Medical Electron LINACS for Accelerator-Driven Sub-critical Systems

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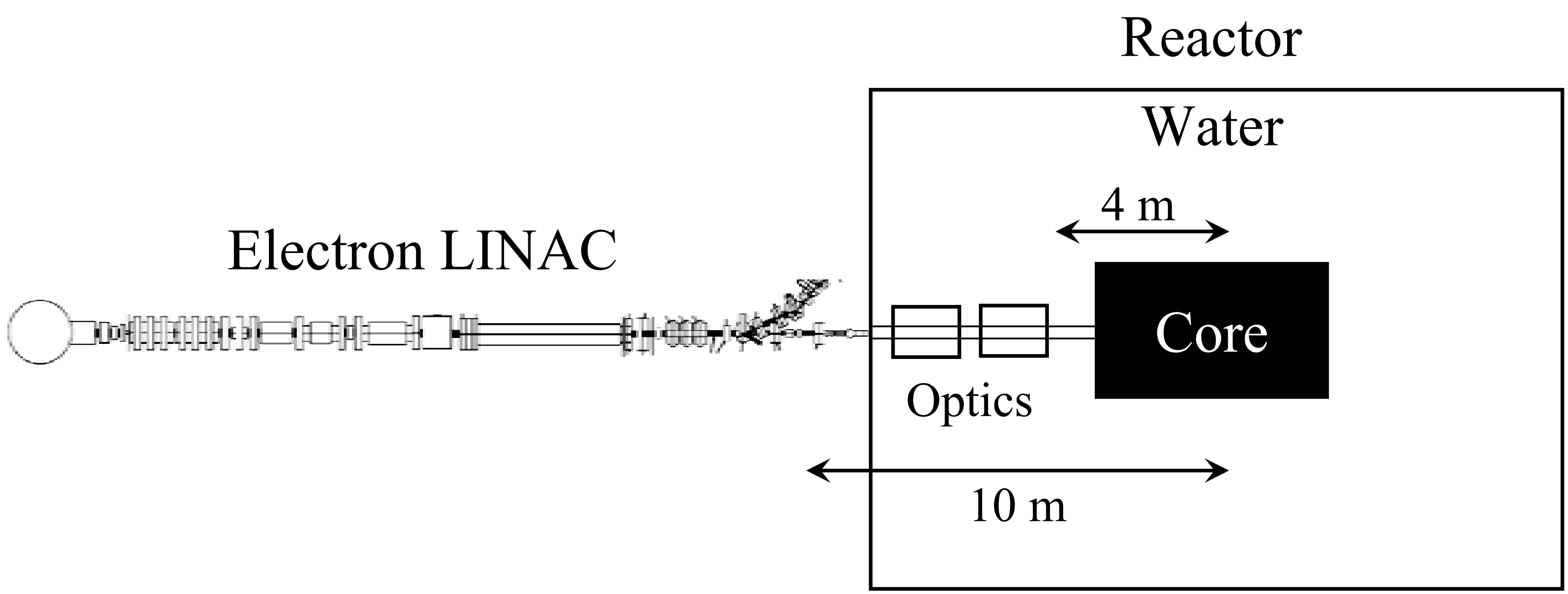
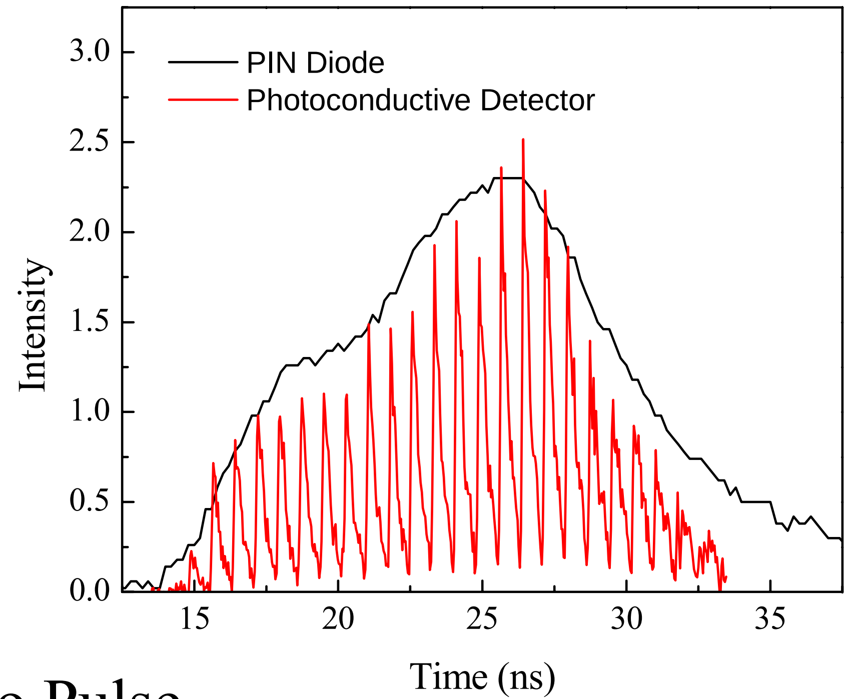
Two Systems in any ADSS (Accelerator and Reactor System)



- Coupling is the Issue
  - ~10 m from Accelerator Exit to Core Center and Target
  - ~4 m Drift Required with No e^- Optics
  - Be Nice if No Optics are "Under" Water
- What is the best Target (Nexus of Nuclear Physics and Engineering)

Two Components to Beam Time Structure

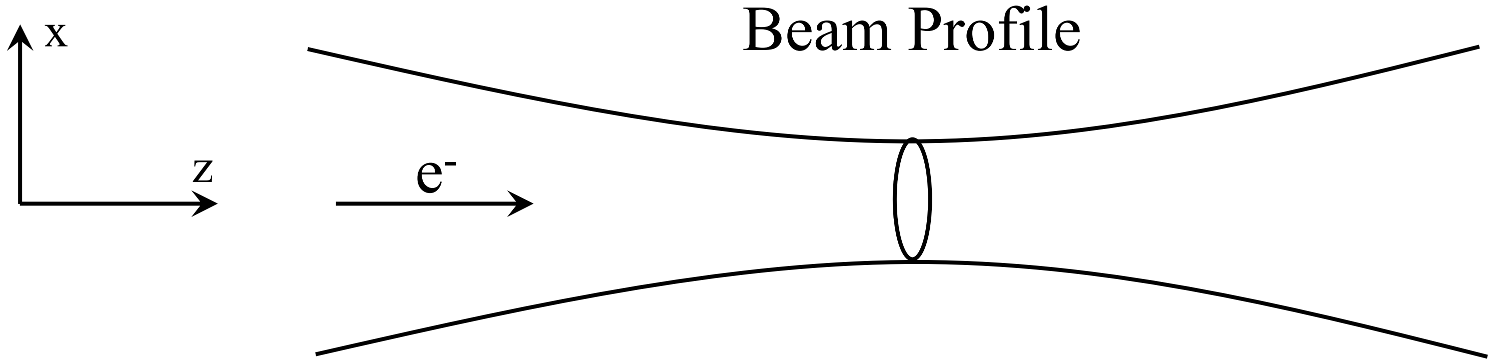
e^- Beam Time Structure from L-Band Accelerator



- RF: 1.3 GHz
- ~20 ns Macro Pulse
- ~769 ps Microstructure

- Macro Pulse
  - Determined by RF Filling of Cavity and e^- Gun
  - ~3 μs for Typical S-Band Machine (can be longer or shorter)
- Microstructure
  - Determined by RF Frequency
  - ~357 ps for S-Band (~2.8 GHz)
- Repetition Rate 1 Shot to ~200 Hz (Maybe Higher)

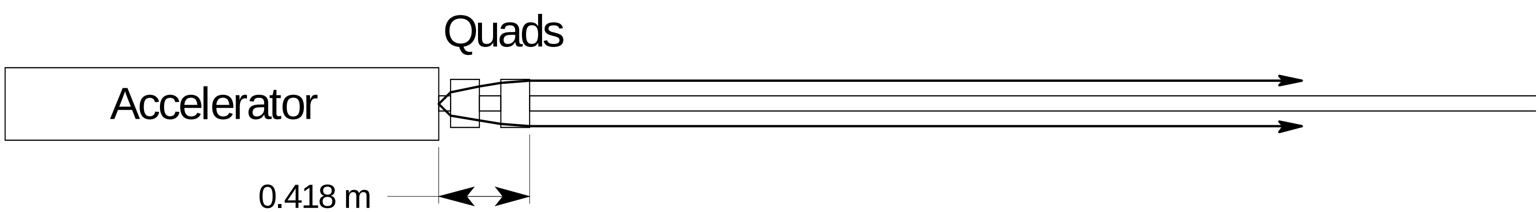
Determining Transport Properties Requires Beam Divergence and Size



- At Waist Emittance is (Beam Radius) × Divergence
- Beam Radius is Easy to Measure (~0.5 mm)
- Divergence (Need to Measure)
  - Unknown!!! Depends on Accelerator and Gun
  - Varian (manufactures Wave Guides) is Mum
  - Worst Case Estimate 5 mrad
  - Best Case Estimate 1 mrad
- Emittance from 0.5 mrad×mm to 2.5 mrad×mm
- Energy Spread ~10% (~2 MeV)

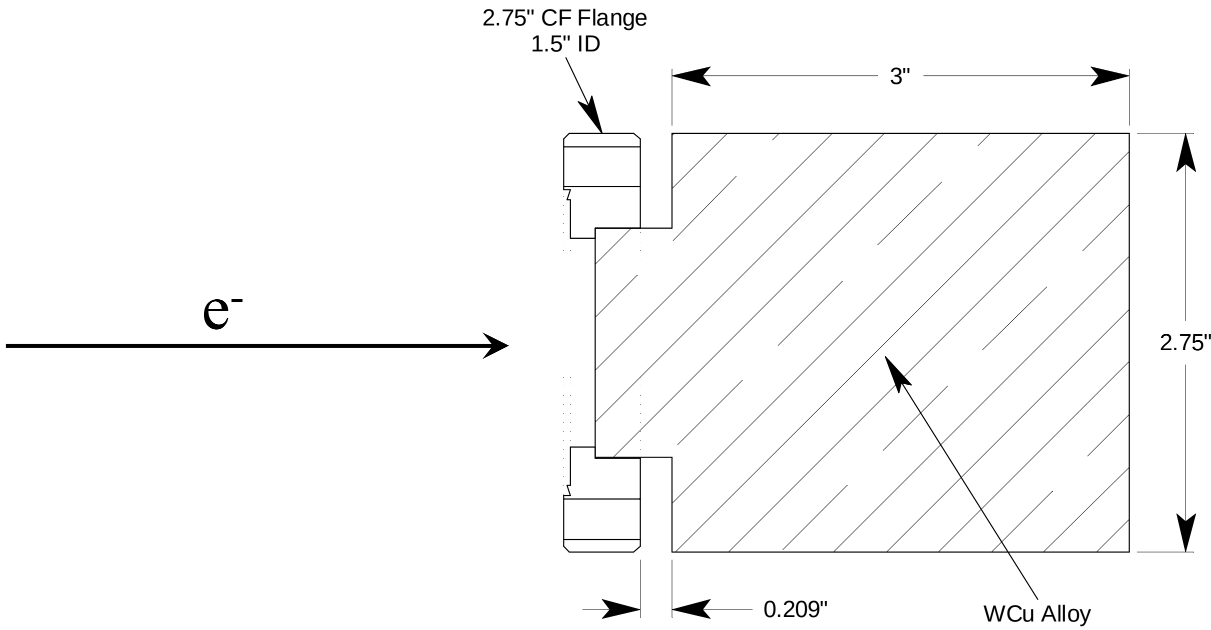
Worst Case Divergence is Okay

Point to Parallel Beam Transport



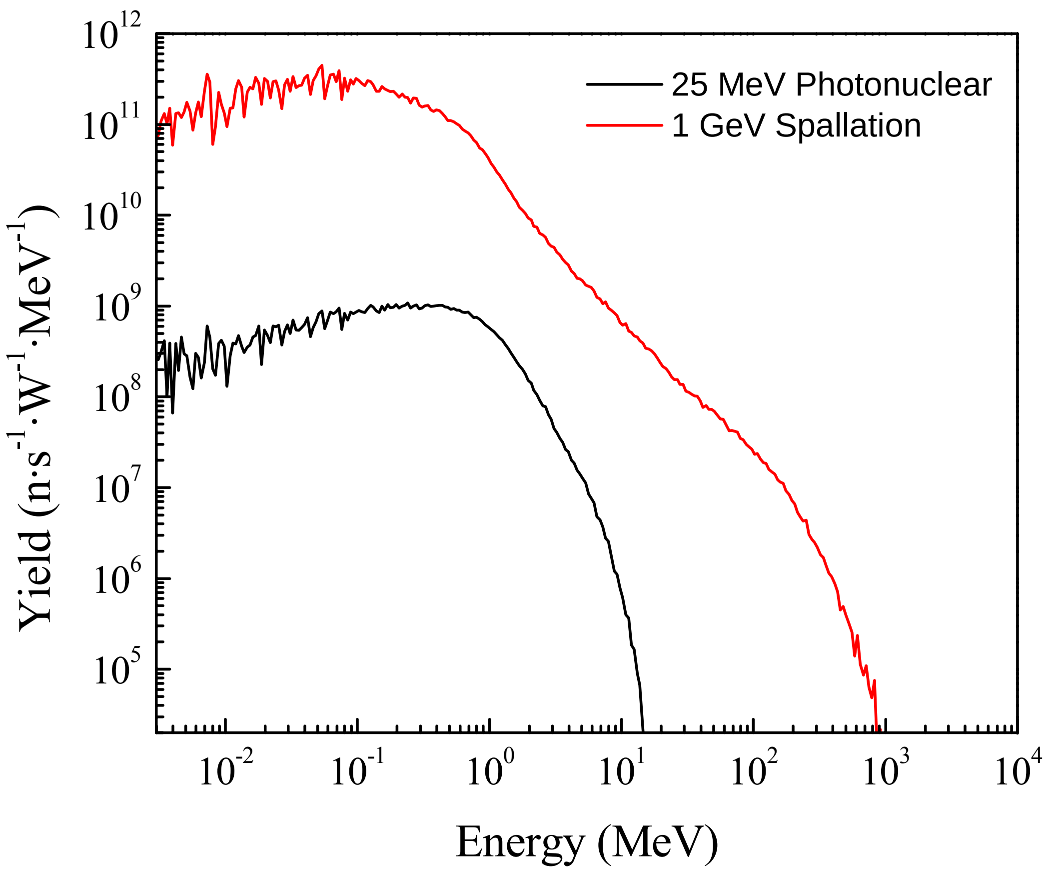
- Start with an Initial Divergent Beam
  - ~5 mrad; 7 mm Diameter; Energy Spread 2.5 MeV
  - Immediately Inject into Quads (Idea from Ion Source)
  - Quads "Focus" to Parallel Beam
  - 10 m from Accelerator ~1 cm Beam Spot
  - 10% of Beam Lost: @ 1kW→100 W; @ 20 kW→2 kW
- Calculated Using COSY INFINITY
- No Optics "Under" Water
- No Bends (This may not be practical)

Electrons Impact High-Z Target to Produce Neutrons



- e^- Bremsstrahlung → Photonuclear Reaction (γ,n); (γ,2n) etc…
- Neutron Yield 1.3×10^{9} $n\cdot s^{-1}\cdot W^{-1}$; @ 25 MeV
  - 1.3×10^{12} $n\cdot s^{-1}$ @ 1 kW
  - 2.6×10^{13} $n\cdot s^{-1}$ @ 20 kW
- May Do Better with Better Target Design
- Heat Dissipation an Issue at 20 kW

Neutron Spectrum Similar to Spallation



•25 MeV e^- on W

•1 GeV Protons on W

- Yields
  - Photonuclear 1.3×10^9 $n\cdot s^{-1}\cdot W^{-1}$
  - Spallation 1.84×10^{11} $n\cdot s^{-1}\cdot W^{-1}$
  - Spallation Still Wins

Conclusions

- Two Time Components to e^- Beam Time Structure
  - Macro Pulse ~3 μs
  - Microstructure ~357 ps (Presumably Does Not Matter)
  - Repetition Rate: Single Shot to ~200 Hz (Higher is Possible)
- Worst Case Beam Transport is Achievable
  - Point to Parallel System Suggested
  - 1 cm Beam Spot on Target
  - ~10% Beam Lost
  - No Optics "Under" Water
- Neutron Yields with Simple Target
  - 1.3×10^{12} $n\cdot s^{-1}$ @ 1 kW
  - 2.6×10^{13} $n\cdot s^{-1}$ @ 20 kW