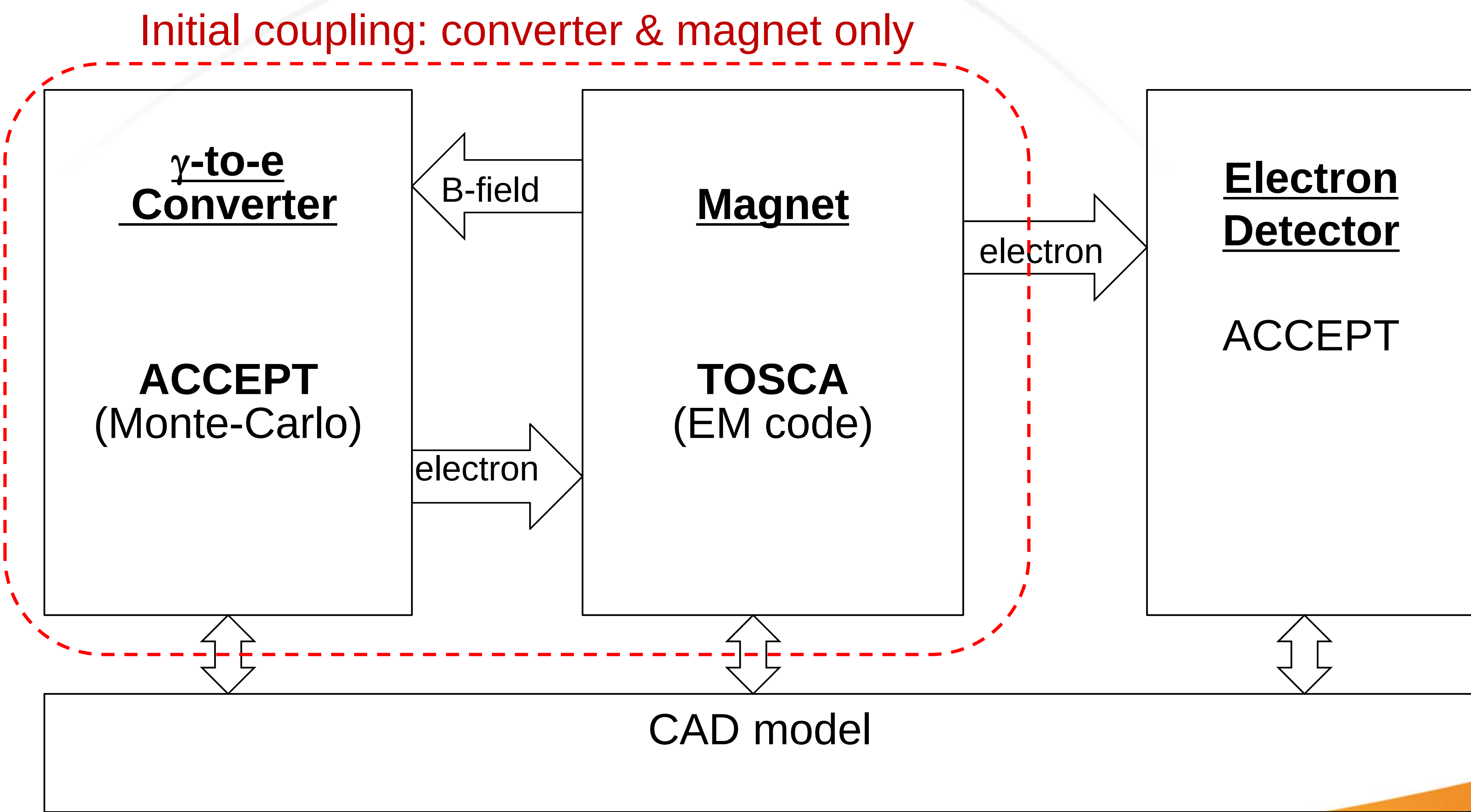
Current Layout of GEMS Design Codes

γ-to-e Converter	Magnet	Electron Detector
ACCEPT (Monte-Carlo)	**TOSCA** (EM code)	ACCEPT

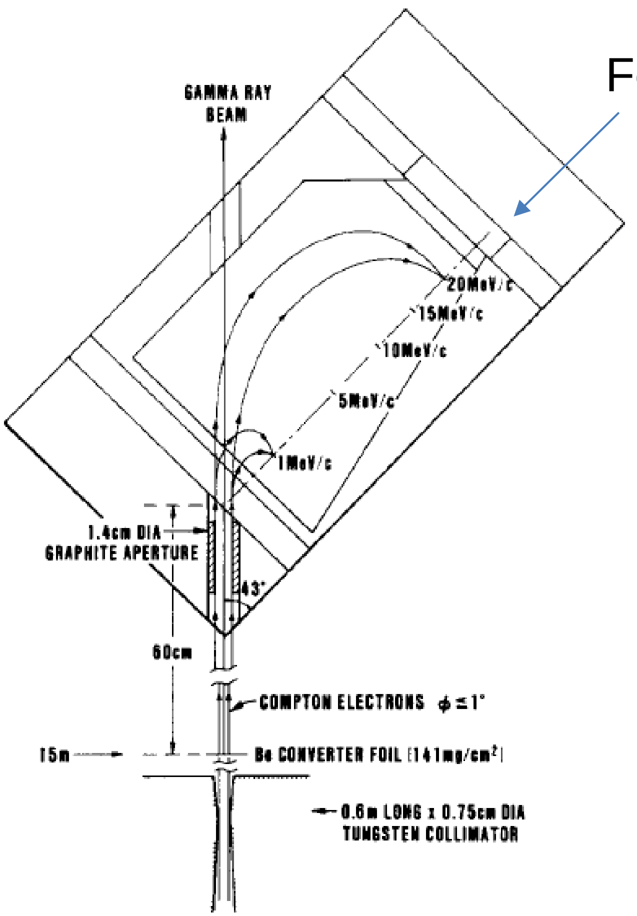
Final Goal of Layout of GEMS Design Codes

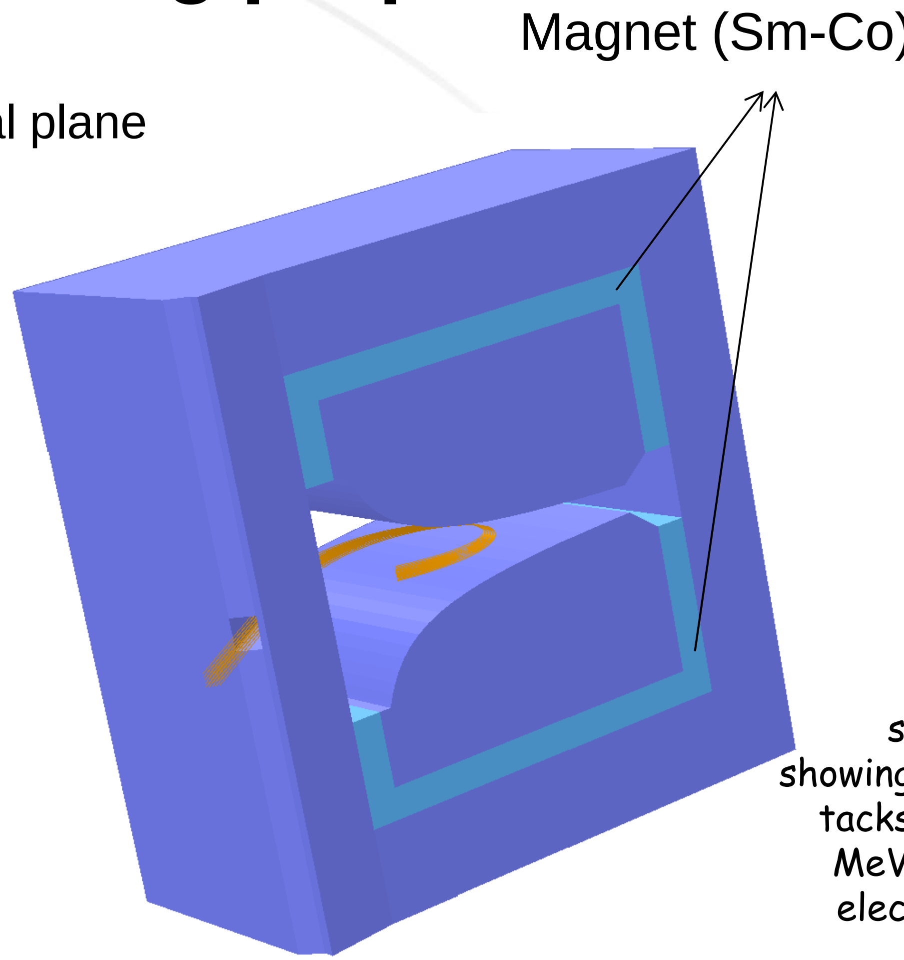


Initial Coupling in Progress



LANL's Pretzel Spectrometer data can be used for benchmarking purpose



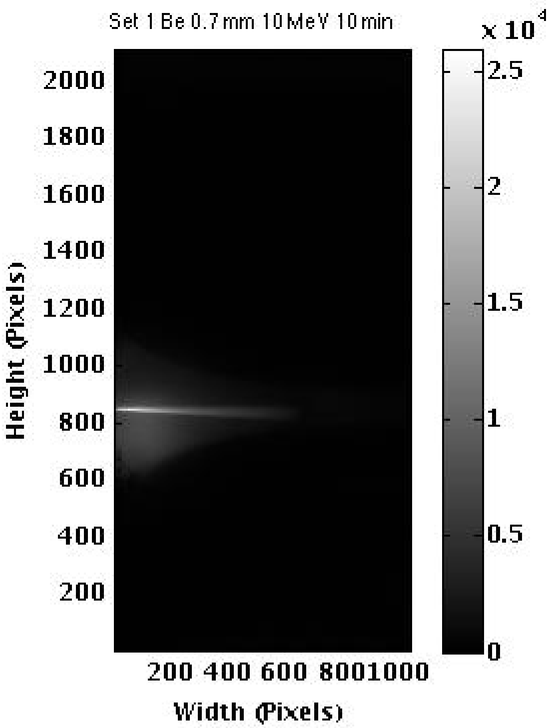


TOSCA simulation showing a set of tacks for a 10 MeV beam of electrons (D. Barlow)

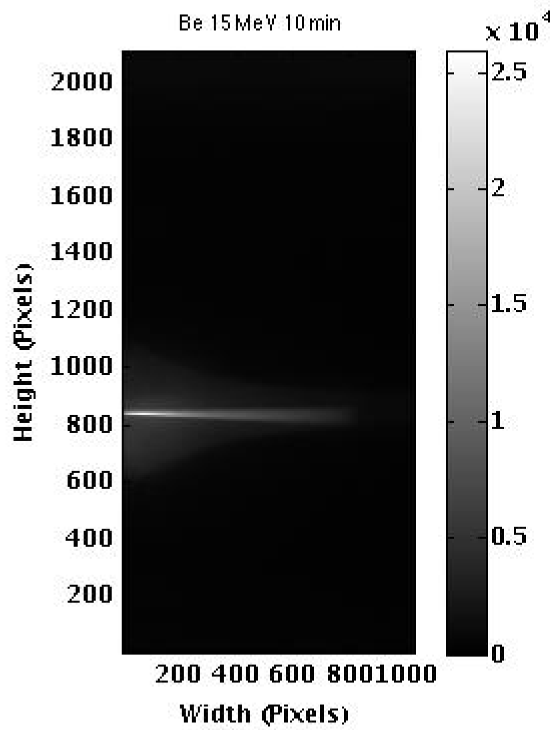
G. Morgan (LANL, 1991) → A. Gehring and M. Espy (LANL, 2015)

Storage phosphor images (A. Gehring and M. Espy)

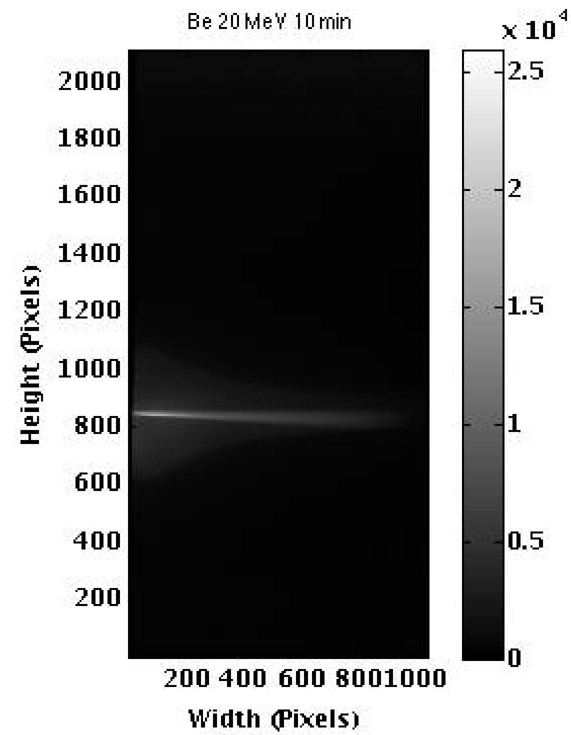
10 MeV e$^-$



15 MeV e$^-$

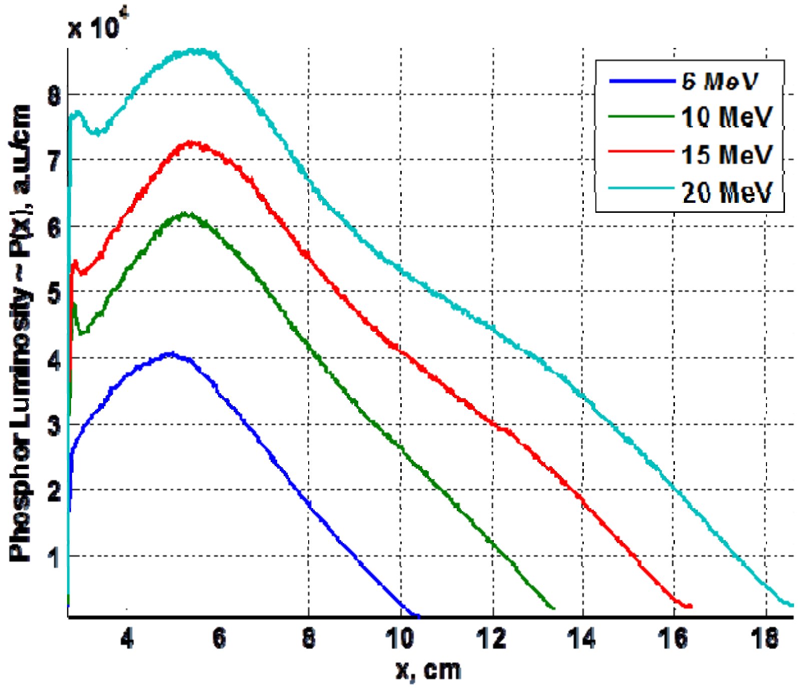


20 MeV e$^-$

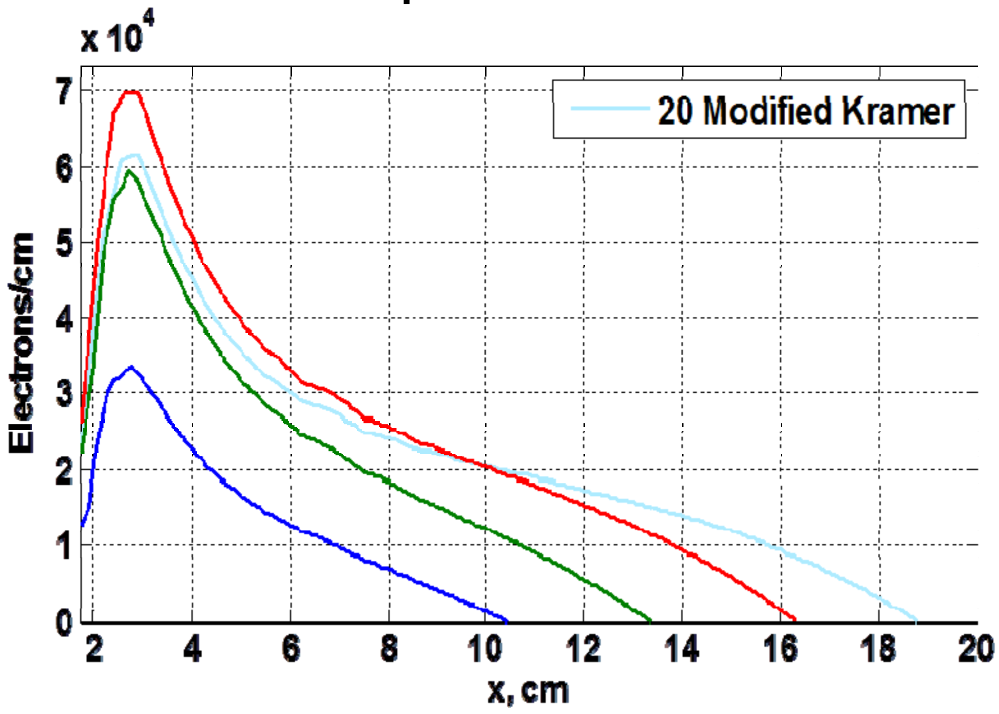


Reconstructed spectra (A. Gehring and M. Espy)

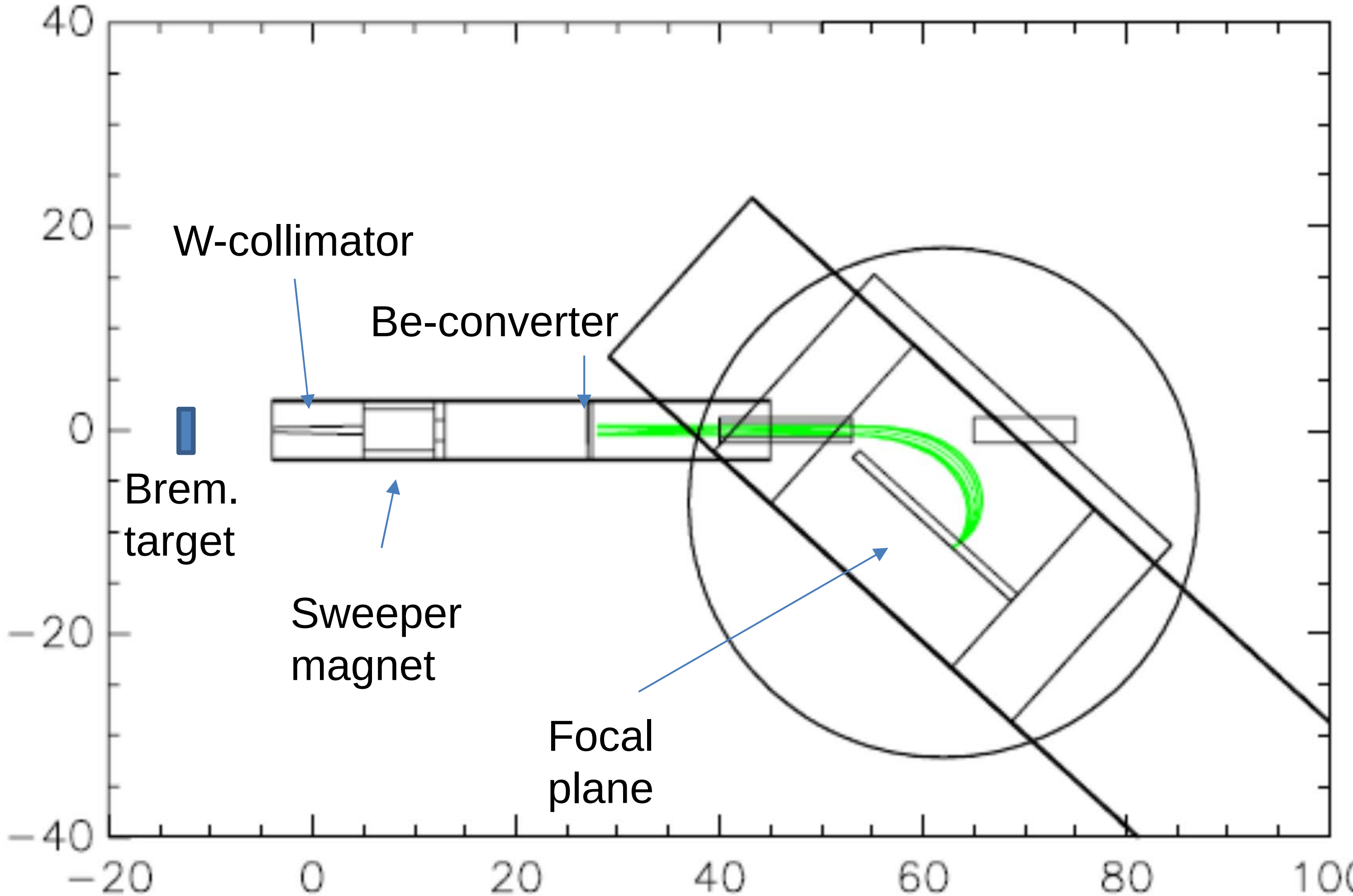
Raw Data



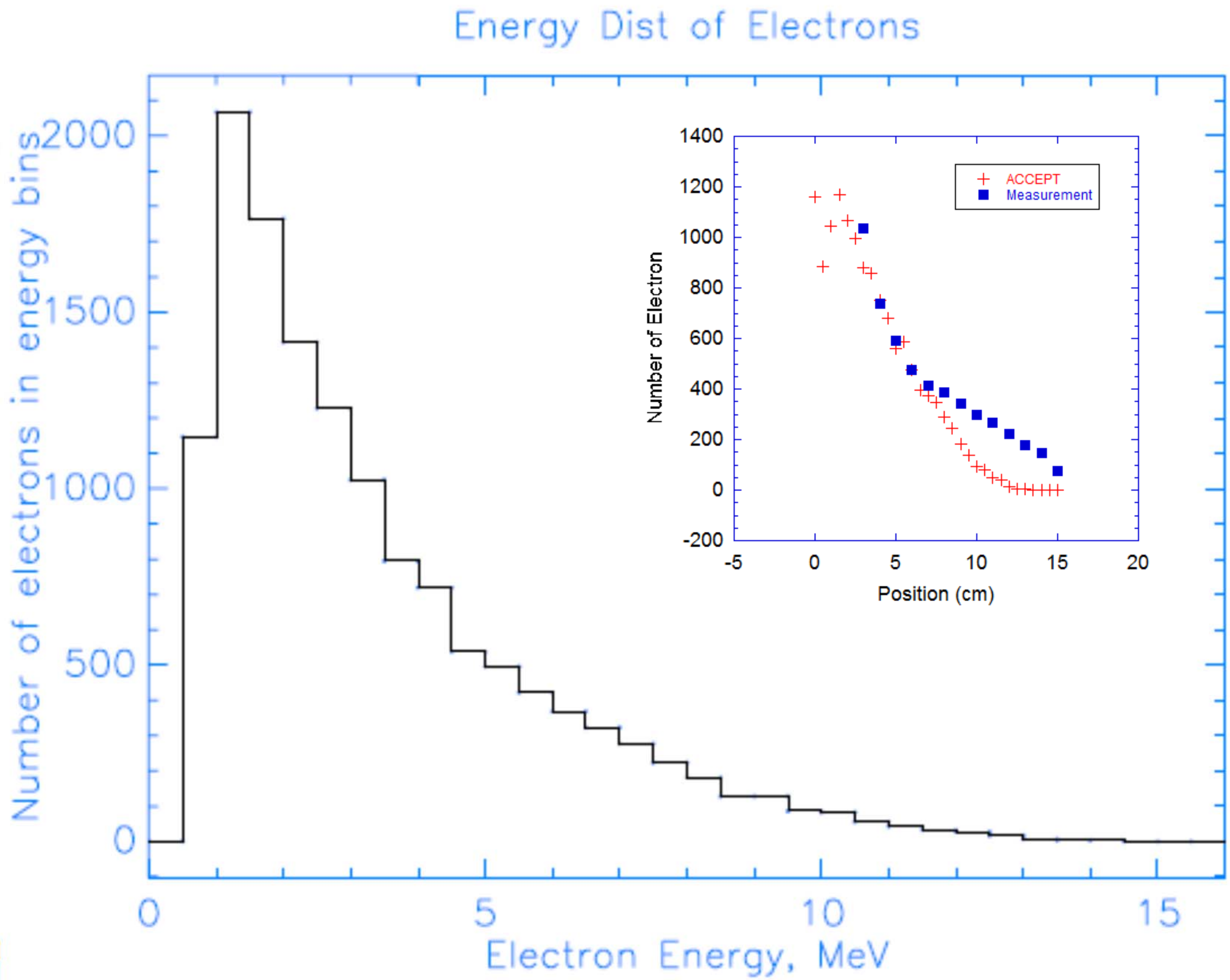
Post-processed Data



ACCEPT simulation incorporating B-field tested with 15 MeV electron energy (C. Young)



Electron profile at focal plane from 15 MeV endpoint energy x-ray source striking converter (C. Young)



Summary

- **GEMS can support high ρR implosions by providing unique observables:**
- burn-averaged observables, providing a global reference for the line-of-sight-specific measurements
- Individual, direct measurement of Fuel ρR, Ablator ρR, and Total ρR

- **GEMS conceptual design was completed (June 2013)**

- **Monte-Carlo simulation incorporated with B-field is in progress**