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Title: Beam Development\_V6MP

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# Conditions....

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- In CCR,
  - Loss Measurements, 03AP – McCrady
  - FTP files to Flash Drives via Laptop, took notes - Sedillo
  - Running WSNAD and expert screens - Gilpatrick
- Gates: LBEG, MPEG, and H+IP
- Beam conditions: 4 Hz, 0.15 ms; 7.5- to 12.75-mA<sub>pk</sub>
- Wire Biased at -12 Volts
- Tungsten (W) sense wire; 0.1 mm
  - Density = 19.3 g/cm<sup>3</sup>
  - Assumed square wire cross-section for simplicity
- “New” wire scanners in locations 03WS001, 04WS001, 10WS001, 11WS001, 14WS001, 15WS001, 16WS001, 17WS001, LXWS005.
  - Took data at 03WS001, 04WS001, 10WS001, 11WS001

## Sternglass states.....

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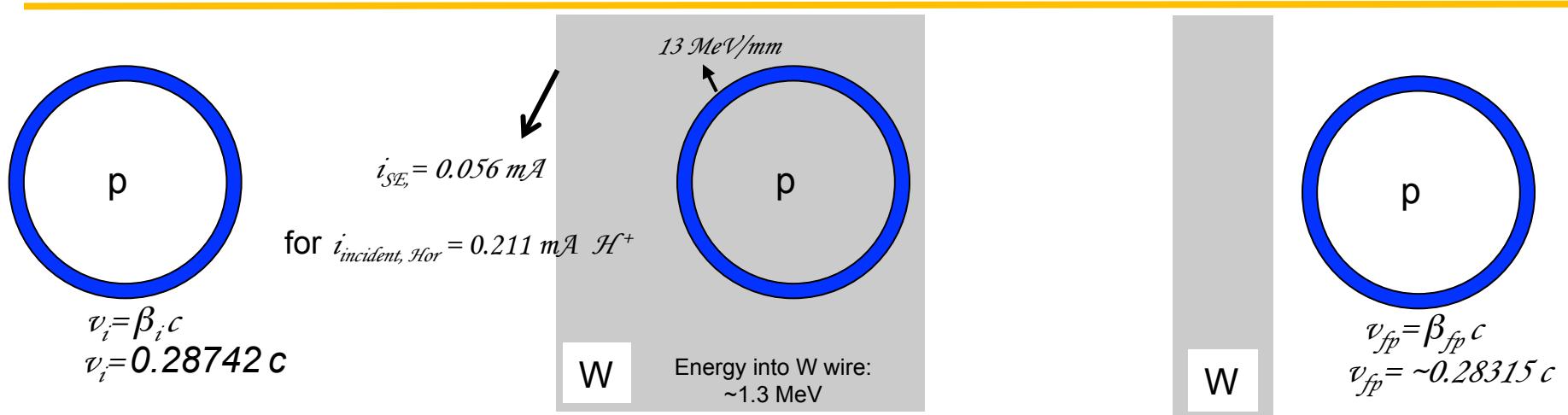
$$\Upsilon = \frac{Pd}{\varepsilon} \frac{dE}{dx} = \left(0.002 \text{ cm/MeV}\right) \frac{dE}{dx}$$

- $\Upsilon$  is the SE yield from a proton beam current impinging on the W wire
- $P$  is the probability that an electron will escape from the W wire material (typically,  $\sim 0.5$ )
- $d$  is the average depth from which electron escape from the W wire material (typically,  $\sim 1$  nm)
- $\varepsilon$  is the average amount of kinetic energy lost by an ion per ionization in material (typically,  $\sim 25$  eV)
- $\frac{dE}{dx}$  is the stopping power of the  $\text{H}^+$  or  $\text{H}^-$  beam with the material density taken into account.

■ The secondary electron emission current,  $i_{SE}$ , from a beam impinging on a sense wire,  $i_{Beam}$ , is .....

$$i_{SE} = \Upsilon i_{Incident}$$

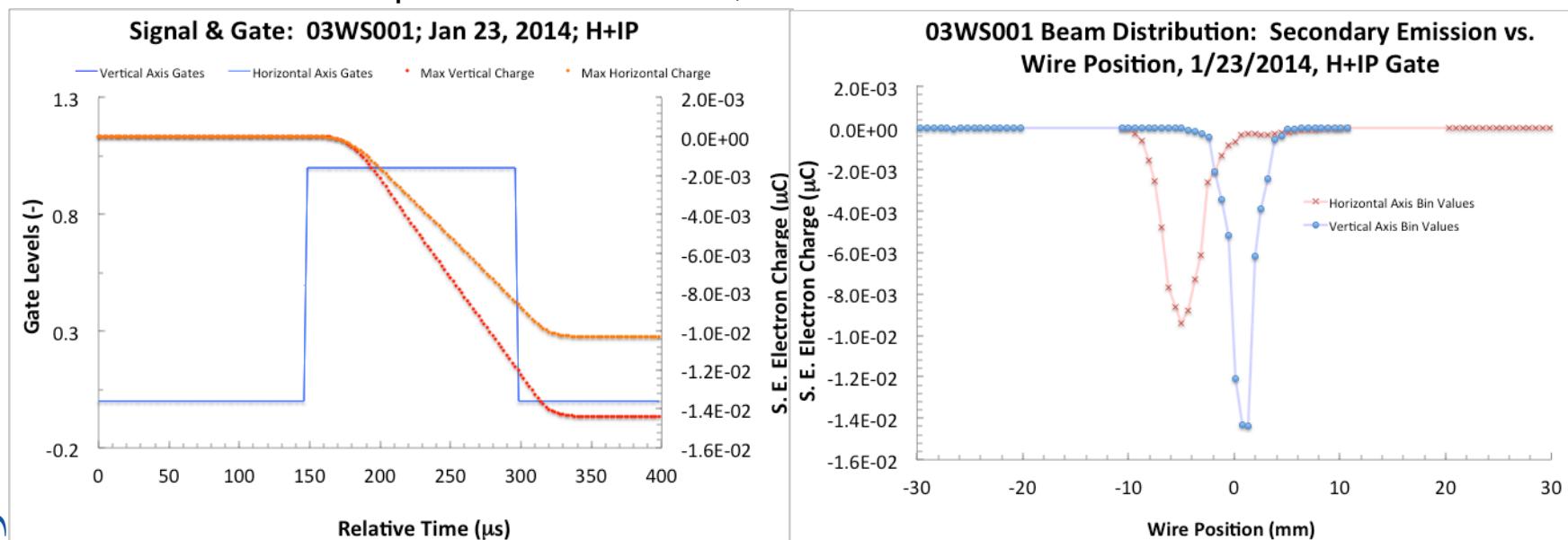
# $H^+$ beam interacts with a W sense wire – Sternglass theory for SE current.



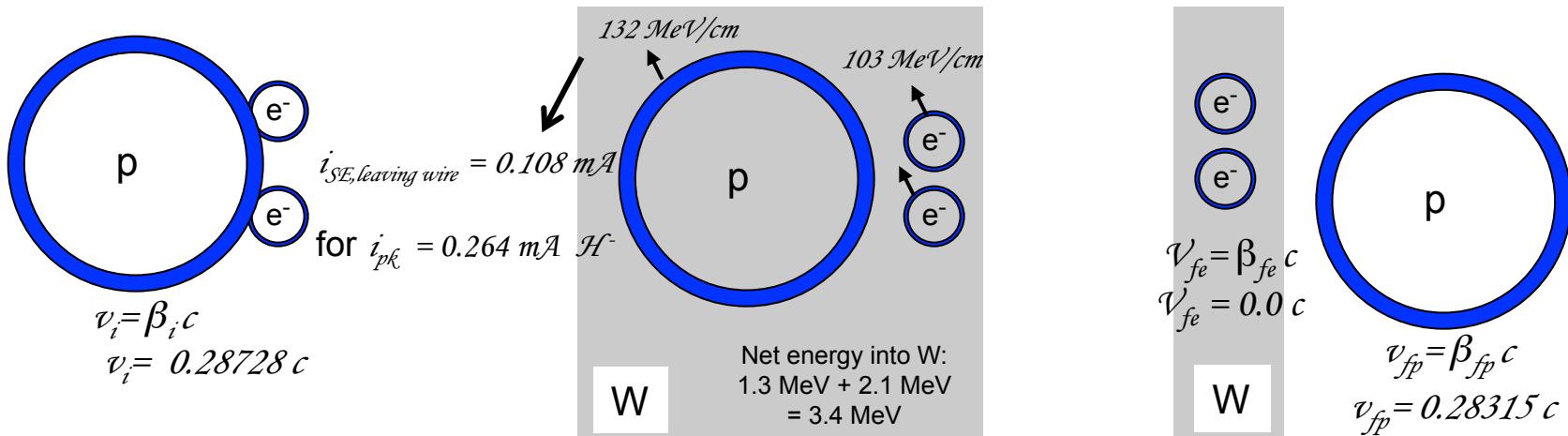
- **Initial  $H^+$  beam at tank #3 input: nom. 41.3353 MeV**
  - ~1 secondary electron for every 3.8 incident protons impinging on wire material
    - Stopping Power = ~132 MeV/cm in W; Range (CSDA) = ~0.19 mm in W
- **$H^+$  beam at spatial peak, 0.211 mA incident current, normalized to 10 mA**
  - 2.47- X 1.31-mm (1.89 mm - round beam), 12.75-mA (TDCM001), 4-Hz X 0.15-ms, H +IP gated beam

## Observed H<sup>+</sup> beam at 03WS001 location; Jan 23 data

- Beam  $dq$  and  $dt$ : 14.4- or 10.3-nC in 140  $\mu$ s or 0.087 mA incident beam for a total of 12.75 mA<sub>pk</sub> (TDCM001), normalized to 10 mA.
  - Rms width: 2.47 mm (Hor) X 1.31 mm (Ver)
- Secondary emission current: -0.069 mA at spatial peak
  - Comparison: ~-124%, current of Sternglass theory (compared to 0.056 mA)
  - Should be a “positive” distribution; electron flow vs. “conventional” flow



# H<sup>-</sup> beam at 03WS001 location, Jan 23 data, Sternglass theory for SE current

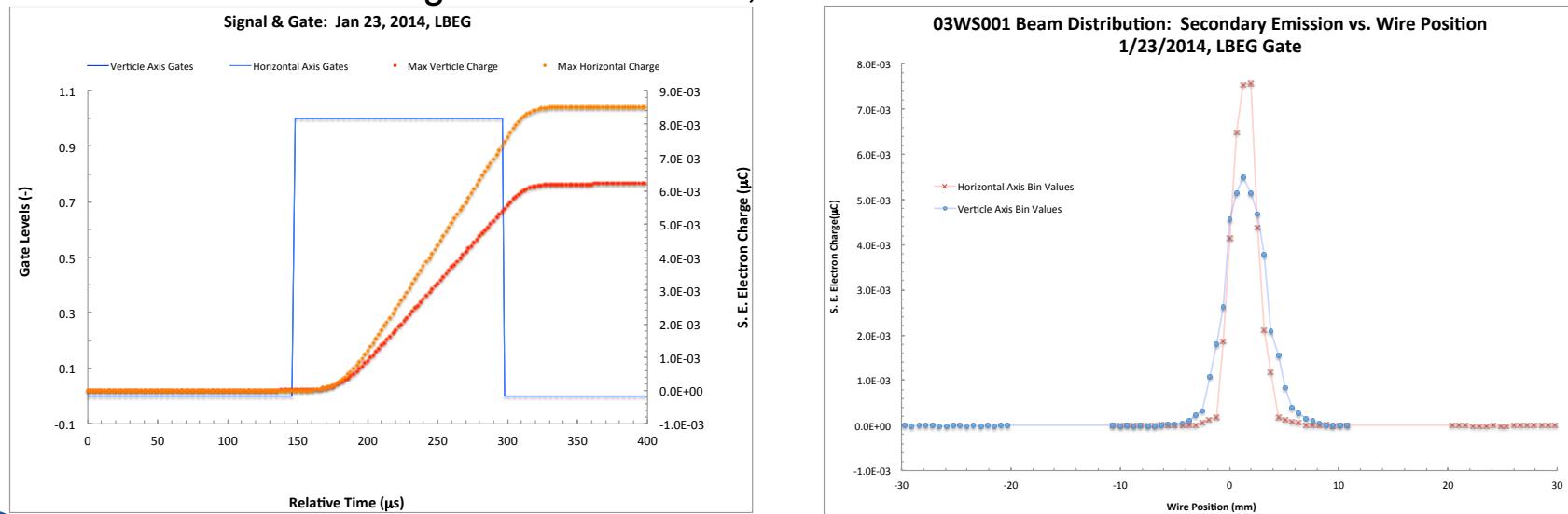


- Initial H<sup>-</sup> beam at tank #3 input: nom. 41.3353 MeV

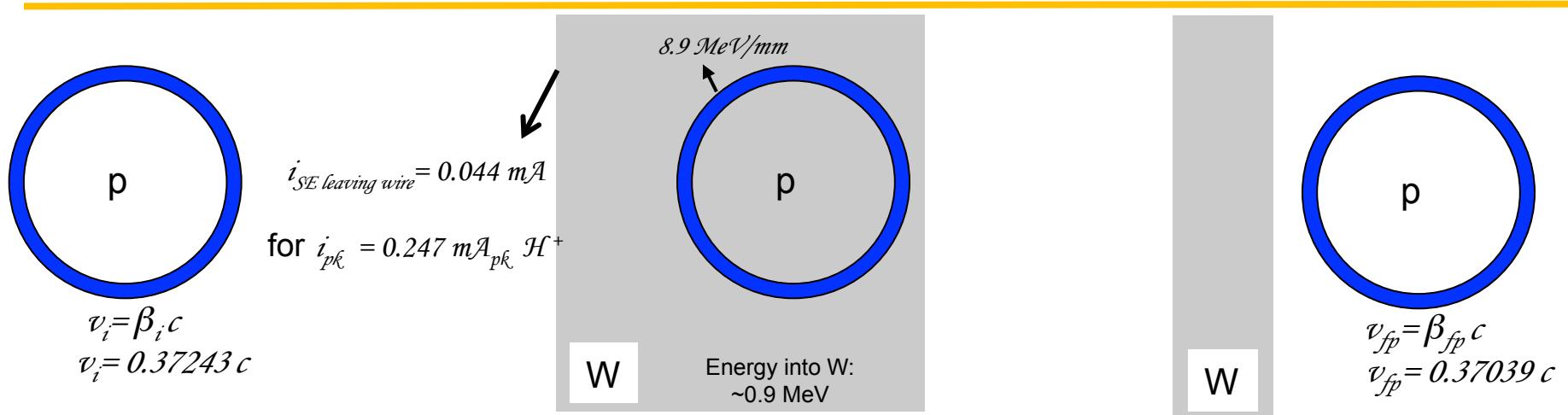
- Total: ~1 secondary electron for every 2.44 incident H<sup>-</sup> particles into W wire
  - ~1 secondary electron for every 3.79 incident H<sup>-</sup> particles into wire
    - Stopping Power = 132 MeV/cm in W; Range (CSDA) = ~0.19 mm in W
    - ~1 secondary electron for every 4.85 incident H<sup>-</sup> particles into wire; however, 2 electrons per incident H<sup>-</sup> particle are stripped and stopped in wire.
      - Stopping Power = 103 MeV/cm in W; Range (CSDA) = 0.00014 cm in W
      - Right after stripping, electrons energy: 22.48 keV
- H<sup>-</sup> Impingement at spatial peak, 0.264 mA incident current, normalized to 10 mA

## H- beam at 03WS001 location; Jan 23 data

- Observed peak  $dq$  and  $dt$ ; average of 8.5- or 6.2-nC in 140  $\mu$ s, Navg = 1, 4-Hz X 0.15-ms beam or 0.053 mA
  - Observed 10.5 mA<sub>pk</sub> at TDCM001, normalized to 10 mA
    - Rms width: 1.18 mm (Hor) X 1.85 mm (Ver)
  - Observed current: 0.050 mA at spatial peak
    - Observation, ~46% current of Sternglass theory (compared to 0.108 mA)
    - Should be a “negative” distribution; electron flow vs. “conventional” flow



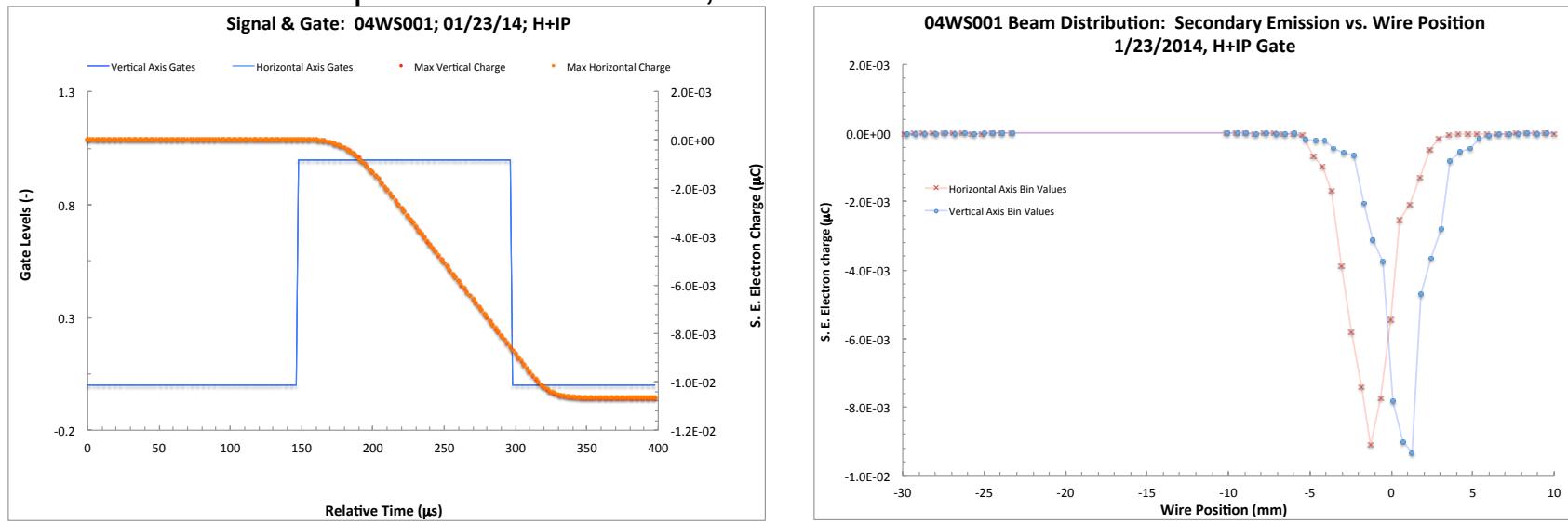
# H<sup>+</sup> beam at 04WS001 location, Jan 23 data, Sternglass theory for SE current



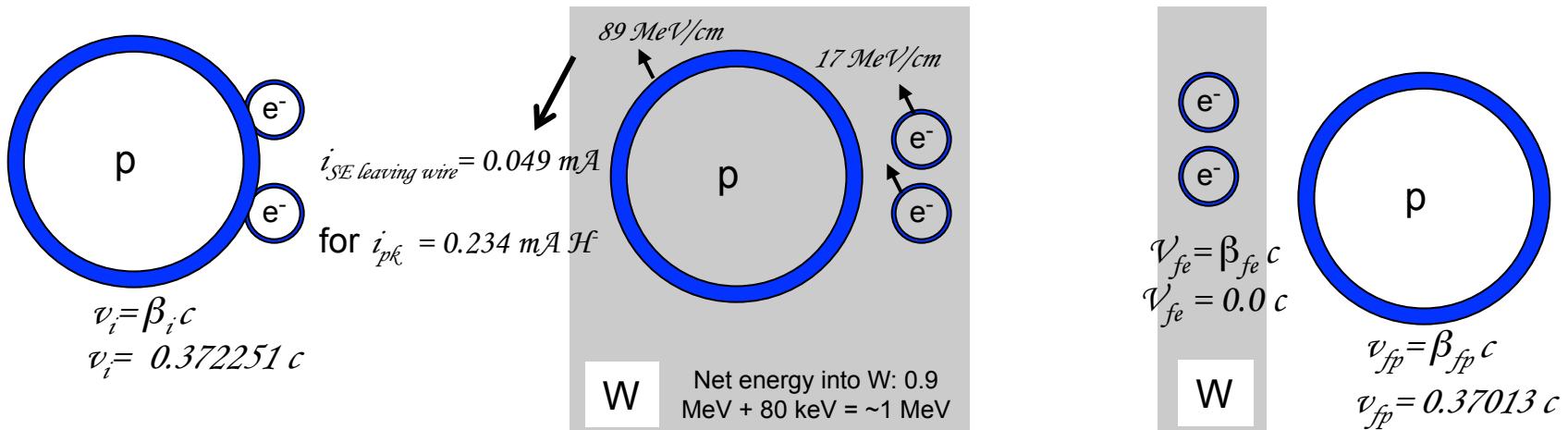
- **Initial H<sup>+</sup> beam at tank #4 input: nom. 72.7322 MeV**
  - About 1 secondary electron (SE) for every 5.6 incident protons into wire material
    - Stopping Power = ~88.8 MeV/cm in W; Range (CSDA) = ~0.48 mm in W
- **H<sup>+</sup> beam at spatial peak, 0.247 mA incident current, normalized to 10 mA**
  - 1.53- X 1.65-mm (1.61 mm – projected round beam), 12.75-mA (TDCM001), 4-Hz X 0.15-ms beam, H+IP gated beam

# H<sup>+</sup> beam at 04WS001 location; Jan 23 data

- **Observed peak  $dq$  and  $dt$ : 10.7 nC in 140  $\mu$ s,  $N_{avg} = 1$ , 4-Hz X 0.15-ms beam or 0.076 mA**
  - Observed 12.75 mA<sub>pk</sub> at TDCM001, normalized to 10 mA.
    - Rms width: 1.53 mm (Hor) X 1.65 mm (Ver)
  - Observed peak current: ~0.060 mA at spatial peak
    - Observation, ~136% current of Sternglass theory (compared to 0.044 mA)
    - Should be a “positive” distribution; electron flow vs. “conventional” flow



# H<sup>-</sup> beam at 04WS001 location, Jan 23 data, Sternglass theory for SE current

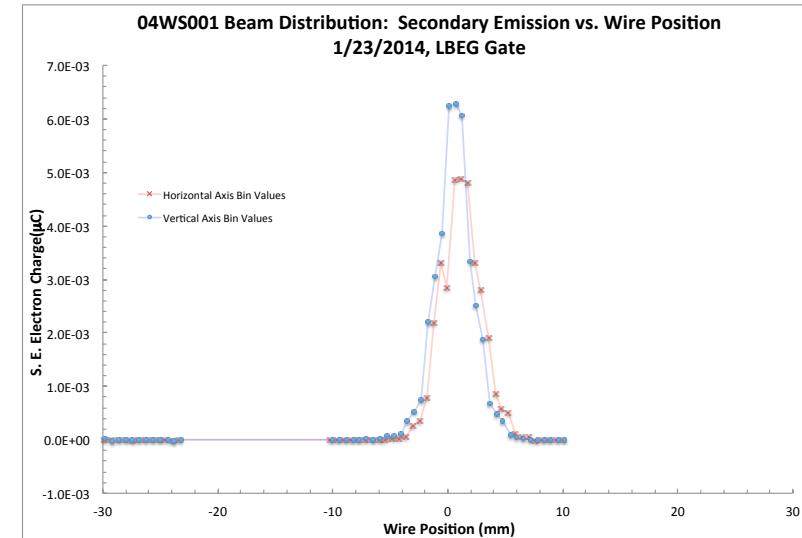
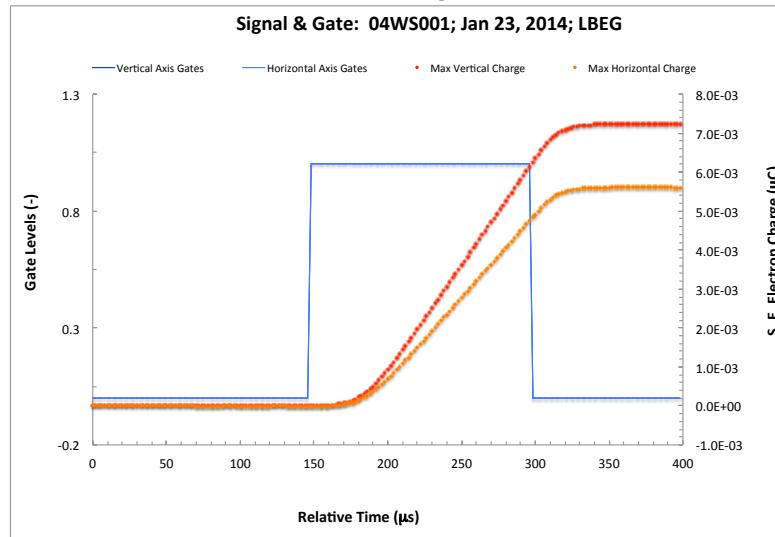


- Initial H<sup>-</sup> beam at tank #4 input: nom. 72.7322 MeV

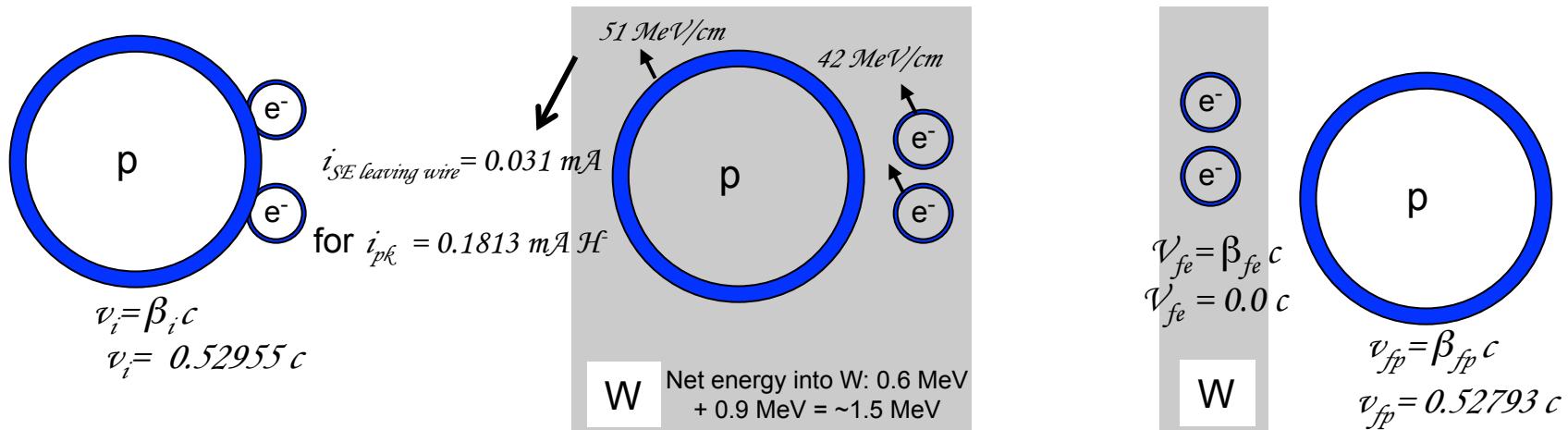
- Total: ~1 secondary electron for every 4.767 incident H<sup>-</sup> particles into W wire
- ~1 secondary electron for every 5.63 incident protons (in H<sup>-</sup> particles into wire)
  - Stopping Power = 88.8 MeV/cm in W; Range (CSDA) = ~0.48 cm in W
- ~1 secondary electron for every 29.1 incident electron (in H<sup>-</sup> particles into wire), however, 2 electrons per incident H<sup>-</sup> particle are stripped and stopped in wire.
  - Stopping Power = 17.2 MeV/cm in W; Range (CSDA) = 0.00034 cm in W
  - Right after stripping, electron energy: 39.57 keV
- H<sup>-</sup> Impingement at spatial peak, 0.234 mA current for 0.1-mm W wire

# H<sup>-</sup> beam at 04WS001 location; Jan 23 data

- Observed peak  $dq$  and  $dt$ ; average of 5.6- & 7.2-nC in 140  $\mu$ s, Navg = 1, 4-Hz X 0.15-ms beam or 0.054 mA
  - Observed 10.5 mA<sub>pk</sub> at TDCM001
    - Rms width: 1.73 mm (Hor) X 1.66 mm (Ver)
  - Observed current: 0.051 mA at spatial peak
    - Observation, ~105% current of Sternglass theory (compared to 0.049 mA)
    - Should be a “negative” distribution; electron flow vs. “conventional” flow



# H<sup>-</sup> beam at 10WS001 location, Nov 17, 2013 data, Sternglass theory for SE current



- Initial H<sup>-</sup> beam at CCL module #10 input: nom. 168.0 MeV

- Total: ~1 secondary electron for every 5.8261 incident H<sup>-</sup> particles into W wire
- ~1 secondary electron for every 9.8371 incident protons (in H<sup>-</sup> particles into wire)
  - Stopping Power = 50.82781 MeV/cm in W; Range (CSDA) = ~2 cm in W
- ~1 secondary electron for every 12.2888 incident electrons (in H<sup>-</sup> particles into wire), however, 2 electrons per incident H<sup>-</sup> particle are stripped and stopped in wire.
  - Stopping Power = 40.6873 MeV/cm in W; Range (CSDA) = 0.0013 cm in W
  - Right after stripping, electron energy: 91.396 keV

H<sup>-</sup> Impingement at spatial peak, 0.1813 mA incident current, normalized to 10 mA.

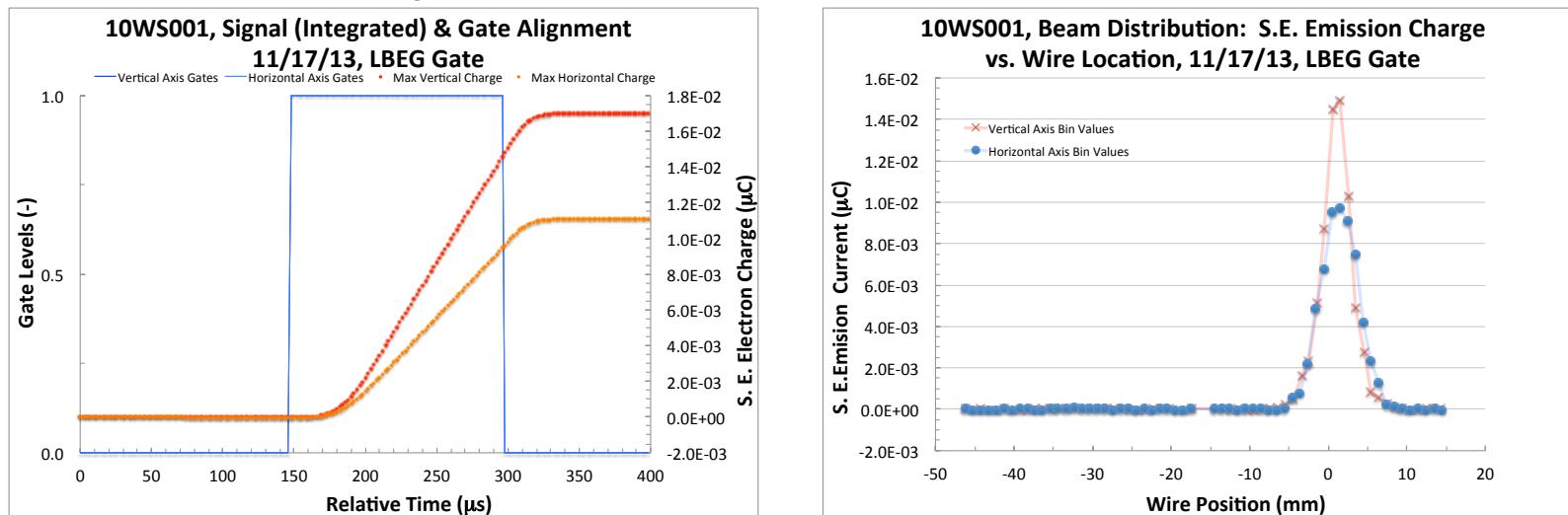
233- X 2.07-mm (2.20 mm projected round beam), 7.7-mA (14CM001), 4-Hz X 0.15-ms LBEG gated beam

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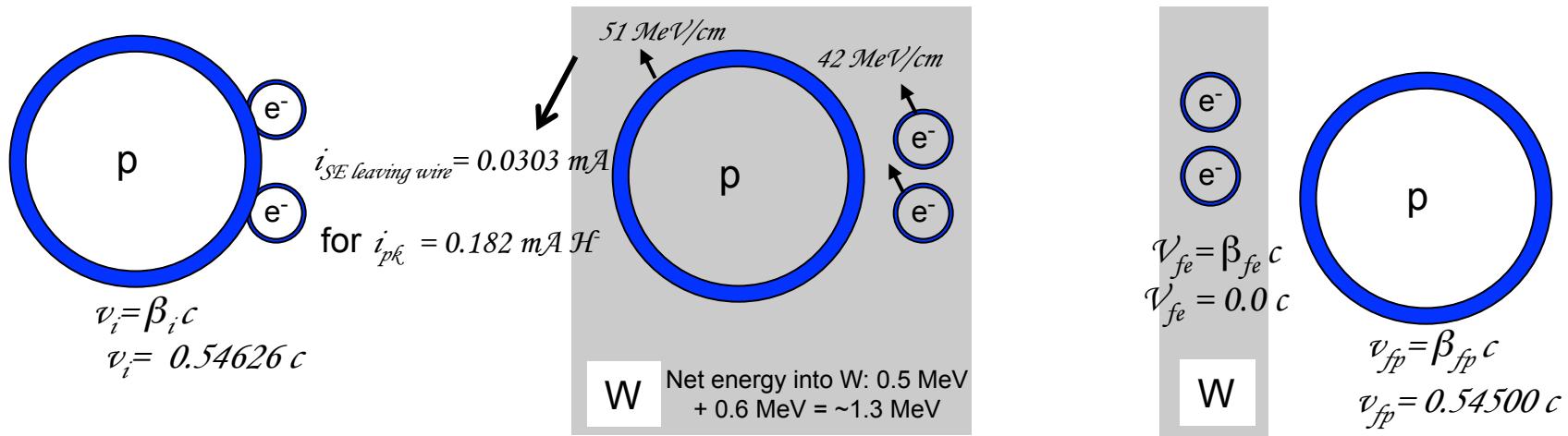


## H- beam at 10WS001 location; Nov 17, 2013 data

- Observed peak  $dq$  and  $dt$ ; average of  $\sim 11.1$ - &  $\sim 17.0$ -nC in  $\sim 140$   $\mu$ s, Navg = 1, 4-Hz X  $\sim 0.15$ -ms beam or  $\sim 0.10$  mA
  - Observed  $7.7$  mA<sub>pk</sub> at 14CM001 [Normalized to 10 mA or 0.13 mA]
    - Rms width: 2.33 mm (Hor) X 2.07 mm (Ver)
  - Observed current: 0.13 mA at spatial peak
    - Observation,  $\sim 4.2$ X current of Sternglass theory (compared to 0.0312 mA)
    - Should be a “negative” distribution; electron flow vs. “conventional” flow



# H<sup>-</sup> beam at 11WS001 location, Nov 17, 2013 data, Sternglass theory for SE current



## ■ Initial H<sup>-</sup> beam at CCL module #11 input: nom. 182.1 MeV

- Total: ~1 secondary electron for every 6.0195 incident H<sup>-</sup> particles into W wire
- ~1 secondary electron for every 10.4 incident protons (in H<sup>-</sup> particles into wire)
  - Stopping Power = 48.2 MeV/cm in W; Range (CSDA) = ~2.3 cm in W
- ~1 secondary electron for every 12.342 incident electrons (in H<sup>-</sup> particles into wire), however, 2 electrons per incident H<sup>-</sup> particle stripped/stopped in wire. 14.34 electrons
  - Stopping Power = 40.513 MeV/cm in W; Range (CSDA) = 0.0015 cm in W
  - Right after stripping, electron energy: 99.07 keV

H<sup>-</sup> Impingement at spatial peak, 0.1822 mA current for 0.1-mm W wire

## H- beam at 11WS001 location; Nov 17, 2013 data

- Observed peak  $dq$  and  $dt$ ; average of 12.5- & 15.5-nC in 140  $\mu$ s, Navg = 1, 4-Hz X 0.15-ms beam or 0.10 mA
  - Observed 7.5 mA<sub>pk</sub> at 14CM001 [Normalized to 10 mA or 0.133 mA]
    - Rms width: 2.43 mm (Hor) X 1.96 mm (Ver)
  - Observed current: 0.133 mA at spatial peak, normalized
    - Observation, ~4.4X current of Sternglass theory (compared to 0.0303 mA)
    - Should be a “negative” distribution; electron flow vs. “conventional” flow

