Time of flight identification of ions around accelerated beams

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• Ion densities in the beam pipe from scattering on the dilute gas
• Ions can then effect the motion and emittance of the beam, for example:
  – Fast ion instability
    • coupling between ions and the beam propagates down the train and severely disturbs the later bunches
  – Non-linear focusing
    • $1/r$ accumulation of the ion density around the beam results in emittance growth
• So we want to identify the ions in the beam pipe - primarily to evaluate the viability of various ion clearing methods
• My project has been constructing a time-of-flight experiment to install on the ERL gun and identify the ions
A First Look:

\[ \frac{1}{2}mv^2 = qV \]

\[ t = \frac{l}{v} \]

\[ t = \frac{l}{\sqrt{2V}} \sqrt{\frac{m}{q}} \]
• Required temporal resolution: 0.05 micro-second

\[ \Delta t = \left( \frac{l}{2} \sqrt{\frac{m}{2qV}} \right) \frac{\Delta m}{m} \]

• Actual detector encompasses the gate ring, focus ring, drift chamber, and detector
  – Rest of the apparatus used to measure the signals from the detector and achieve appropriate resolution
• The detector is an electron multiplier, a ‘Channeltron’, which converts incident ions, via an electron cascade, into a measurable signal
• Gate ring gates the flow of ions into the detector
• Focus ring focuses ions into the detector at -200V
• Drift chamber imparts -400V to the ions per TOF scheme
• The detector:
• **Test assembly:**
  – Filament heated to generate electrons to scatter on gas and produce ions
  – Leak valve installed to allow control of gas concentrations for calibration of the detector
Test assembly and detector

Ion signals on oscilloscope
• To start TOF measurements,
  – Pulse the gate ring to discharge it and allow the ions to enter the detector
  – Use the same pulse to trigger a measurement device
  – Watch for the first signals from the Channeltron
  – Use a time-to-amplitude converter to generate a pulse with an amplitude proportional to the time between the start pulse for the gate ring and the pulse from the Channeltron

• In this manner, we can get the distribution we are looking for
  – A distribution of no. of ions versus time, and calculate the relative concentration of different ion species/charge of the ion density in the beam pipe
• TOF begins on switching gate ring:
- At the same time we start a TAC and stop it with ion signals
- Then we record the voltage of the TAC output signals and their count
• Measurement setup with additional equipment for test assembly
• **Results:**
  – Assembly of the experiment through test assembly phase
  – Reliable detection of ion signals
  – Successful gating of ions
  – But noise problems persist
  – And resolution problems render TOF distributions meaningless
• TOF experiment
  – Test assembly
  – CESR
  – ERL
• Test assembly (current state) for calibration of the detector by correlating measurements to known ion densities
• Installation on CESR in September
• Sometime thereafter installation on ERL gun
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