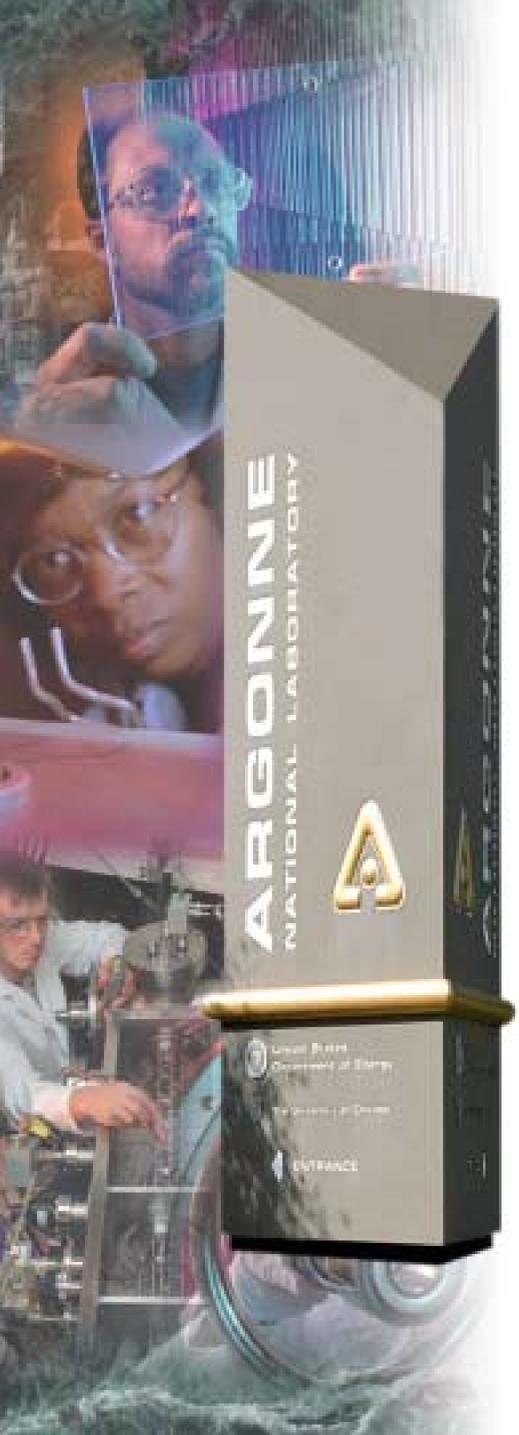

2004 AAC Workshop

The Argonne Wakefield Accelerator Facility: Capabilities and Experiments

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Argonne National Laboratory

Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

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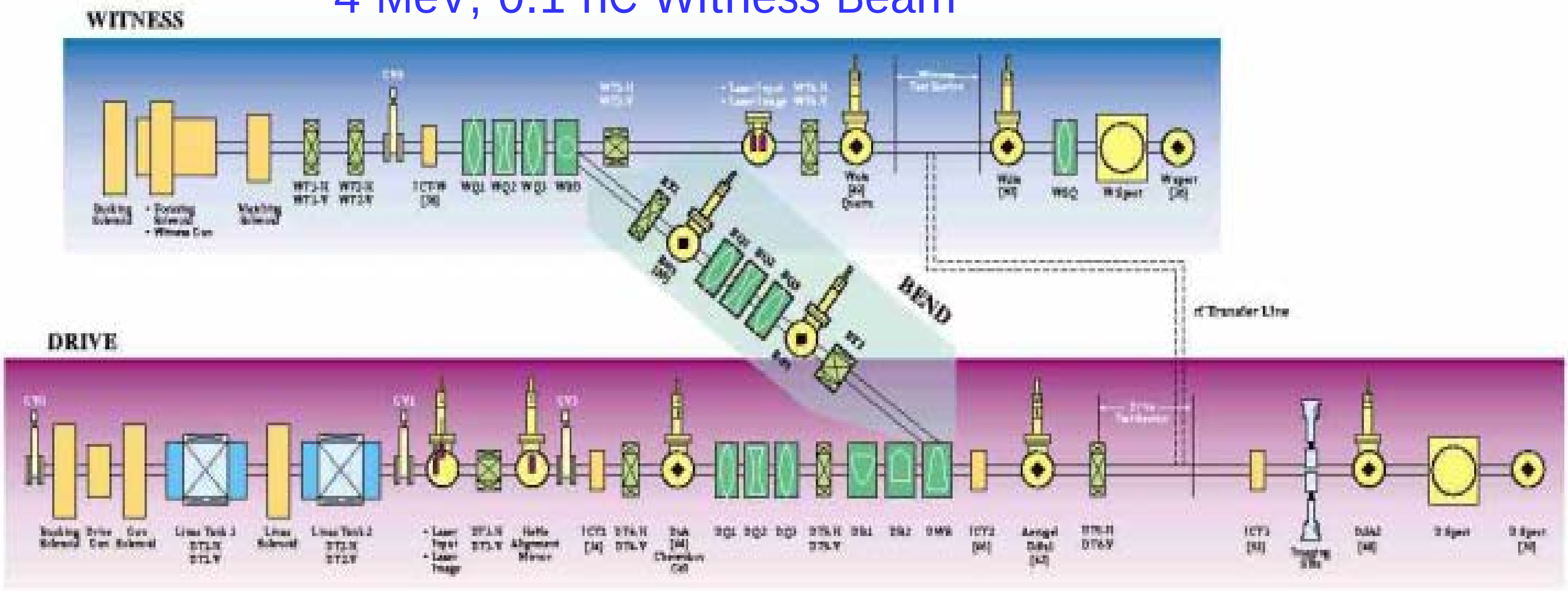
Argonne Wakefield Accelerator Beamlines

4 MeV, 0.1 nC Witness Beam

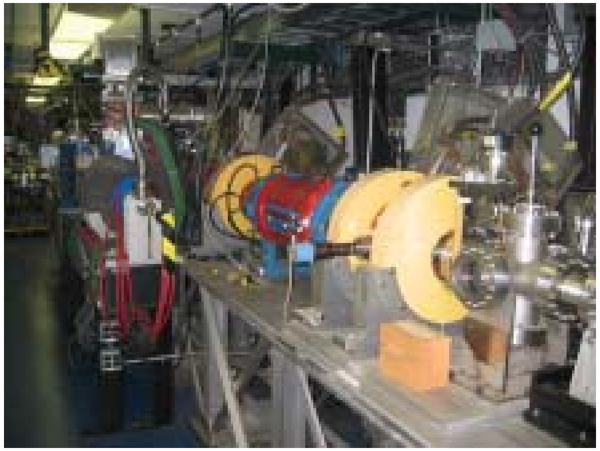


15 MeV, 20 – 100 nC Drive beam

Two Electron Beams

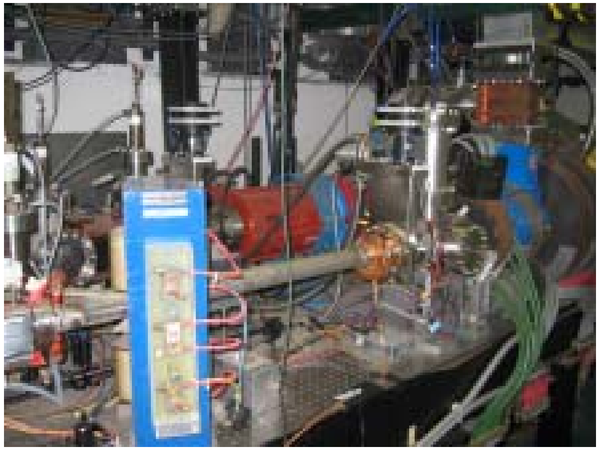
Drive Beam

- **L-band RF Gun**
- **Magnesium photocathode**
- **Two L-band standing-wave linac tanks**
- **15 MeV, 1 – 100 nC**



Witness Beam

- **4 ½ cell, L-band RF Gun**
- **Copper photocathode**
- **3.5 MeV, 0.1 – 1 nC**



AWA Sub-systems

Laser System

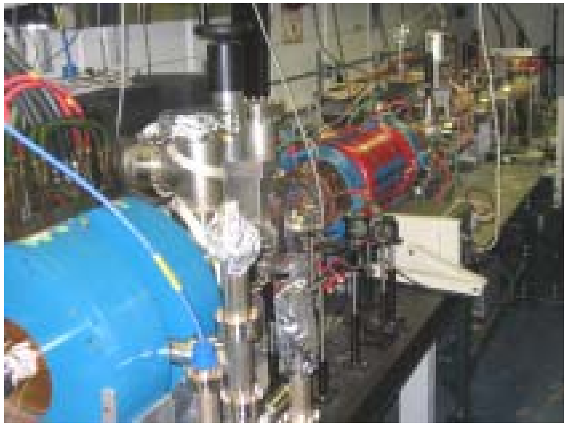
- Spectra Physics Tsunami oscillator, Spitfire regenerative amplifier, and two Ti:Sapphire amplifiers (TSA 50):
  - 1.5 mJ at 248 nm
  - 6 – 8 ps FWHM
  - timing stability: < 1ps rms
  - amplitude stability: ± 3% rms at high energy, and ±1% at lower energy.
- If use Excimer amplifier:
  - 15 mJ at 248 nm

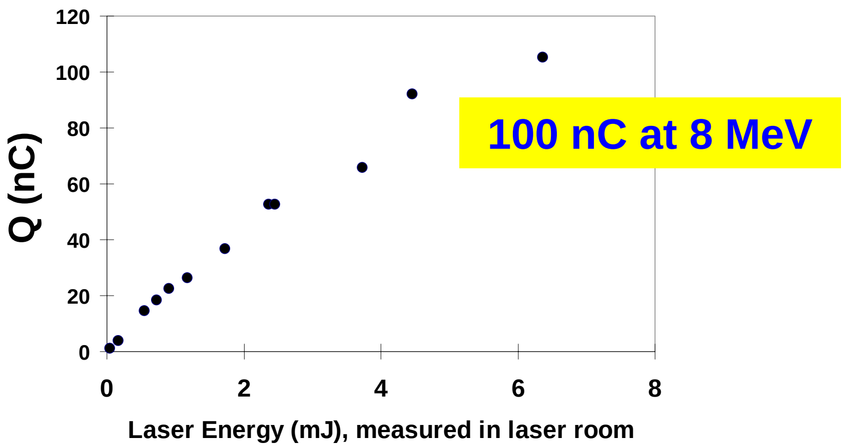
RF System

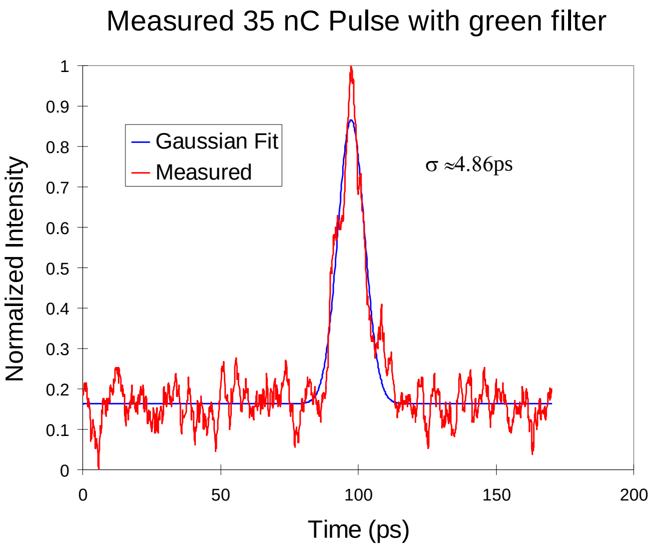
- Single klystron: 1.3 GHz, 24 MW, 8μs

New AWA Drive Gun

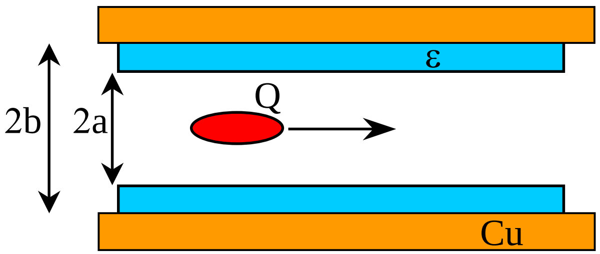
- 1 ½ cell, L-band (1.3 GHz)
- 12 MW yielding 80 MV/m on cathode
- Base pressure: $4x10^{-10}$ Torr
- Beam characterization in progress:
  - 14 MW RF power injected in the gun.
  - measured beam parameters in agreement with design expectations: 1 – 100 nC, 8 MeV
  - Mg photocathode (laser cleaning)







Wakefields in Dielectric Structures



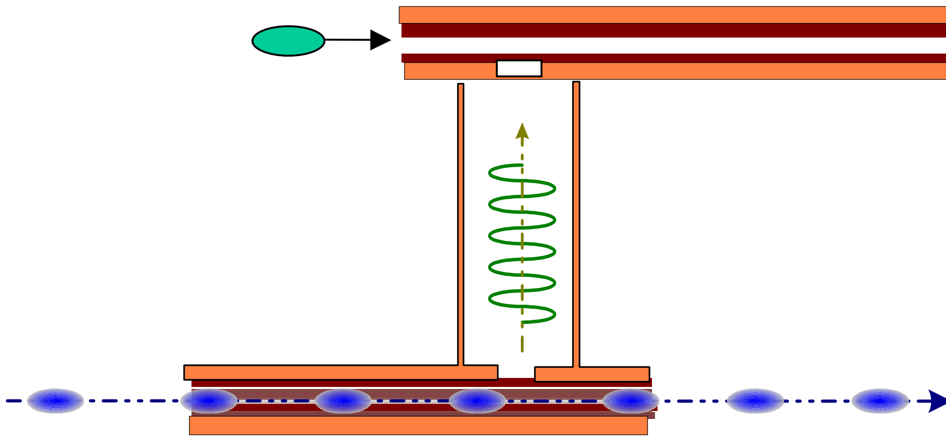
$$W_z \approx \frac{Q}{a^{3/2}} \exp\left[-2\left(\frac{\pi\,\sigma_z}{\lambda_n}\right)^2\right]$$

$$\sigma_r = \left(\frac{\varepsilon_N}{\gamma}\beta\right)^{1/2}$$

Direct wakefield acceleration:

- Dielectric parameters: 2a = 6 mm, 2b = 10 mm, ε = 4.6
- Electron bunch: σ_z = 1 mm, Q = 100 nC, RF power: 400 MW, yielding 92 MV/m at 19 GHz
- Field superposition from bunch train: four bunches of 100 nC or eight bunches of 50 nC generate over 300 MV/m

Wakefields in Dielectric Structures (TBA)



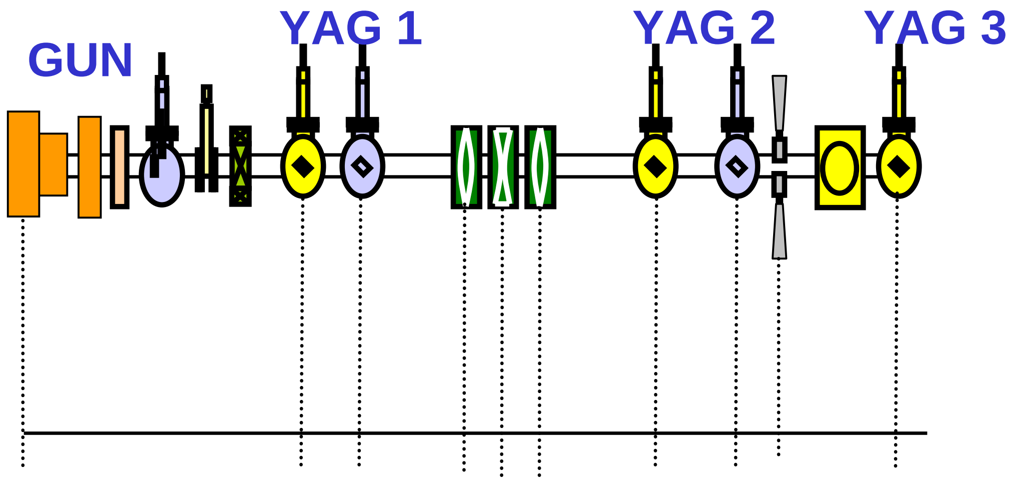
Two-Beam Wakefield Acceleration

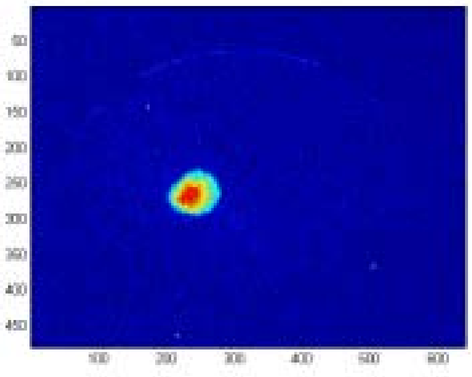
- Drive beam: 64 bunches of 50 nC, each separated by one RF period, generating a 50 ns long RF pulse.
- Stage I (28 cm long): 2a=11 mm, 2b=22 mm, ε = 4.6, 45 MV/m deceleration field, generating 500 MW (flat top).
- Stage II (85 cm long): 2a= 6mm, 2b= 11 mm, ε = 20, 112 MV/m acceleration field, yielding a total acceleration of 95 MeV.

High Brightness Beam Studies I:

Use Drive Gun to generate “low” charge, high brightness electron beam.

- Generate ~ 1nC with a normalized emittance on the order of 1 – 5 mm-mrad
- Use a modified three screen technique to measure emittance (space charge effects included)
- Initial measurements agree qualitatively with predictions.





High Brightness Beam Studies II:

Schottky-enabled photoemission

- **A new scheme to generate low emittance electron beams**
- **Relies on Schottky effect to enable photoemission with low energy photons**

$$\varepsilon^2 = \varepsilon^2_{thermal} + \varepsilon^2_{RF} + \varepsilon^2_{sc} + 2\varepsilon_{RF}\varepsilon_{sc}J_x$$

$$\varepsilon_{thermal} \propto \sqrt{E_{kin}}$$

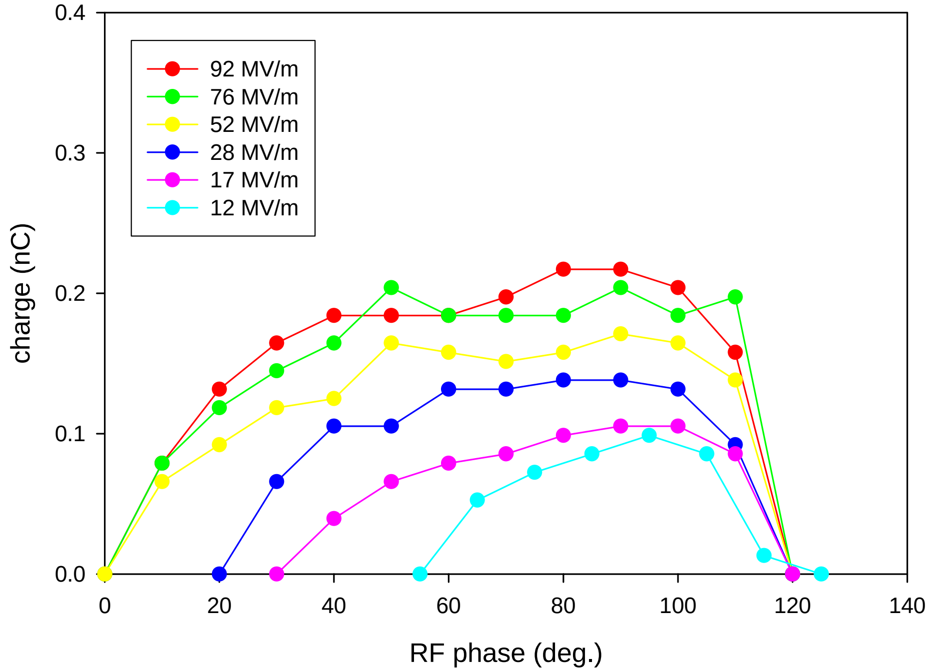
Schottky Term

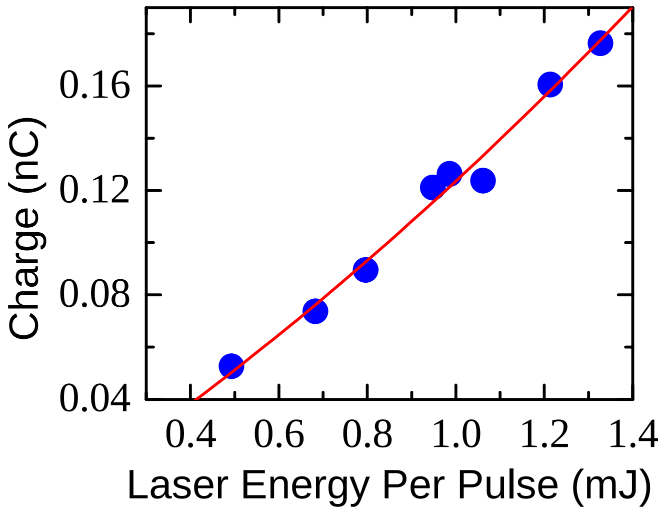
$$E_{kin} = h\nu - \Phi_w + \alpha\sqrt{E_c\beta\cos\phi}$$

hv=3.3 eV and Φ_W=3.6 eV

Schottky-Enabled Photoemission Observed

Limited emission phase region due to Schottky effect





Beam Diagnostics Development
(R. Fiorito, A. Shkvarunets)

Motivation: Low Energy Divergence Diagnostic

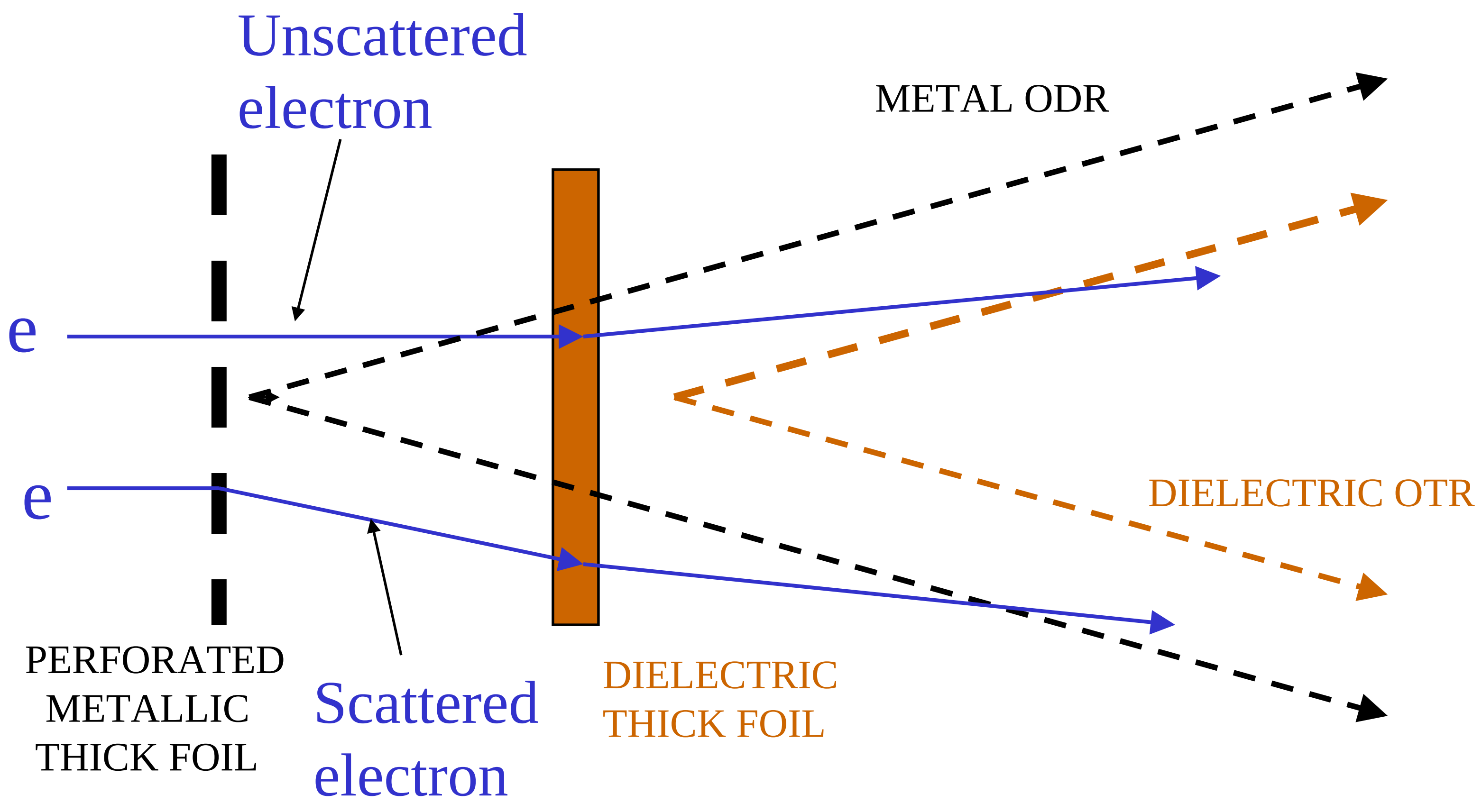
Problems with Use of Conventional OTRI Divergence Diagnostics

1. Low energy electrons are heavily scattered by first solid foil of a two foil OTR interferometer.
2. At very low energy (E < 10 MeV) the formation length (gap between foils) is very small (< ~ mm).

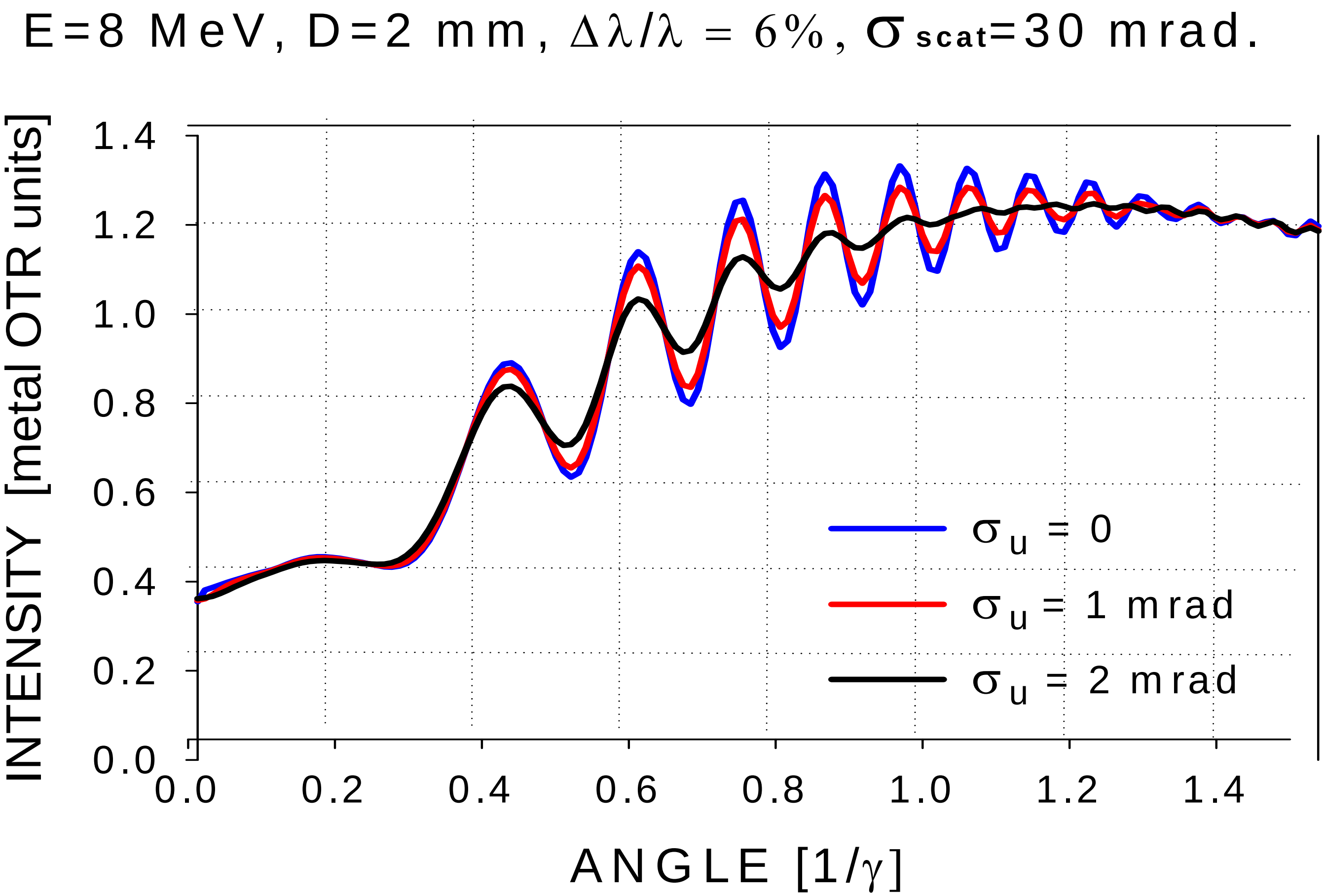
Solution: ODR (Mesh) – OTR (Dielectric Foil) Interferometer

1. Fraction of beam passing through mesh holes is unscattered allowing the fringes produced by the unscattered fraction to be measured over an incoherent background from the scattered fraction.
2. Transparent dielectric foil allows observation of **forward ODR-OTR** despite the small gap spacing.

METAL MESH (ODR) - DIELECTRIC (OTR) INTERFEROMETER



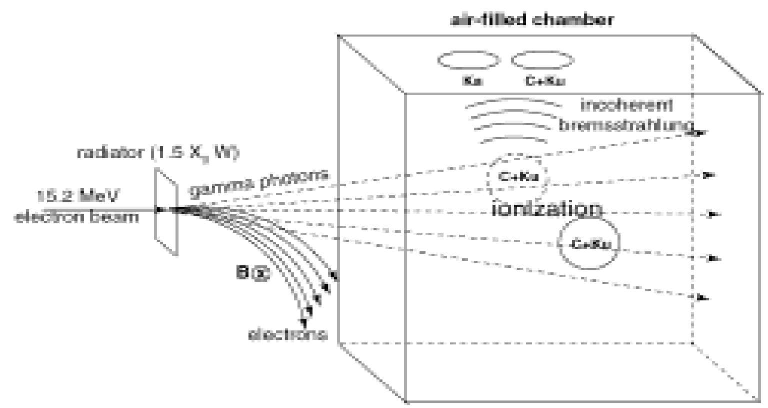
EFFECT of UNSCATTERED BEAM DIVERGENCE on ODR-OTR INTERFERENCES



(Fiorito & Shkvarunets)

Astrophysics applications

1. **Radio Cherenkov radiation generated by charged particles traversing a solid target (sand, Moon)**
2. **Incoherent molecular microwave bremsstrahlung from ionized air**



3. **Fluorescence light generated by charged particles traversing the atmosphere (AIRFLY Collaboration)**