APS Linac Ultra-Short Bunch Generation and Diagnostics

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Objective:
To study the potential for generation of ultra-short pulse generation - tens of femtoseconds - using the APS Linear Accelerator

Strategy:
A combination of particle simulation, empirical observation, and new mm-wave beam diagnostics

Operations Analysis Group
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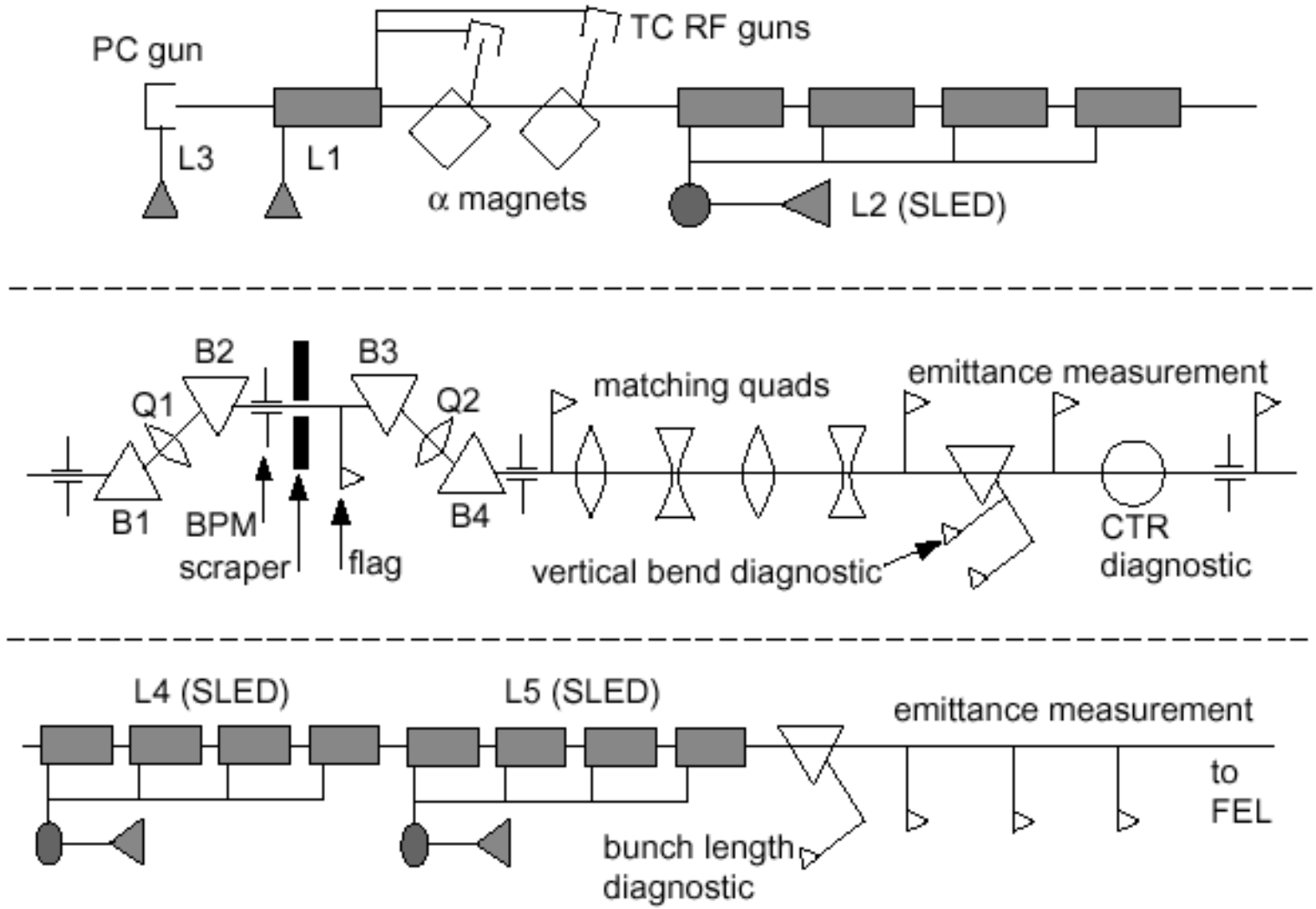
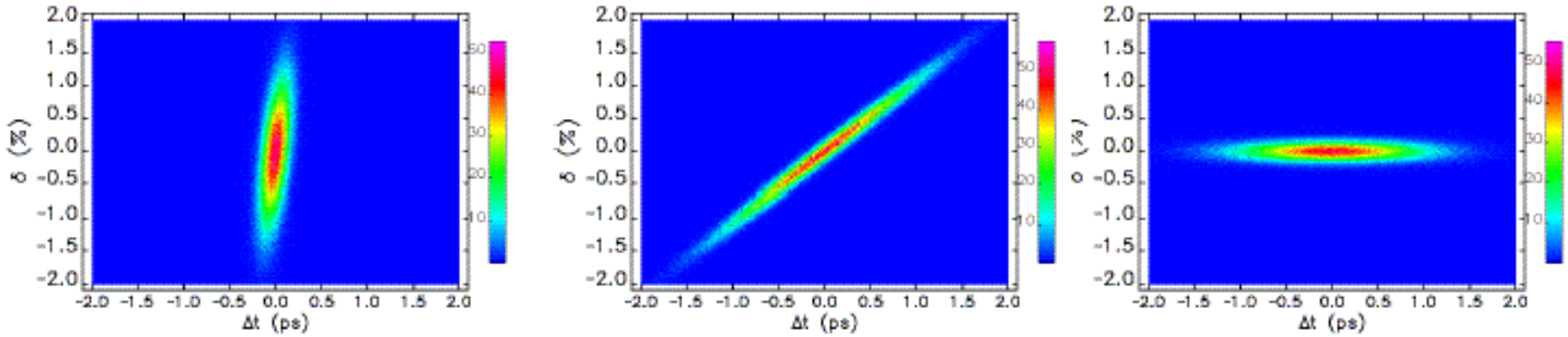
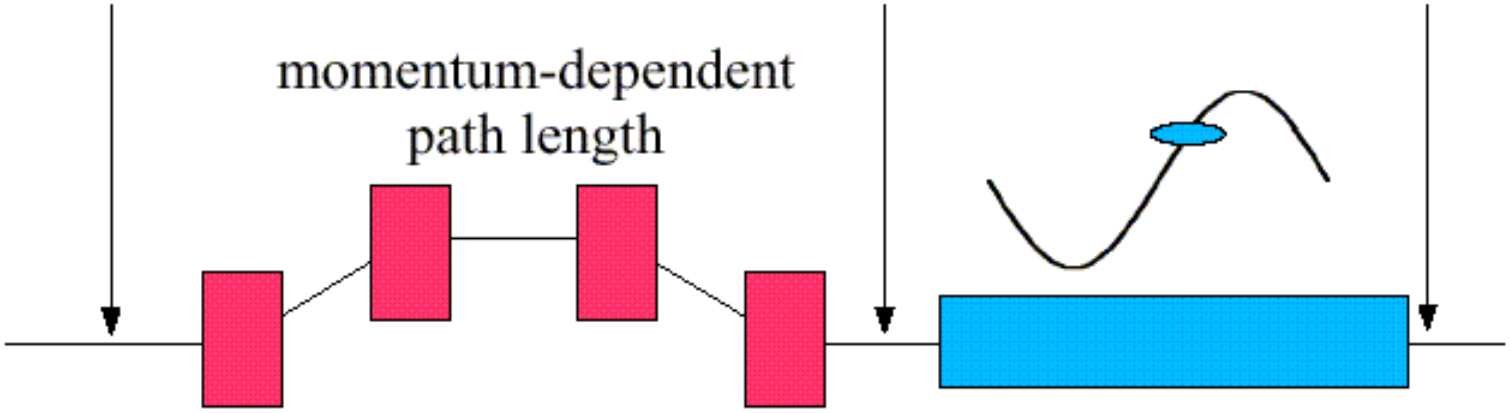
APS Linac and Bunch Compressor

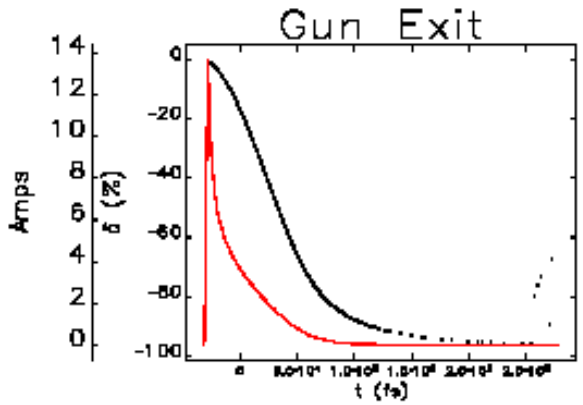


Magnetic Bunch Compression





M. Borland, June 6, 2002

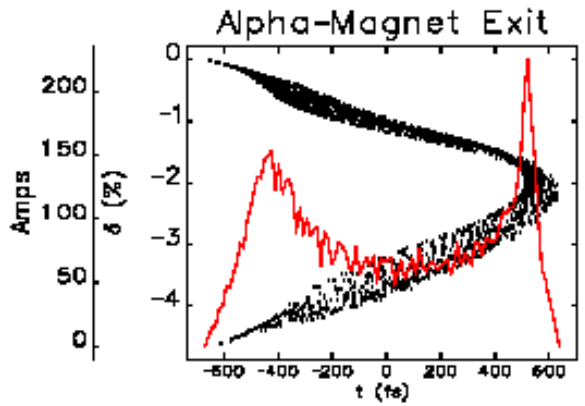


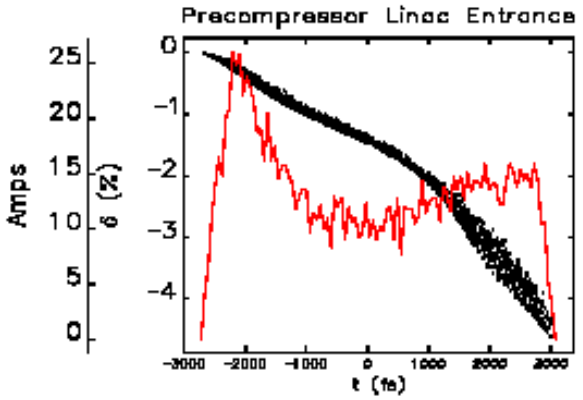
3 MeV, 300 pC/pulse
S-band thermionic rf gun

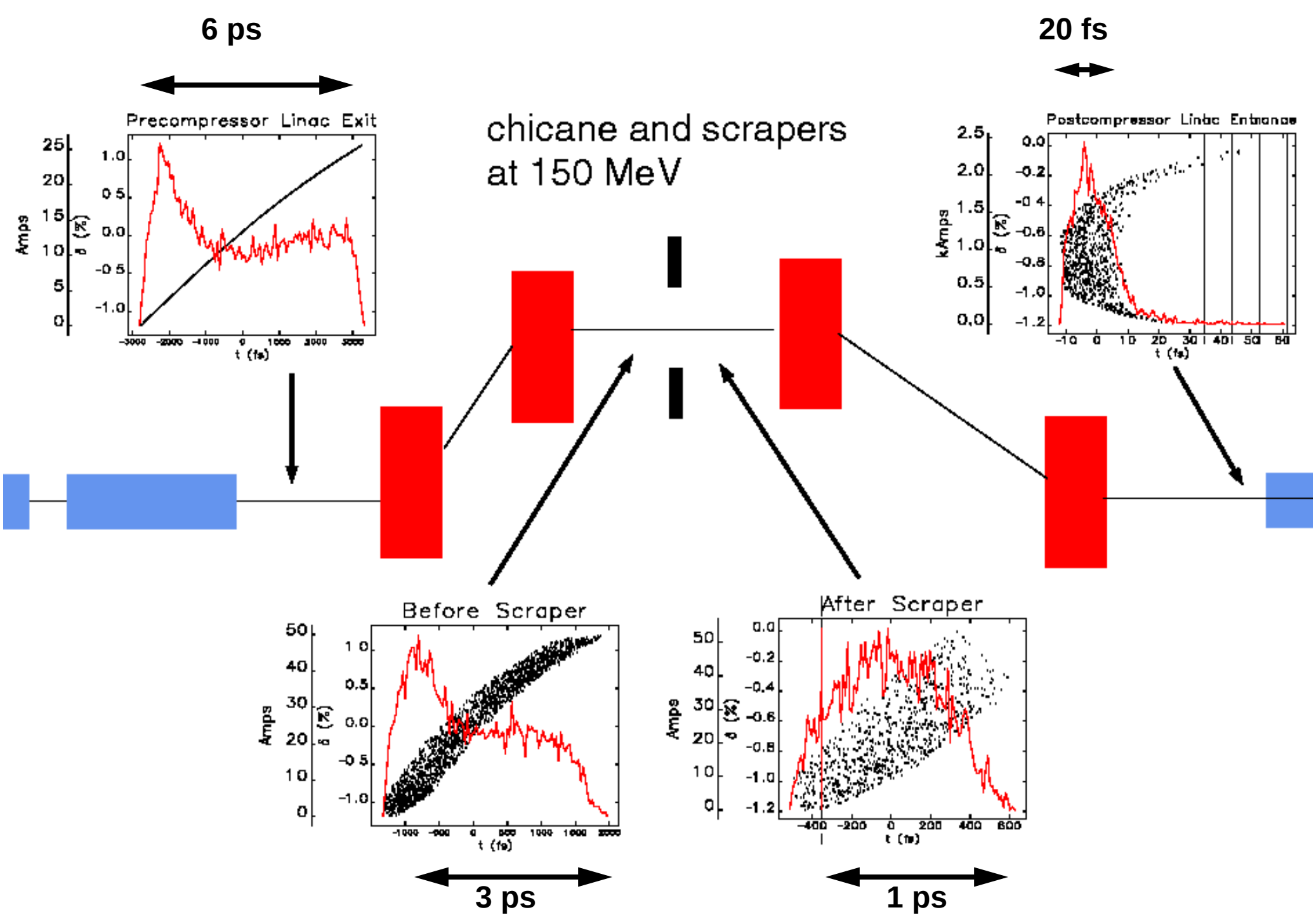
3m S-band structures

alpha magnet with
low-energy scraper

6 ps

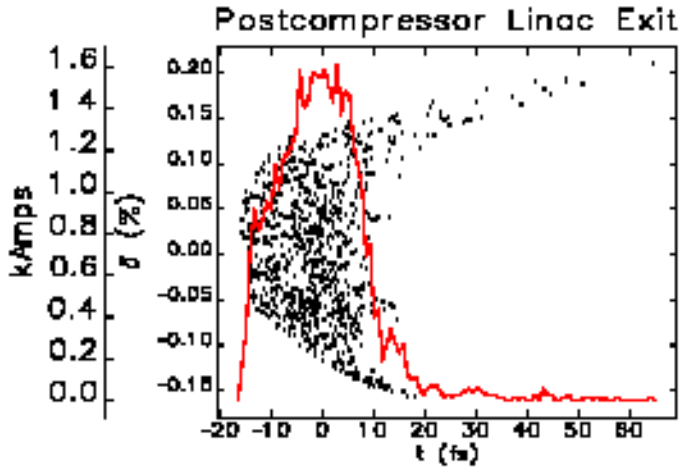


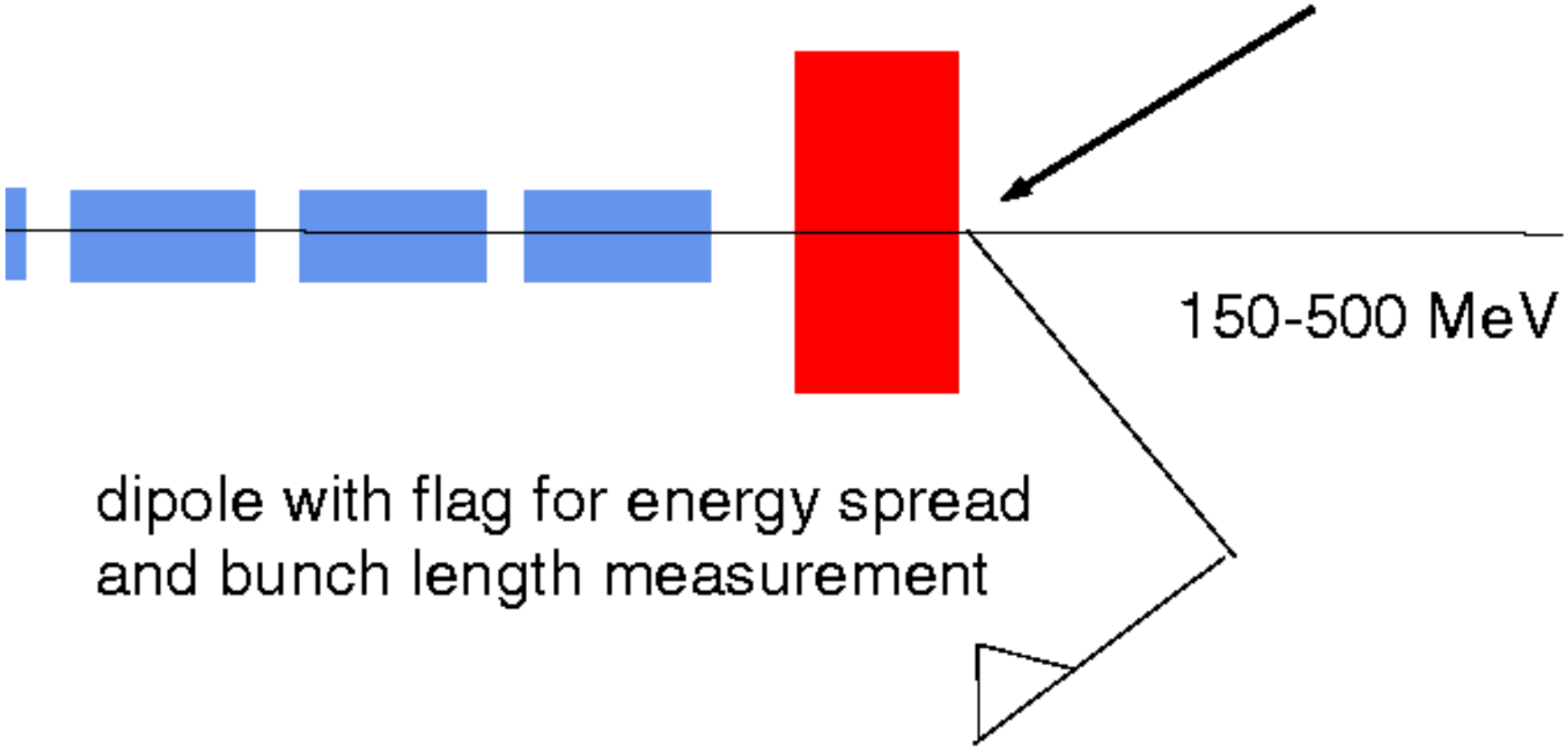



6 ps
20 fs
Precompressor Linac Exit
chicane and scrapers
at 150 MeV
Postcompressor Linac Entrance
Before Scraper
After Scraper
3 ps
1 ps

20 fs

Downstream end of linac, with analysing magnet





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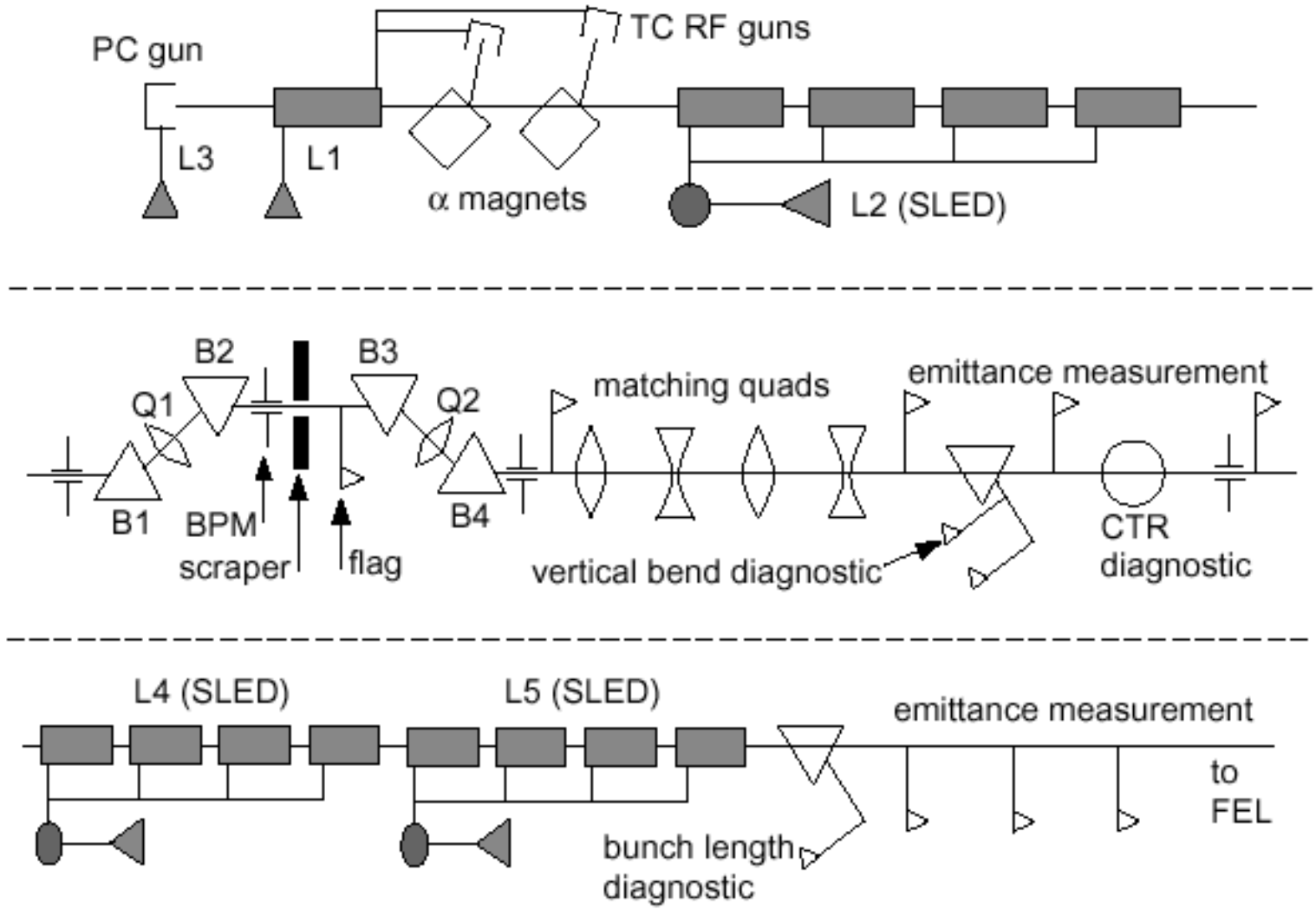
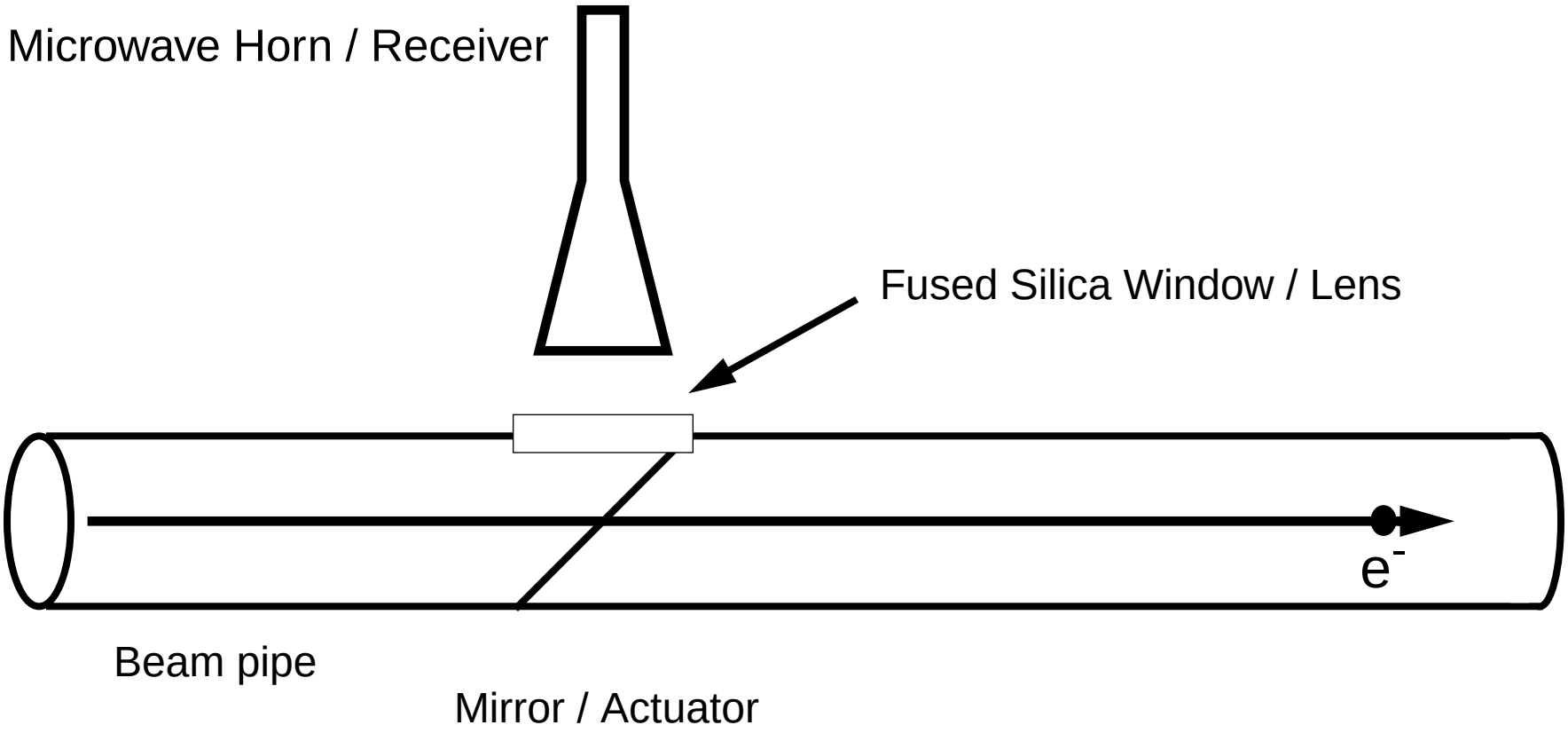
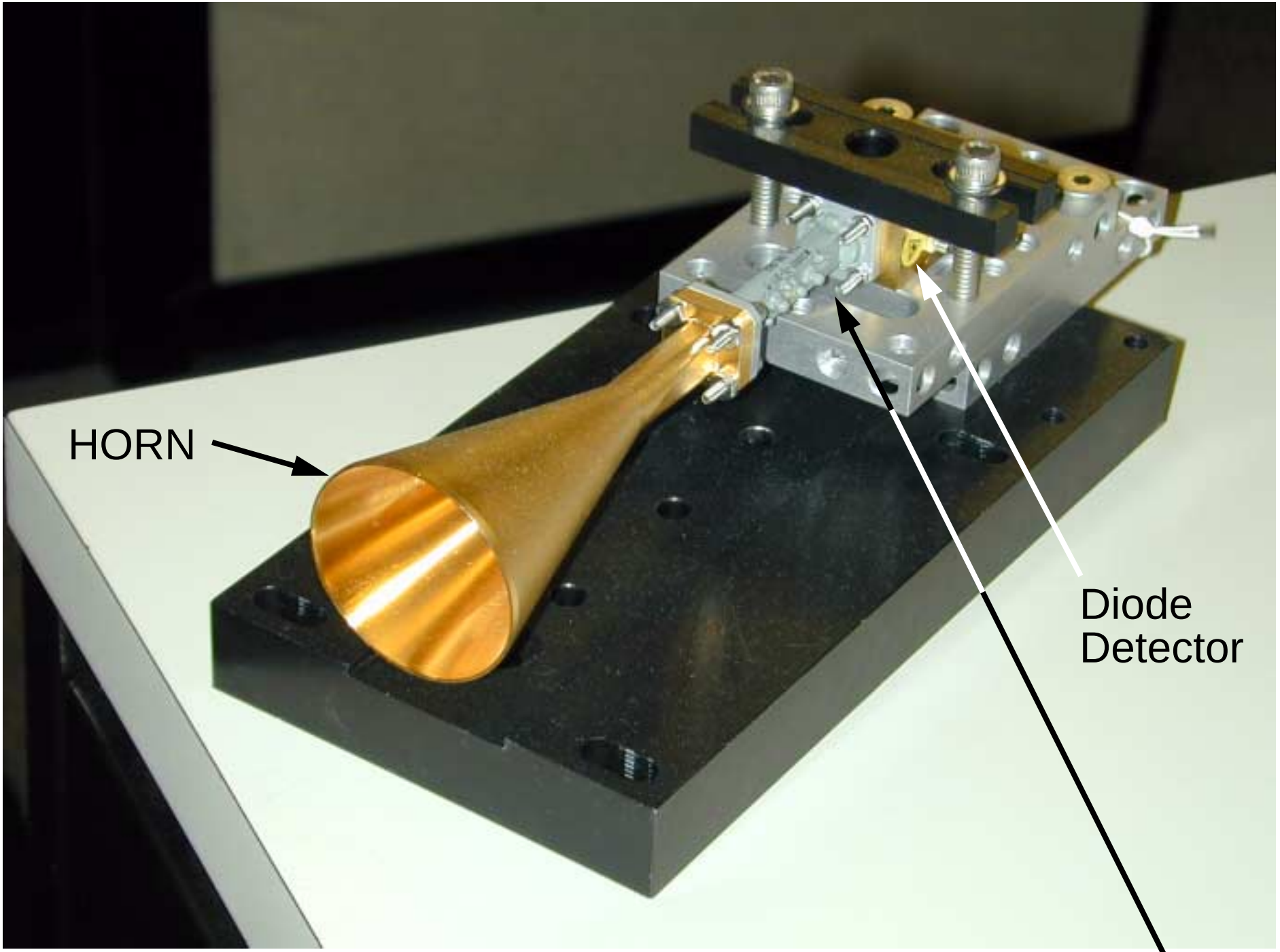


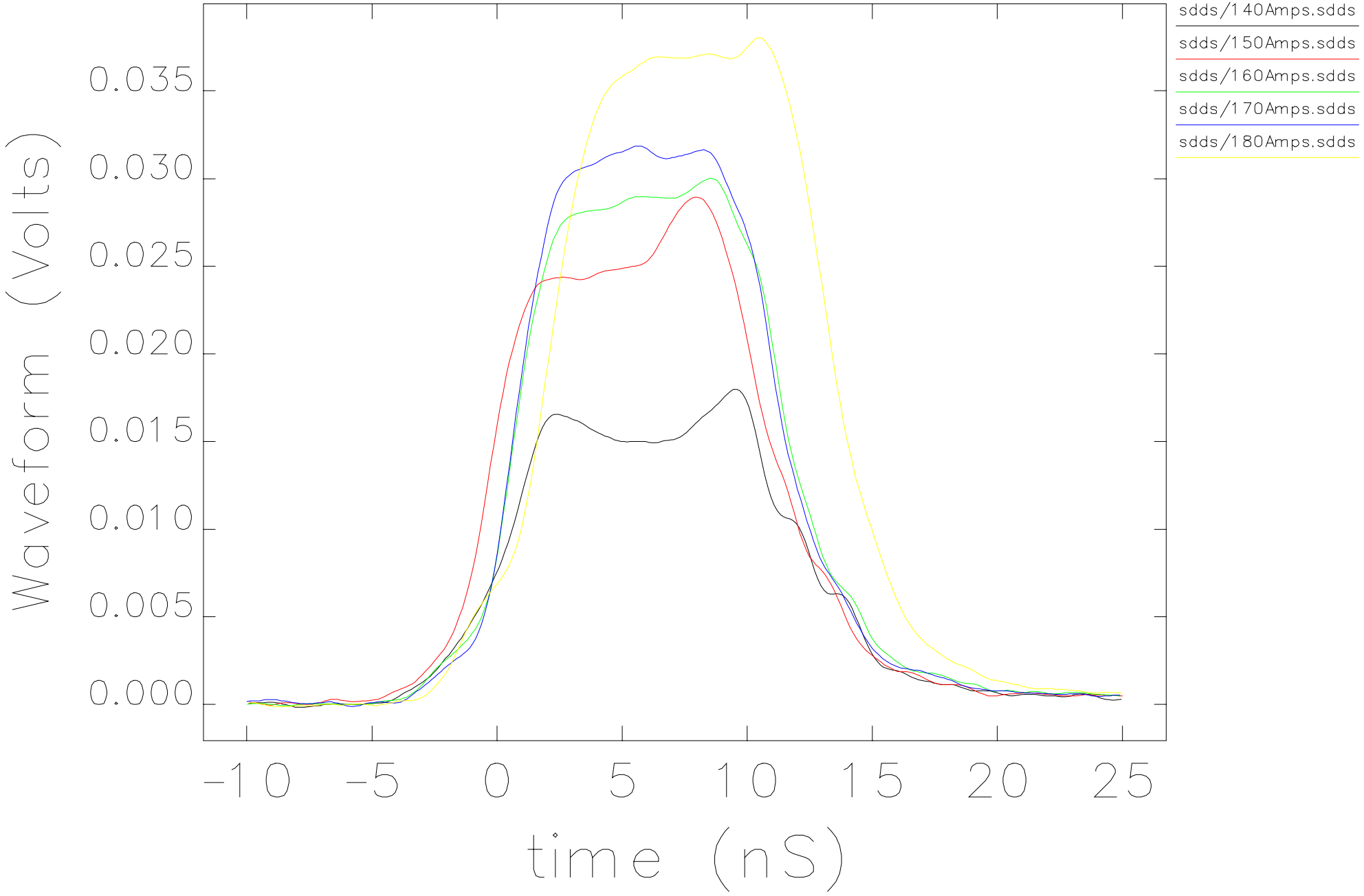
Experimental Arrangement for Detection of 30 GHz Coherent Transition Radiation (L3 CTR Diagnostic)



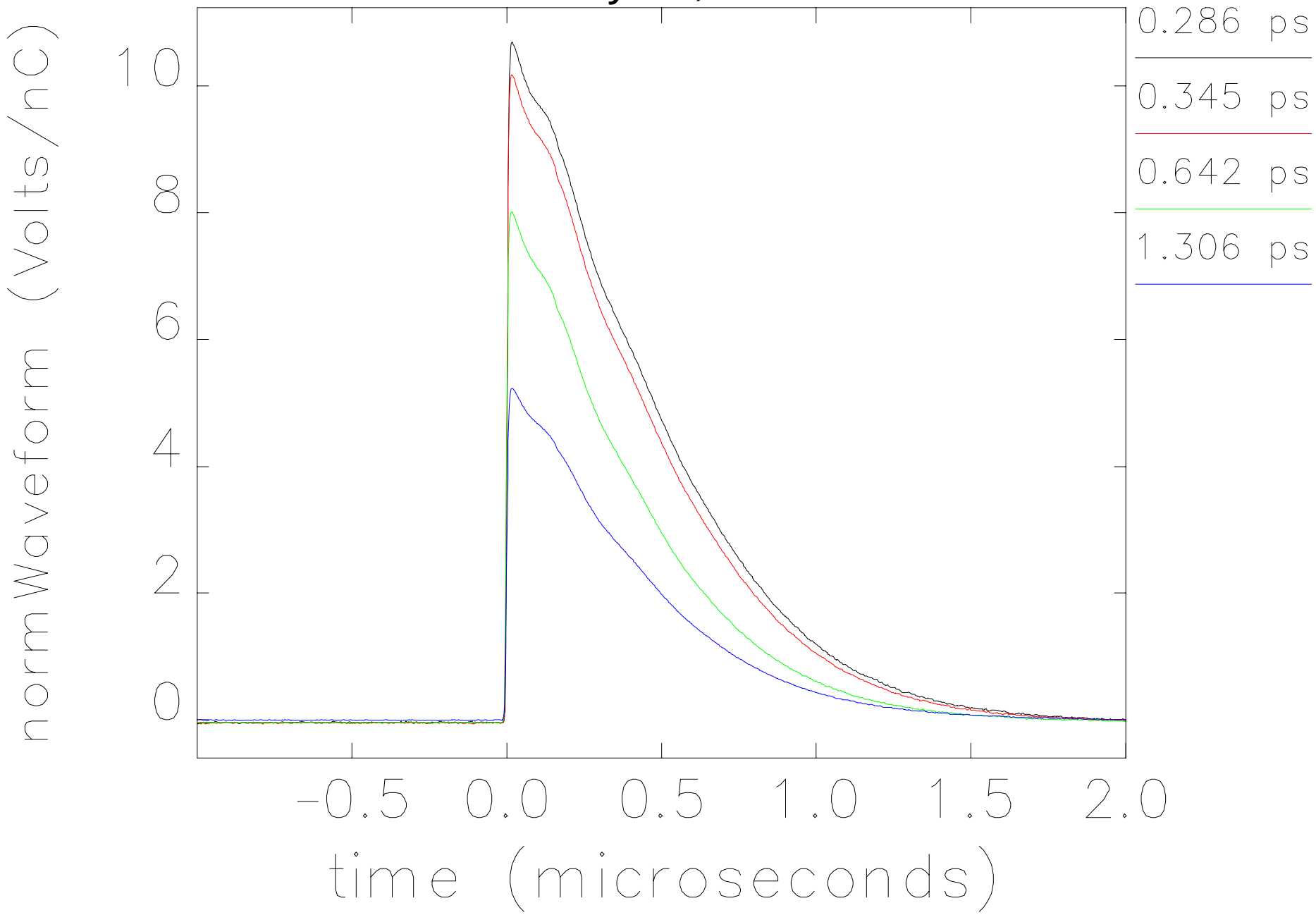
30 GHz mm-wave detector



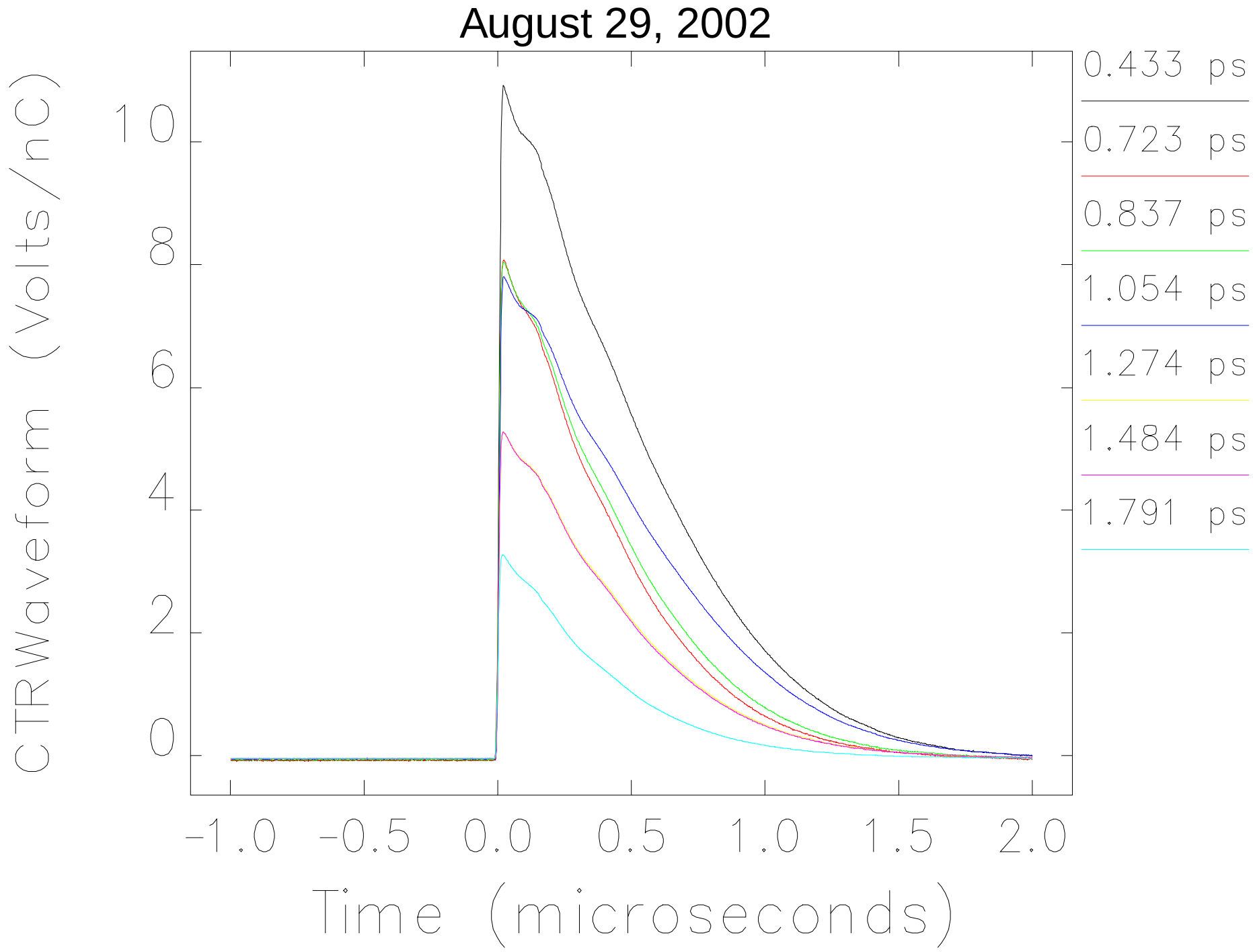
First Results June 2, 2002
30 GHz detector driving 50 Ohm line



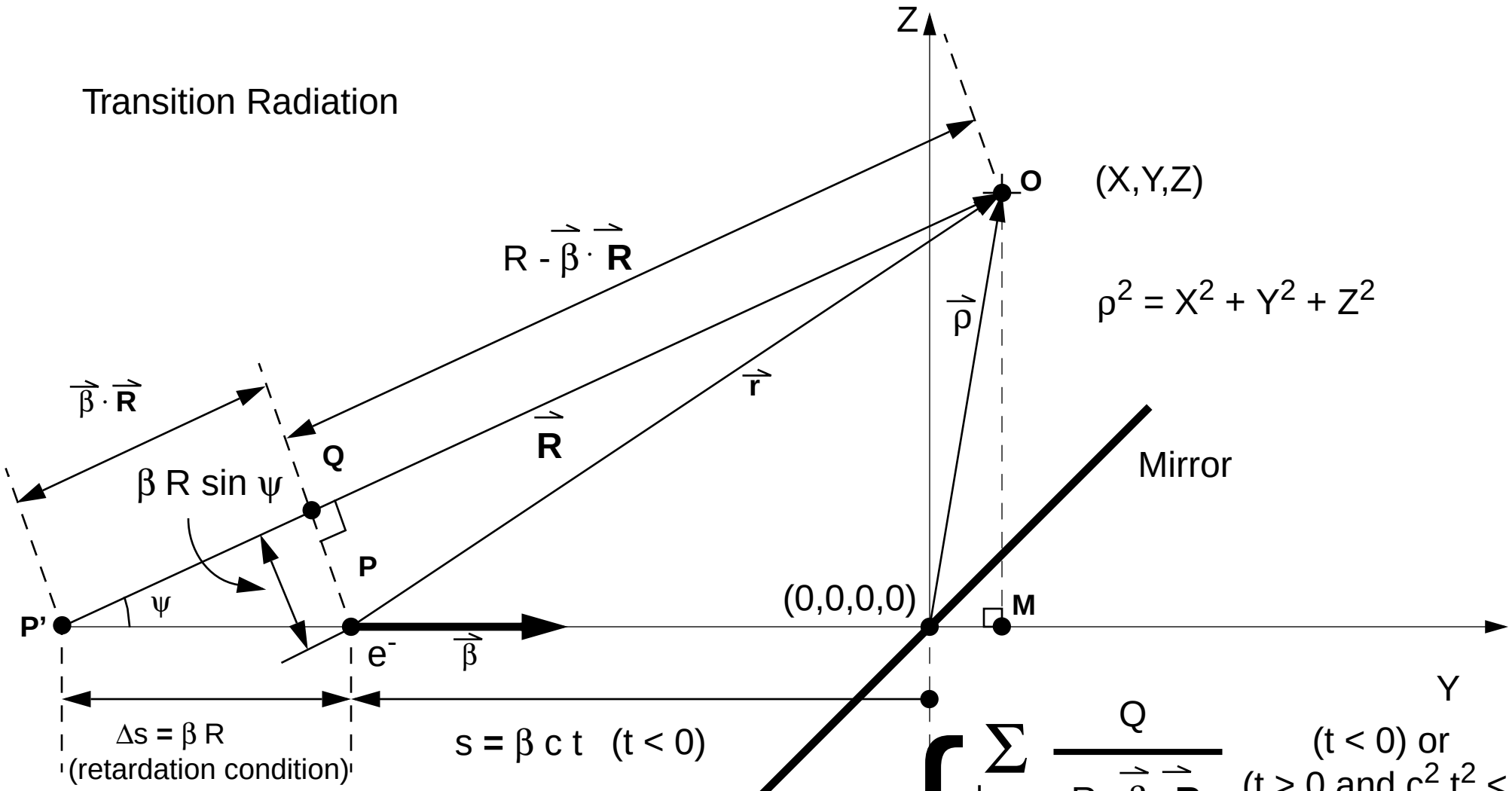
Results with 20:1 Transimpedance Amplifier
Bunch Lengths Measured w/ L5 Zero phase method
July 12, 2002.



RF gun 2, approx .25 nC / 8 ns macropulse; Charge normalization “by eye”


August 29, 2002
CTR Waveform (Volts/nC)
0
2
4
6
8
10
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Time (microseconds)
0.433 ps
0.723 ps
0.837 ps
1.054 ps
1.274 ps
1.484 ps
1.791 ps

Transition Radiation



$$\Phi = \begin{cases} \sum_{+,-} \dfrac{Q}{R - \vec{\beta} \cdot \vec{R}} & (t < 0) \text{ or } (t > 0 \text{ and } c^2 t^2 < \rho^2) \\ 0 & (t > 0;\ c^2 t^2 > \rho^2) \end{cases}$$

Triangle OQP:

$$(R - \vec{\beta} \cdot \vec{R})^2 = r^2 - (\beta R \sin\psi)^2$$

Triangle OMP':

$$X^2 + Z^2 = R^2 \sin^2\psi\ ;$$

$$r^2 = (Y - s)^2 + X^2 + Z^2$$

$$R - \vec{\beta} \cdot \vec{R} = [(Y - s)^2 + (1 - \beta^2)(X^2 + Z^2)]^{1/2}$$

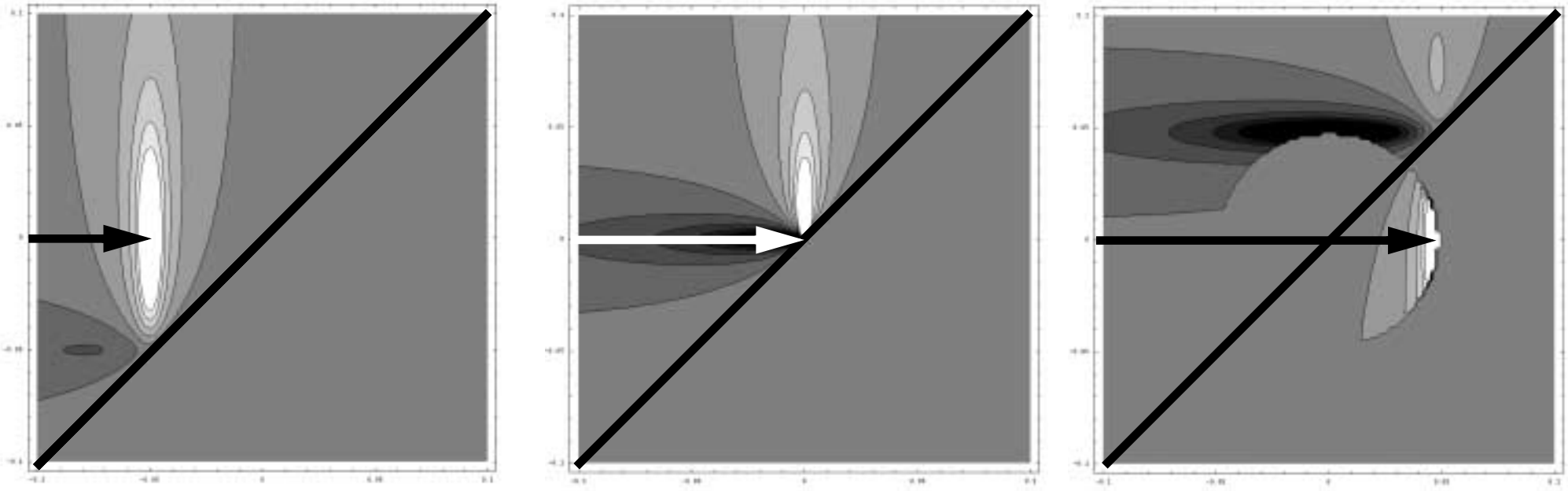
$$= [(Y - s)^2 + (X^2 + Z^2) / \gamma^2]^{1/2}$$

For image charge, exchange Y <-> Z

Ref: J.D.Jackson, Classical Electrodynamics, 2nd Edition, p. 658

Scalar Potential for Point Charge Striking Mirror

$\beta = 0.99$



Conclusions

- **Simulations indicate generation of very short pulses is limited by overall linac system stability**
- **Sensitivity to various noise sources determined by simulation**
- **In practice, the present APS linac using rf thermionic gun achieves rms bunch length > 200 fs**
- **mm-wave coherent transition / diffraction radiation diagnostic is inexpensive, with adequate resolution for 200 to 300 fs - scale rms bunch length measurement**
- **Increasing frequency from 30 GHz to 100 GHz should yield resolution of rms bunch length < 100 fs**