Storage Ring Kicker Update

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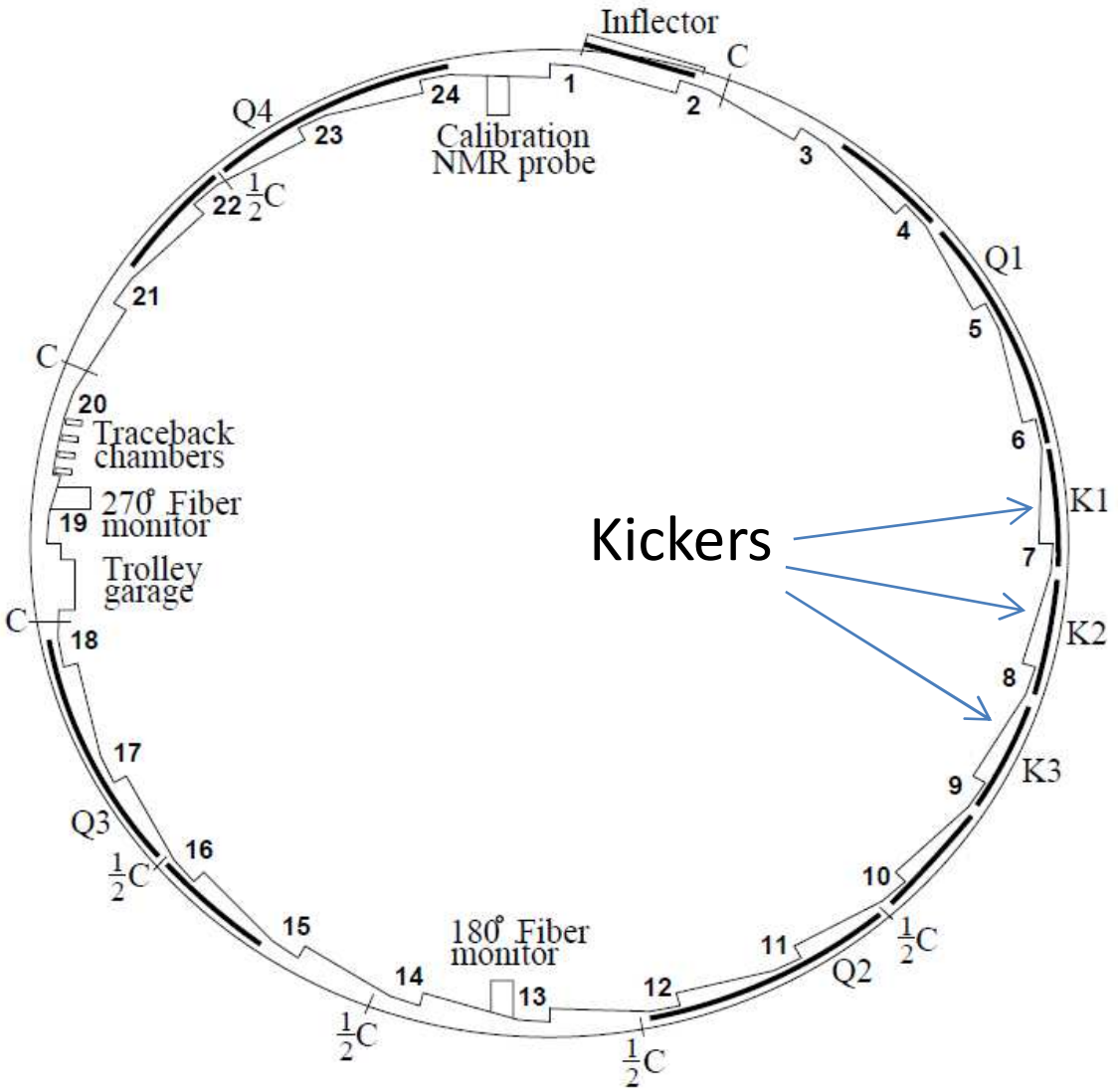
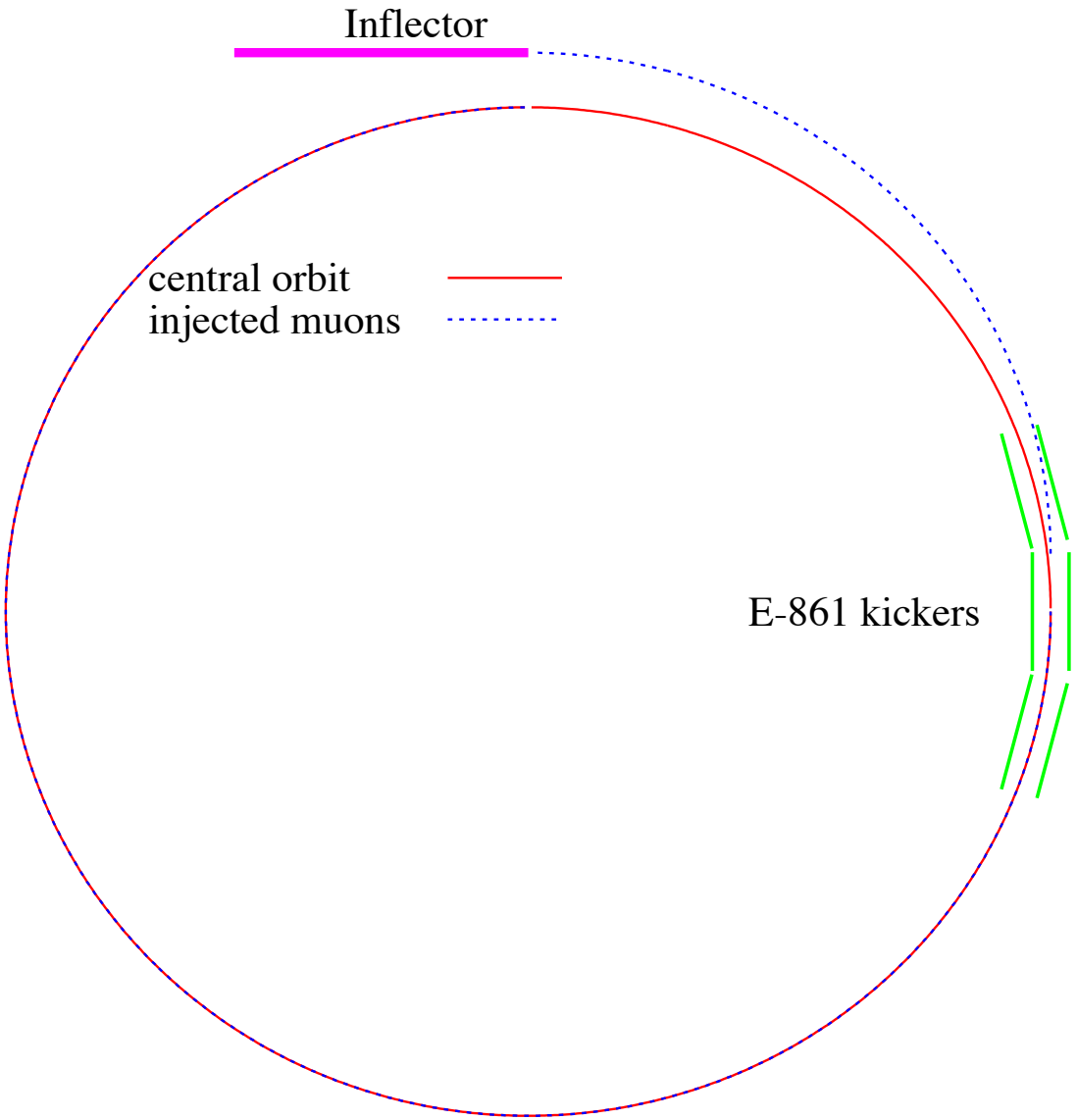
- Status of E821 kicker prototype
  - Concept
  - Components
  - Configuration
  - Hardware
- Injection dynamics
  - Trajectories
  - Energy and angular acceptance
  - Time dependence
- Kick amplitude and width
  - Pulse forming network
  - Implementations
- Muon beam
  - Bunch length
  - Energy and angular spread



Kickers are 90° in betatron phase from the inflector exit

Injected muons are crossing the central trajectory inside the kickers

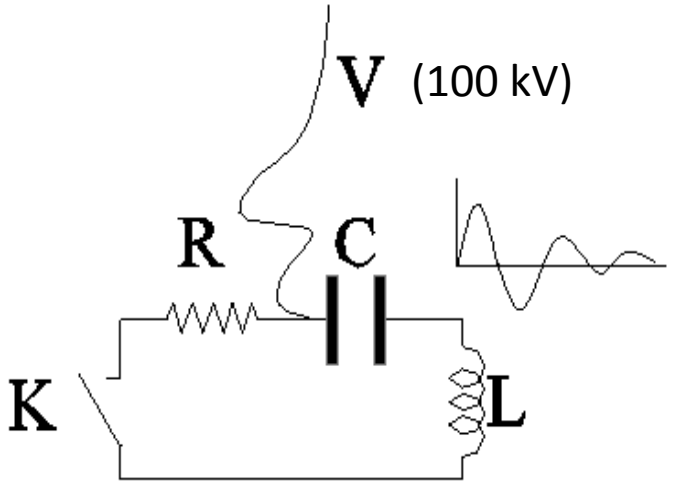
Kick directs muons onto central orbit



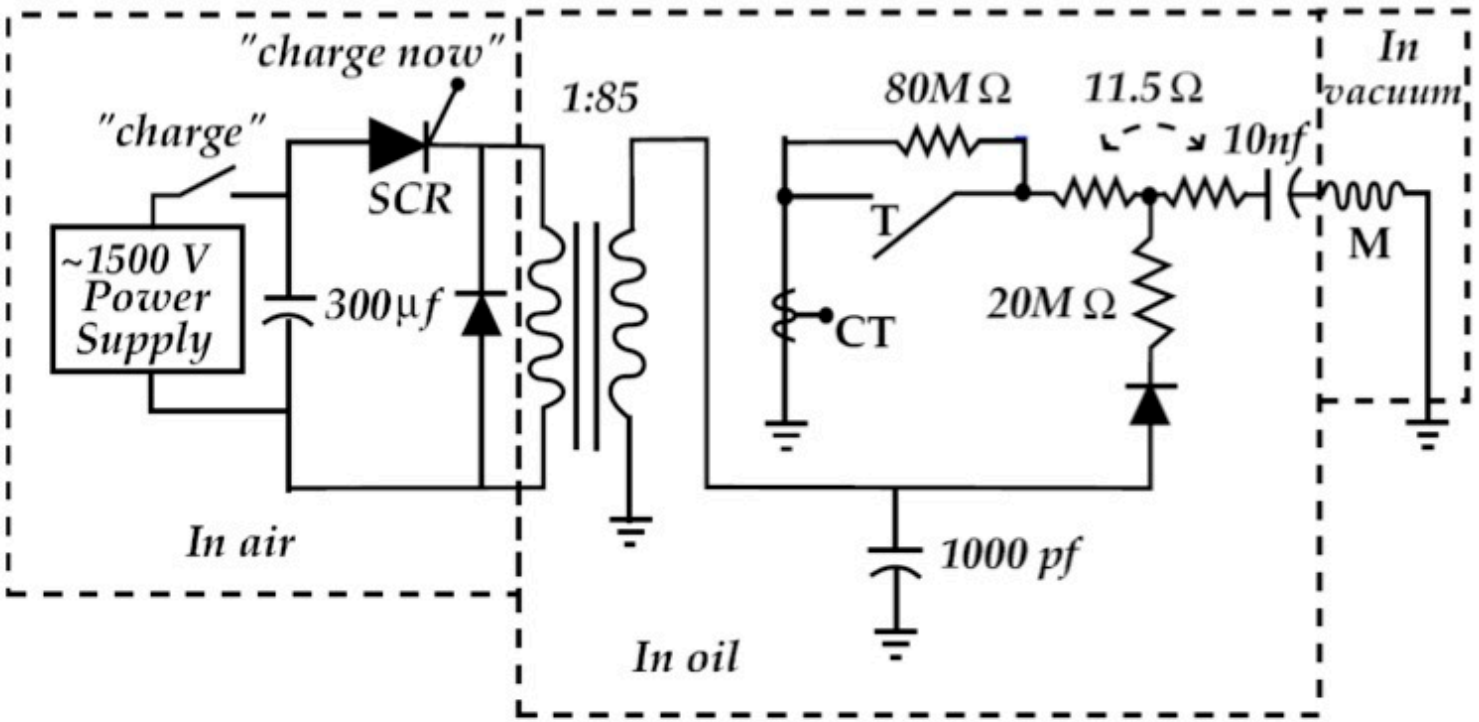
End of inflector is displaced 7.7cm radially outward from the central orbit

Radius of central orbit = 7.112 m

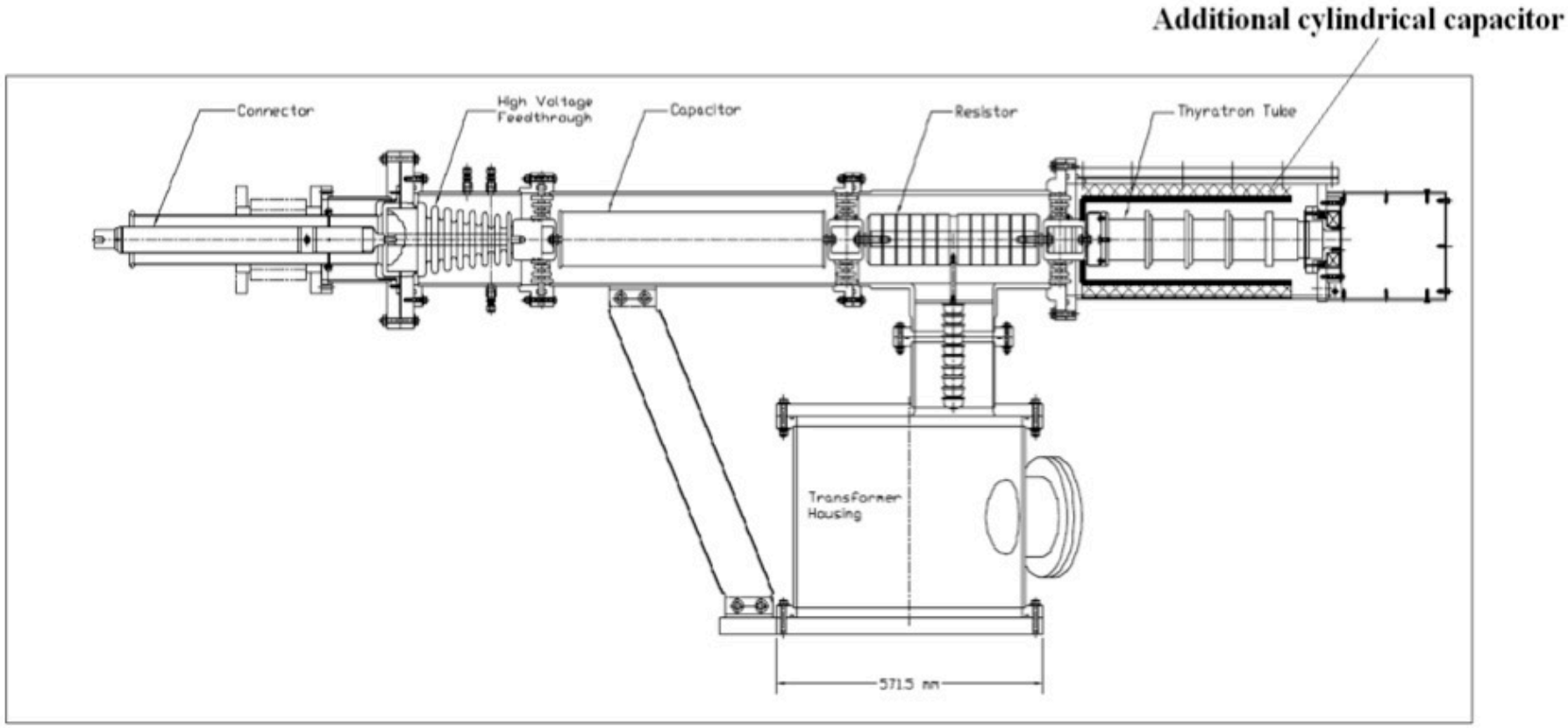
Kick ~ 10 mrad on first pass and 0 on next turn



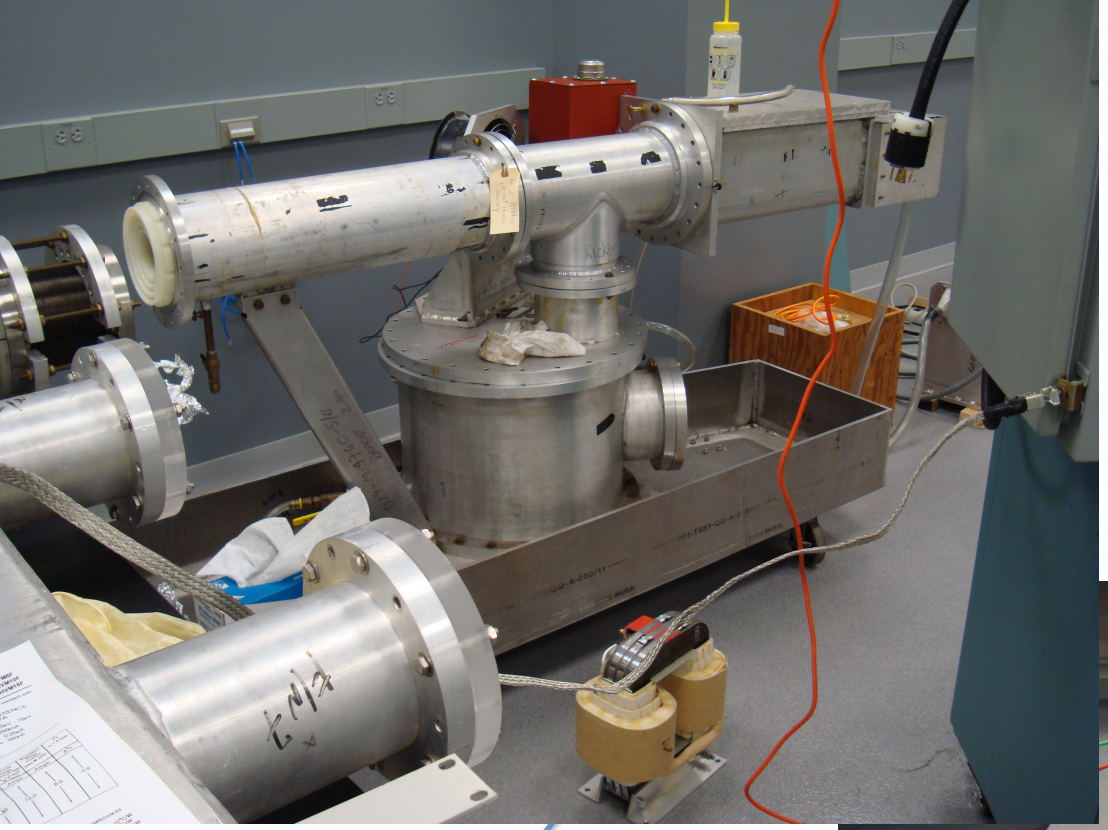
Pulser circuit



E821 – Pulser schematic


Additional cylindrical capacitor
Connector
High Voltage Feedthrough
Capacitor
Resistor
Thyratron Tube
Transformer Housing
3715 mm

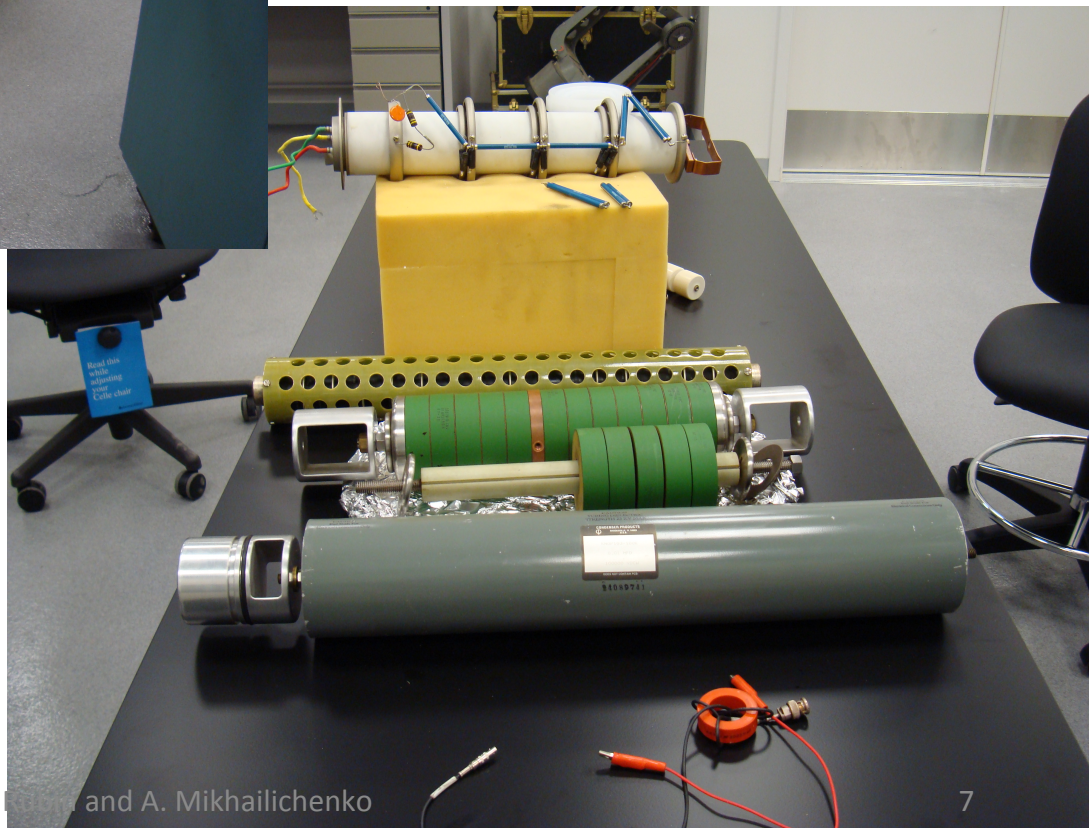
E-821 Pulser



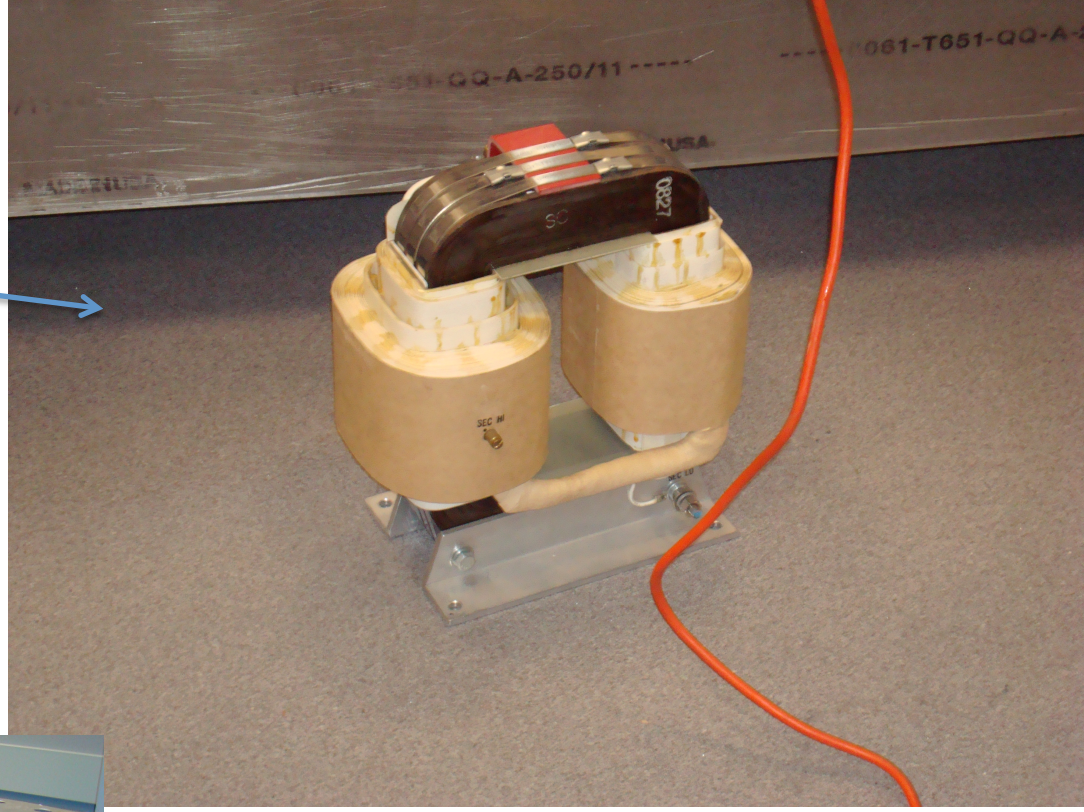
Pulser housing

HV Transformer

Thyratron
Charging Diodes
Charging resistors
Capacitor

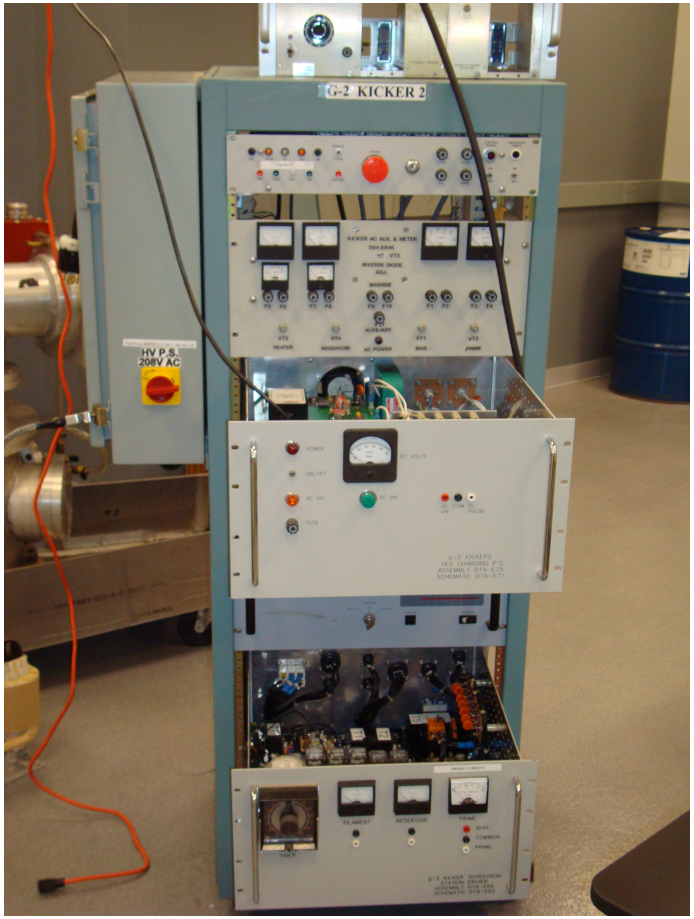


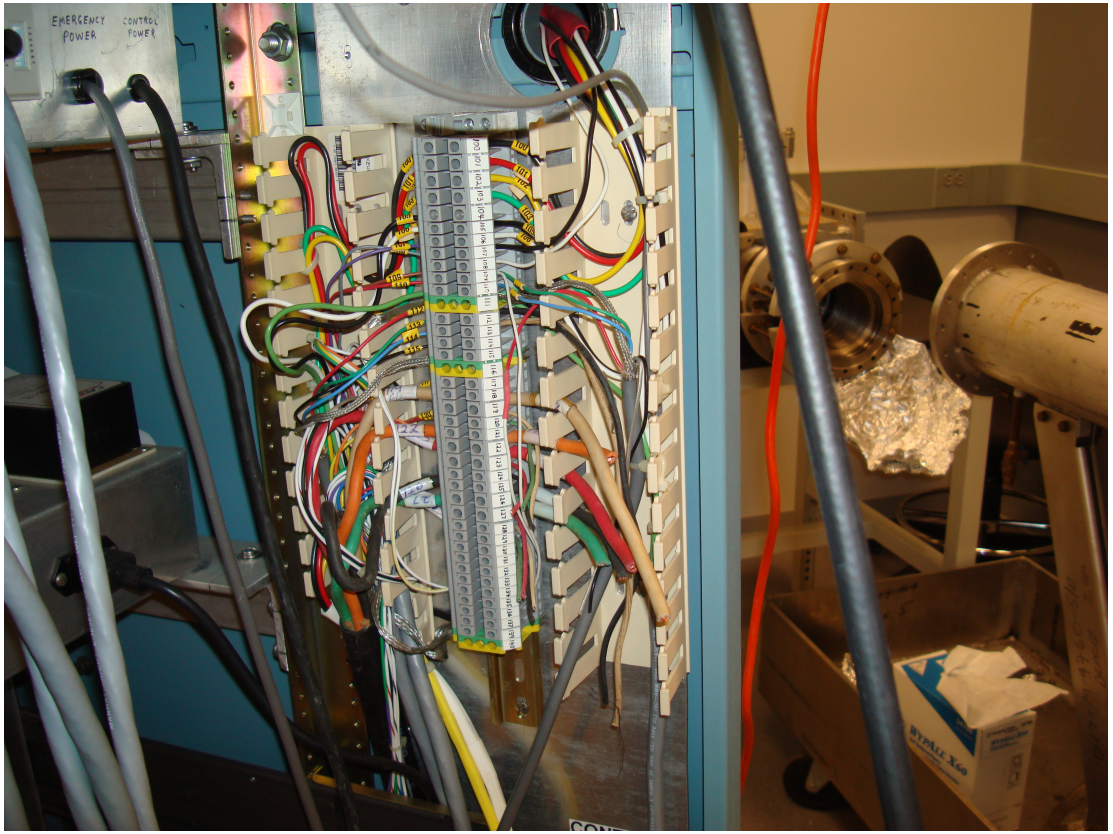
HV transformer

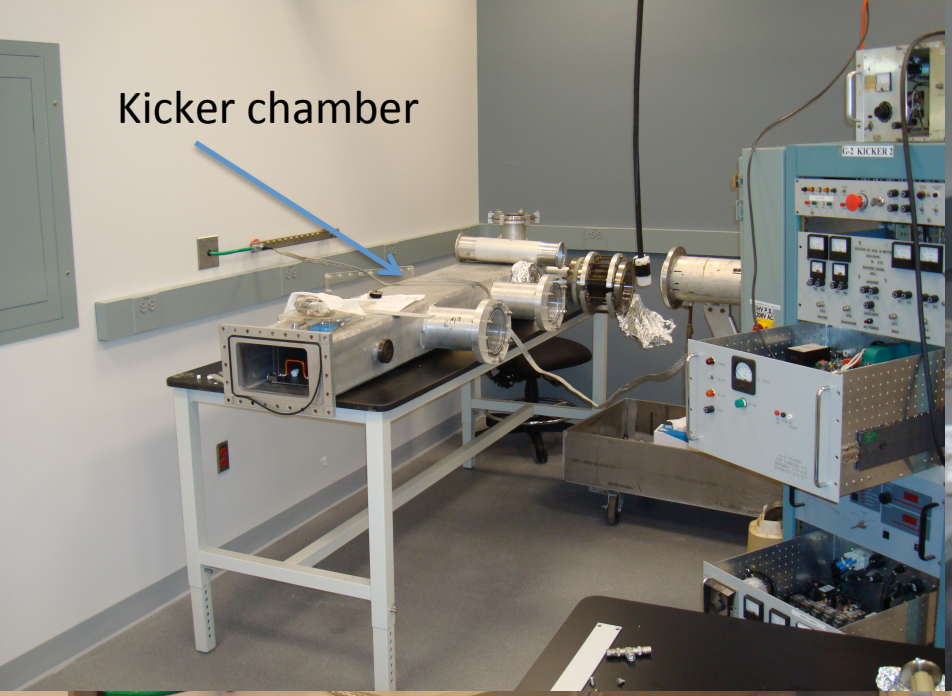


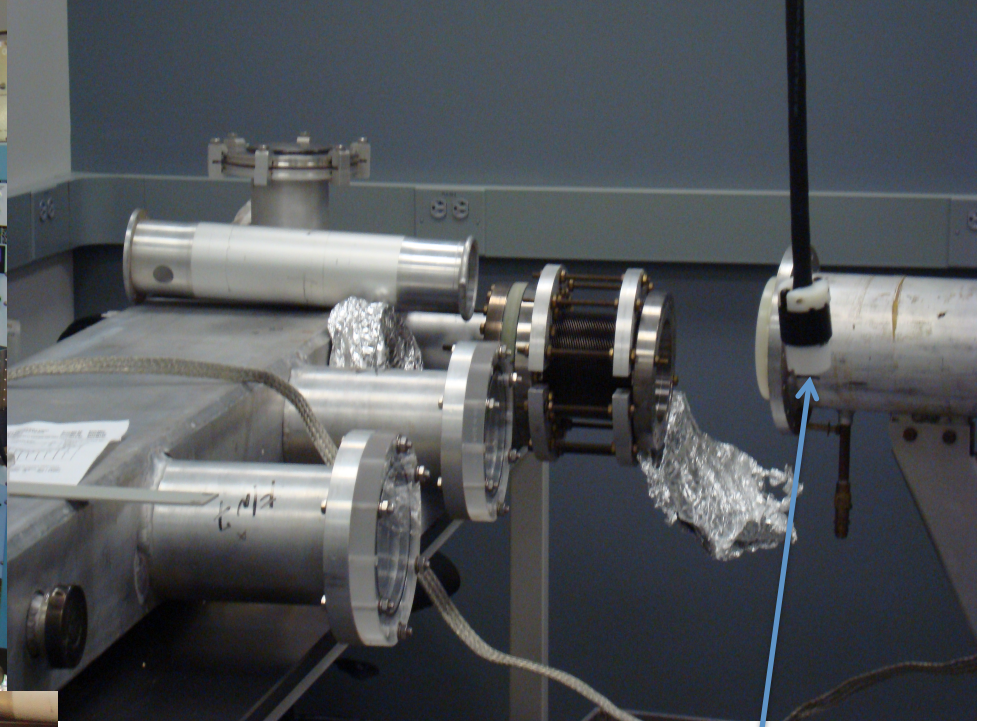
Overflow oil pool

Pulser electronics

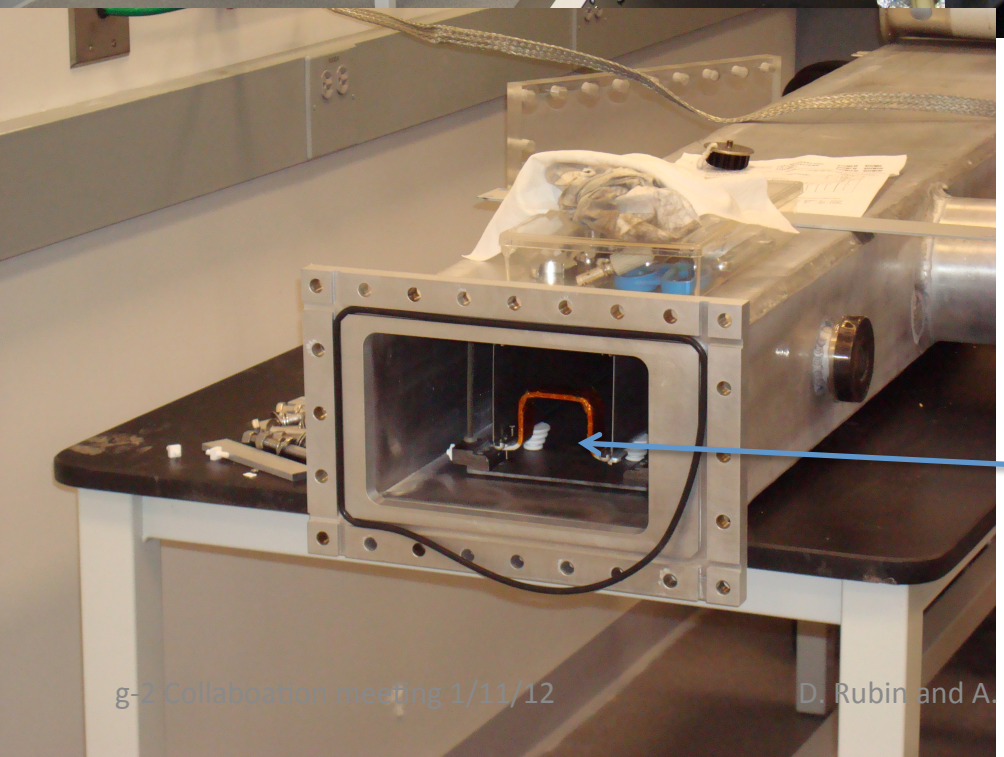




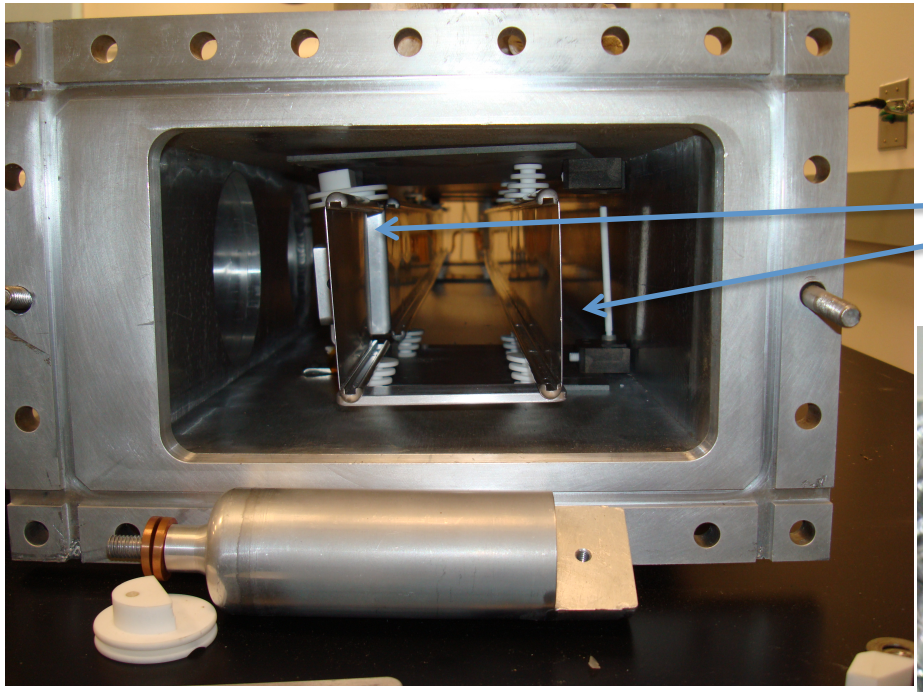




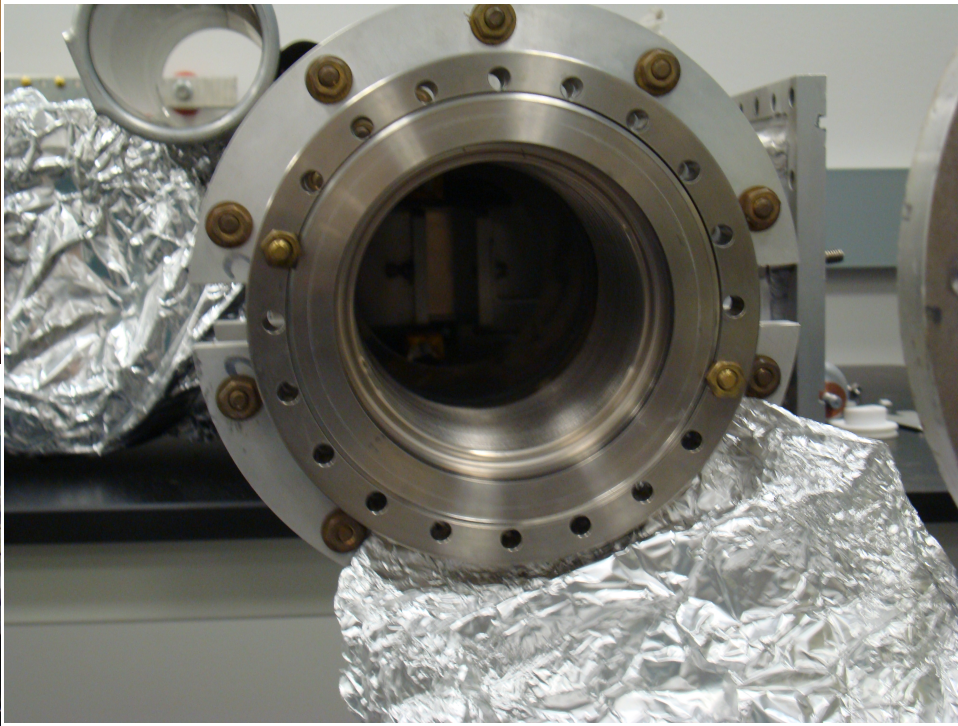
Power

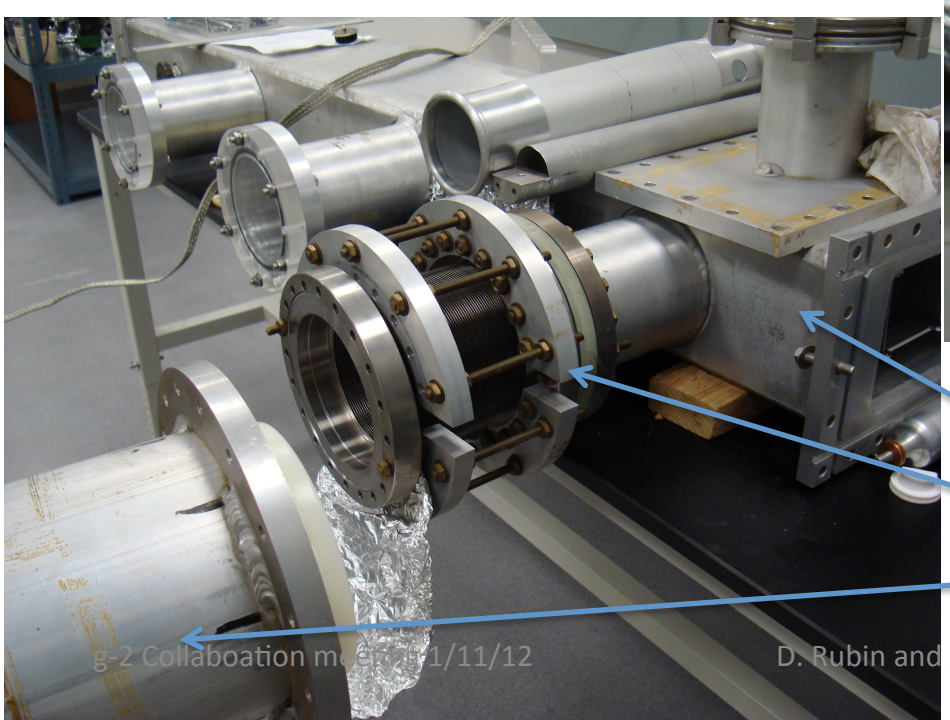


Downstream end of kicker



Kicker plates

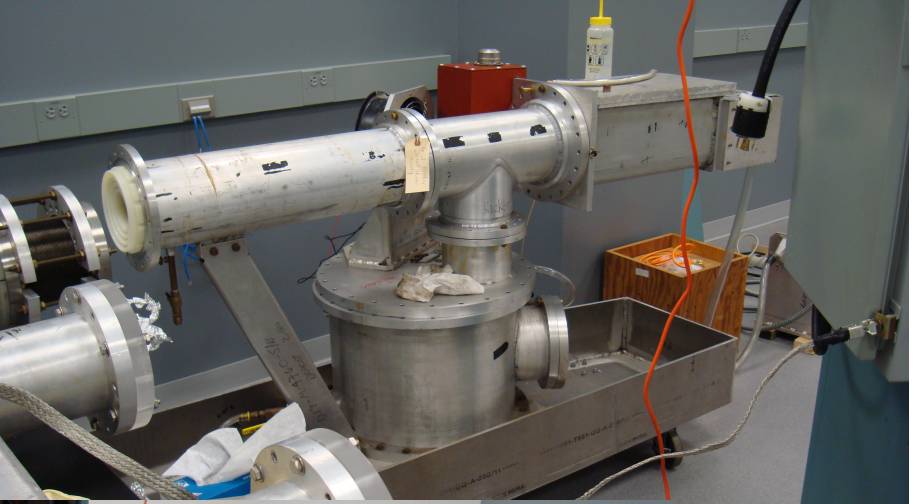


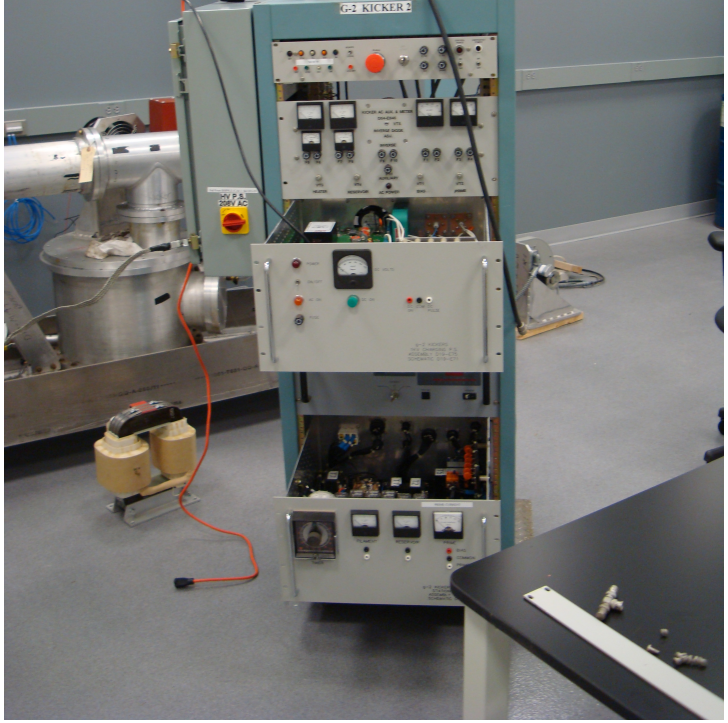


Kicker chamber

Pulser feed

Pulser housing





High voltage feedthrough

Plan for E-821 prototype kicker /pulser test

Reassemble

Test at low voltage (no oil) and measure field with single turn coil
Test at 100kV with high voltage components in oil

Injected Beam dynamics

Weak focusing – with vertical focusing from electrostatic quadrupoles approximately uniformly distributed around ring

Field index n≈0.139

$$\beta_x = \frac{R}{\sqrt{1-n}} = 7.67 \text{ m}$$

$$Q_x = \frac{R}{\beta_x} = 0.927$$

$$\eta = \frac{R}{1-n} = 8.26 \text{ m}$$

$$x_{\text{inf}} = 7.7 \text{ cm}$$

$$x(s) = x_{\text{inf}} \cos\phi_x + \beta x'_{\text{inf}} \sin\phi_x$$

$$x'(s) = -\frac{x_{\text{inf}}}{\beta} \sin\phi_x + x'_{\text{inf}} \cos\phi_x$$

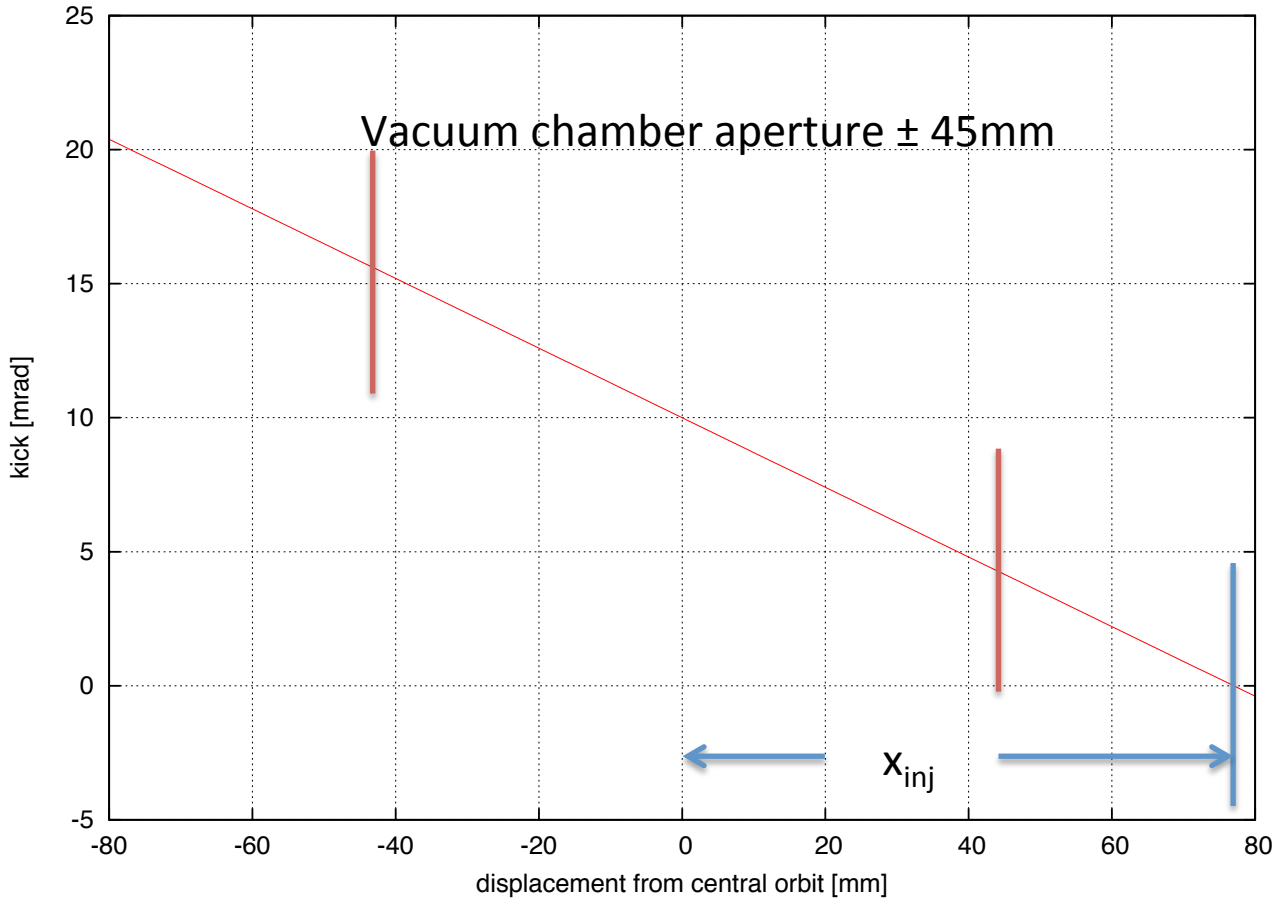
$$\text{At } \phi_x = \pi/2,\ x(s) = 0,\ \text{and } x'(s) = -x_{\text{inf}}/\beta$$

Kicker changes angle by $\theta = x_{inf}/\beta \cong 10$ mrad to put injected muons on central orbit

Now suppose the injected muon has fractional energy error $\Delta E/E = \delta$

$$\begin{aligned} x_{\text{inf}} &= x_\beta + \eta\delta \\ \rightarrow x_\beta &= x_{\text{inf}} - \eta\delta \\ x(s) &= (x_{\text{inf}} - \eta\delta)\cos\phi + \eta\delta \\ \rightarrow x(\frac{\pi}{2}) &= \eta\delta \\ \rightarrow x'(\frac{\pi}{2}) &= -\frac{x_{\text{inf}} - \eta\delta}{\beta} \end{aligned}$$

The ideal kick for off energy muons is $\theta = (x_{inf} - x)/\beta$



Energy dependence

If the kicker field depends on displacement from central orbit according to kick [mrad] ≈ $10(1-x/x_{inj})$ then all energies kicked onto corresponding closed orbit

Dependence on angular distribution of injected muons

$$
\begin{aligned}
x(s) &= x_{\mathrm{inf}} \cos\phi_x + \beta x'_{\mathrm{inf}} \sin\phi_x \\
x'(s) &= -\frac{x_{\mathrm{inf}}}{\beta} \sin\phi_x + x'_{\mathrm{inf}} \cos\phi_x
\end{aligned}
$$

Then at Φ = π/2

$$
\begin{aligned}
x(\frac{\pi}{2}) &= \beta x'_{\mathrm{inf}} \\
x'(\frac{\pi}{2}) &= -\frac{x_{\mathrm{inf}}}{\beta}
\end{aligned}
$$

There is no kick that puts the muon onto the central orbit
The best we can do is to minimize the invariant amplitude

Invariant amplitude $$a = \frac{x^2}{\beta} + \beta x'^2$$

The best we can do with the kicker is to set angle to zero.

Then $$a_{min} = \frac{x^2}{\beta} = \beta x'^2_{\mathrm{inj}}$$

If the kick is not uniform but has radial dependence to match energy offset then

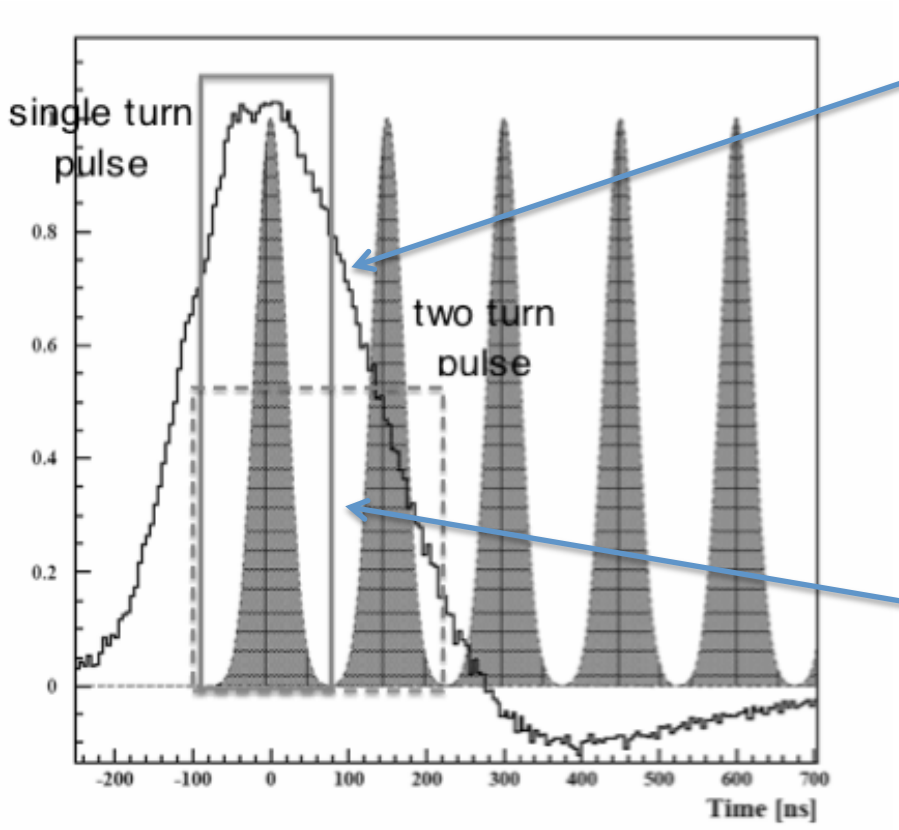
$$a = 2\beta x'^2_{\mathrm{inj}} = 2a_{min}$$

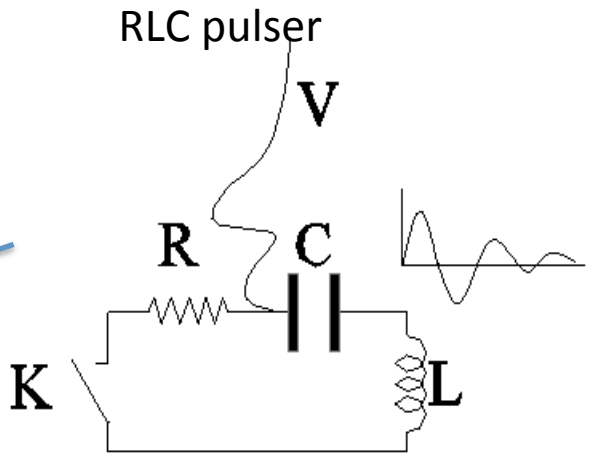
We find that the kick that minimizes the betatron amplitude of off energy muons will increase the amplitude for on energy particles with finite injection angle

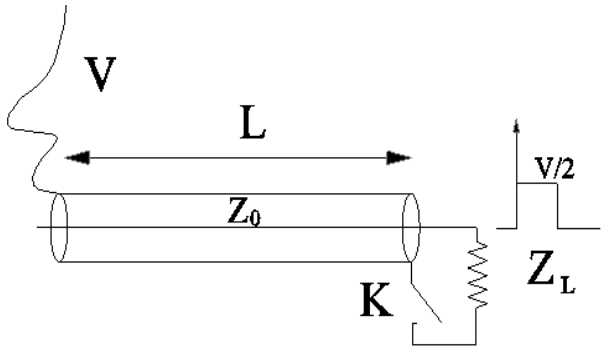
Optimal kicker field profile depends on energy and angular distribution of muons exiting the inflector

Time Dependence

Kicker Pulse width

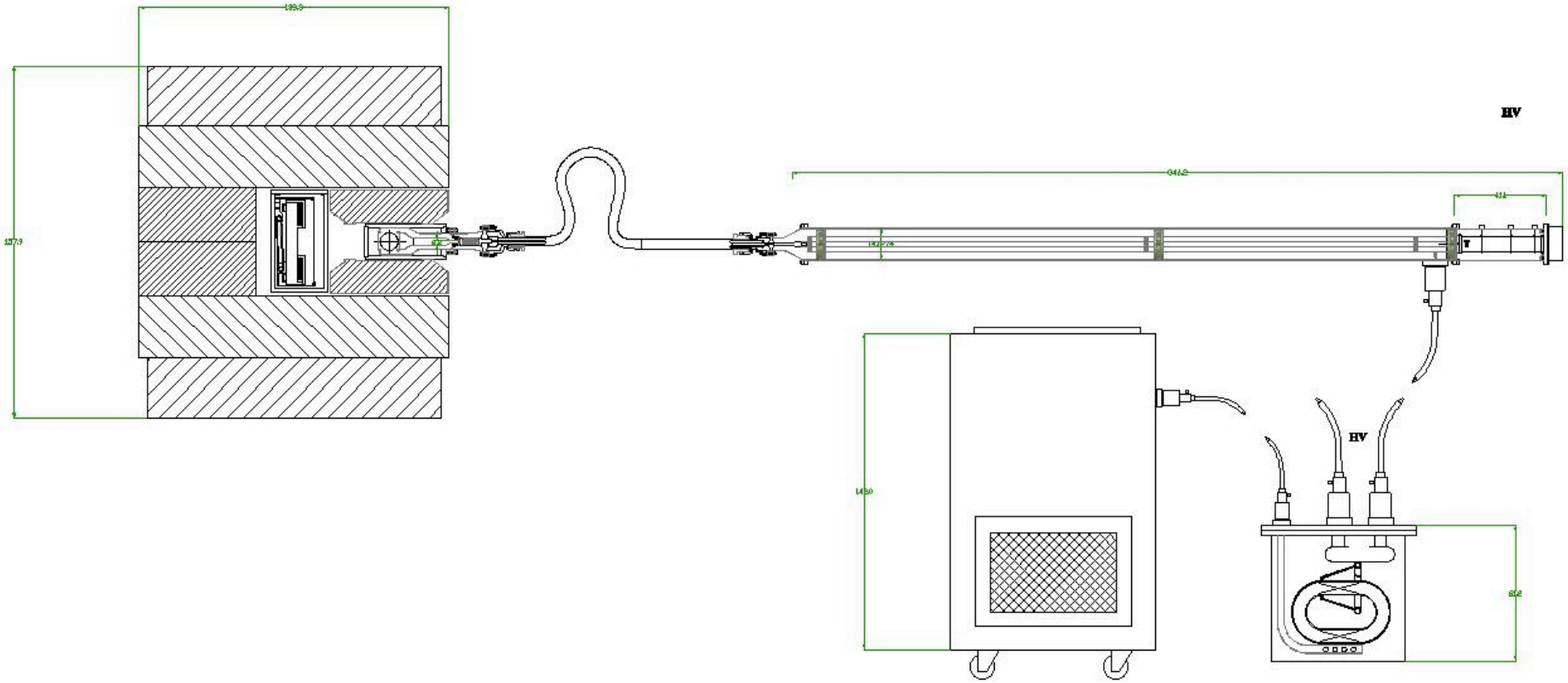




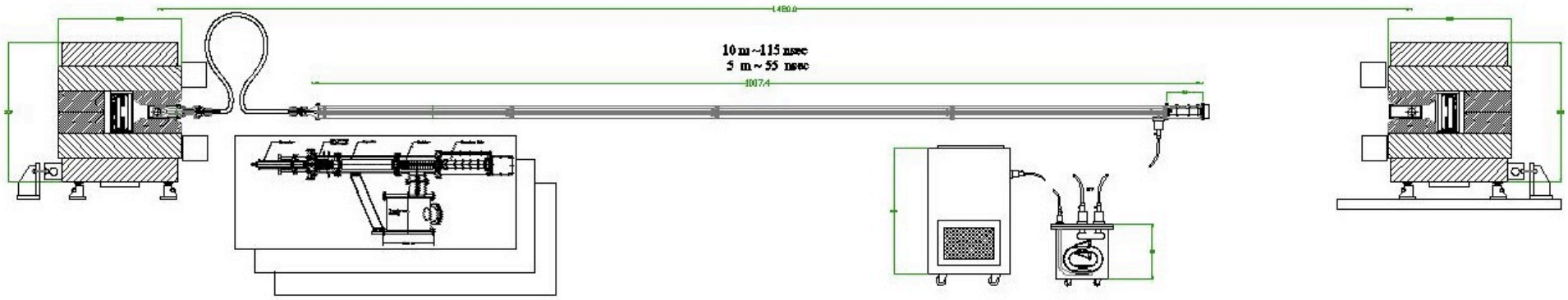


Matched line ($Z_0 = Z_L$)

$\tau = 2L/c \sqrt{(\mu_r \varepsilon_r)}$

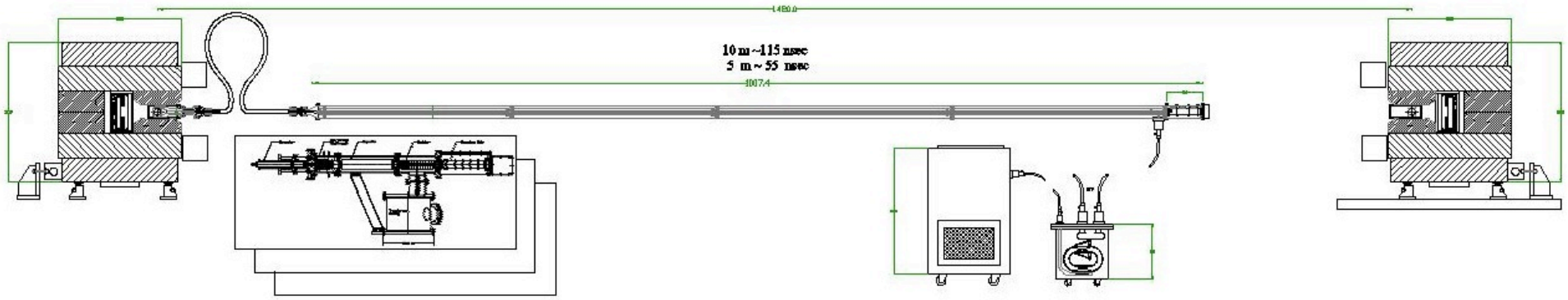

HV
HV

L=10m => τ = 115 ms

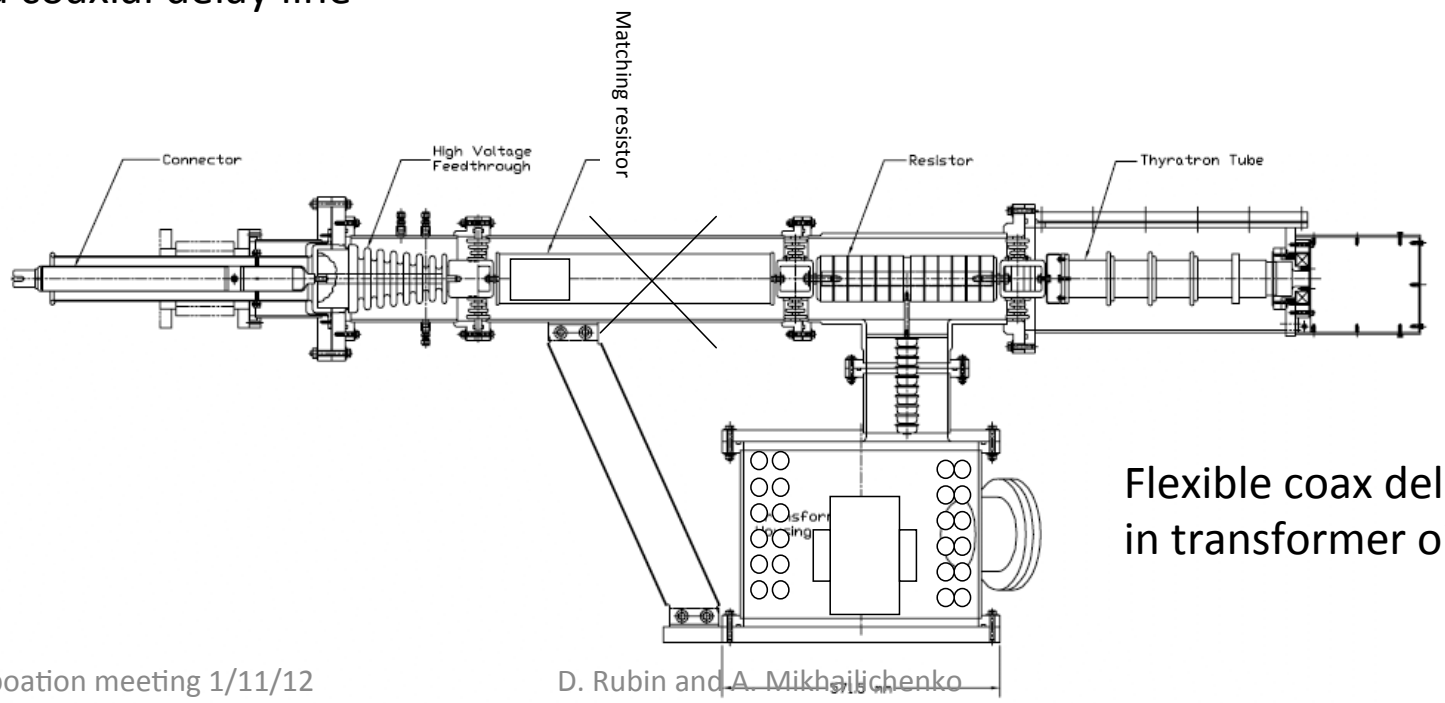


Rigid coaxial delay line

L=10m => τ = 115 ms



Rigid coaxial delay line



Flexible coax delay line in transformer oil tank

Matched line PFN issues

1. Current I = V/Z and the impedance of the kicker magnet is relatively high (Z>100Ω),
   implying a high charging voltage. (Require I ≈ 4kA)
2. If muon bunch is long, then so is the coax
3. Mismatch of impedance of line and load gives reflections. Quantify ?
4. Voltage on kicker is half the charging voltage implying an even higher charging voltage (Blumlein ?)

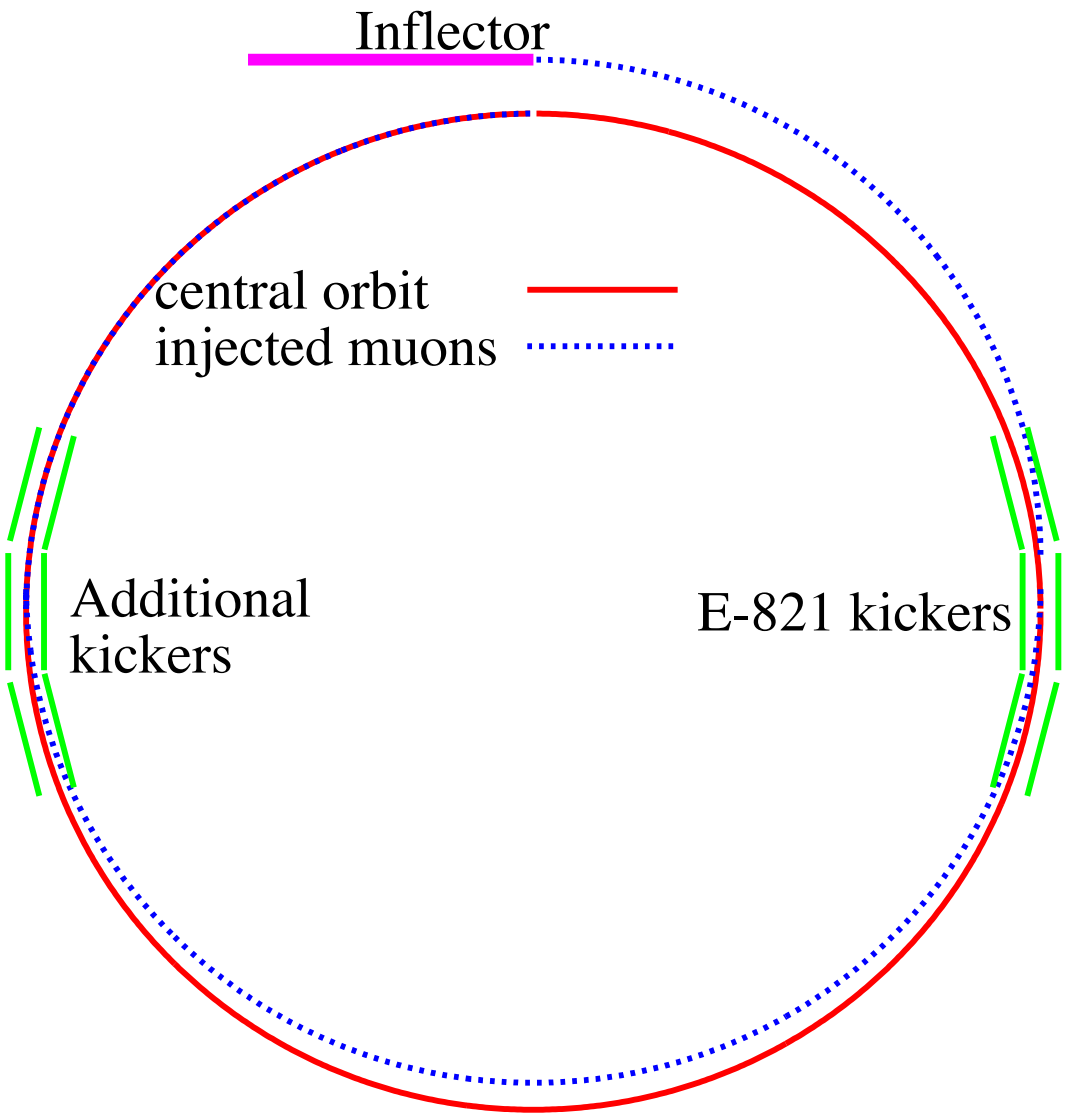
We will test sensitivity to impedance match at low voltage

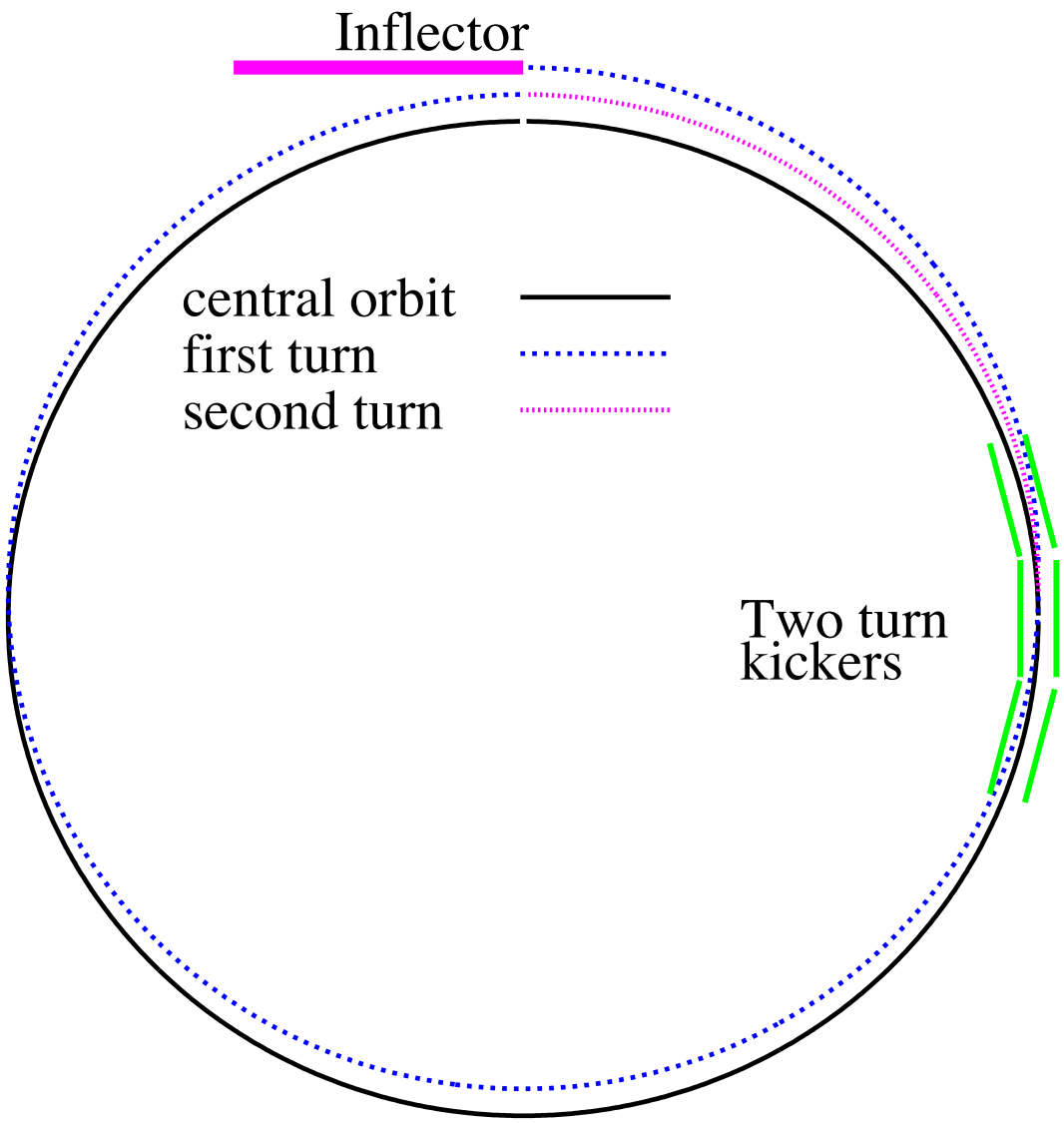
1. With flexible coax delay line
2. Rigid line

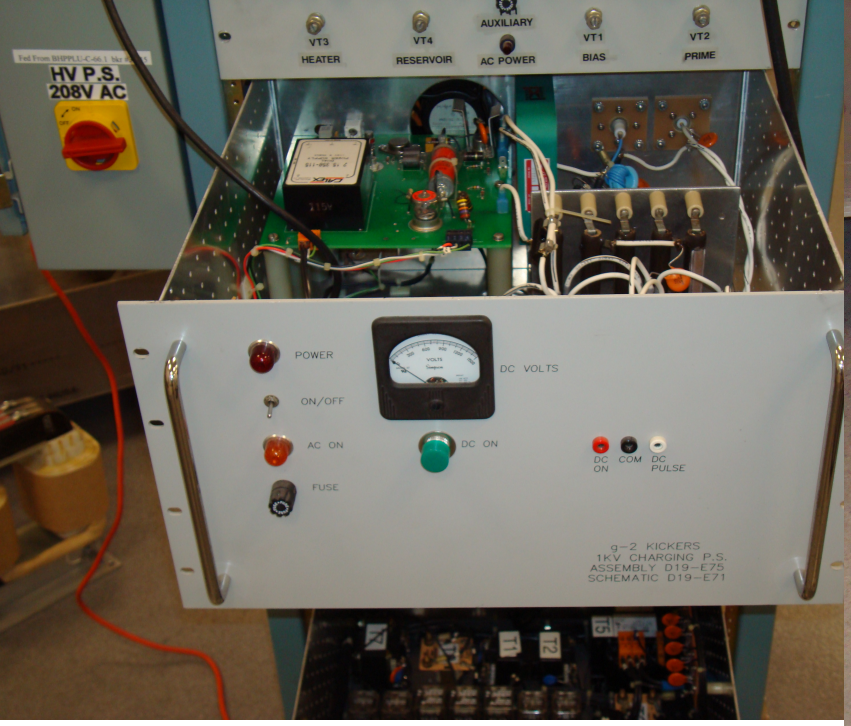
Conclusion

- Reconstruction and test of E-821 prototype kicker and pulser is underway
- Low voltage tests of delay line pulse forming network
- Explore alternative kicker plate geometry for
    - lower impedance
    - optimal field profile
- Investigate in simulation sensitivity to muon energy and angular distribution and bunch length

Bunch length – shorter is easier to deal with
We can achieve good acceptance for energy spread or angular spread but not both


Inflector
central orbit
injected muons
Additional
kickers
E-821 kickers


Inflector
central orbit
first turn
second turn
Two turn
kickers


HV P.S.
208V AC
VT3
HEATER
VT4
RESERVOIR
AUXILIARY
AC POWER
VT1
BIAS
VT2
PRIME
POWER
ON/OFF
AC ON
FUSE
DC VOLTS
DC ON
DC ON
COM
DC PULSE
g-2 KICKERS
1KV CHARGING P.S.
ASSEMBLY D19-E75
SCHEMATIC D19-E71