Beam Scraping Effect in SE Production
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1 Motivation of Study

- AGS Booster Au^{31+} injection efficiency is not high. Beam is scraped at the injection inflector - effects.
- SE production in PSR instability - scraping effect (M. Plum).
- SNS collimator surface - SE production.
- SE multipacting - possible role of scraping effect.

2 Status

- Factor of $\cos\theta^{-n}$ in SE production, where $0.8 \leq n \leq 1.5$ reported in literature (Seiler, 1983).
- Experiments done at $\theta \leq 80$ degrees.
- Observed peak SE production at 70 to 80 degrees - various explanations.
- If this peak production is true, then only factor of 5 increase of SE scraping effect from perpendicular hit - not significant.
- If it is not true, then what is the limit?
- Typically using electron collectors in previous experiments - question about accuracy with shallow angle of projectile.

3 Prepare for Study

- Possibility of using Booster and Tandem with proton and heavy ions at various velocities to get useful information.

- For SE production, electronic stopping (Coulomb collision) is dominant if $v > 10^8\ cm/s$.

- Sputtering effect (nuclear stopping) is not as important.

- Experiments show that under same velocity, proton and electron have similar SE production rate. Heavy-ions do the same (Borovsky et. al., 1989).

- Projectile charge state dependence.

  1. Bethe and Lindhard formulations predicted q^2 dependence.
  2. Various experiments support $\sim q^{1.7}$ dependence.

- Projectile energy dependence.

1. Sternglass model (1957)

$$Y = \frac{1.22q^2}{E_k} \log(2.76E_k) \left(1 + \frac{0.183}{0.183 + E_k}\right)$$

   E_k in MeV/u.

2. Seiler model (1983)

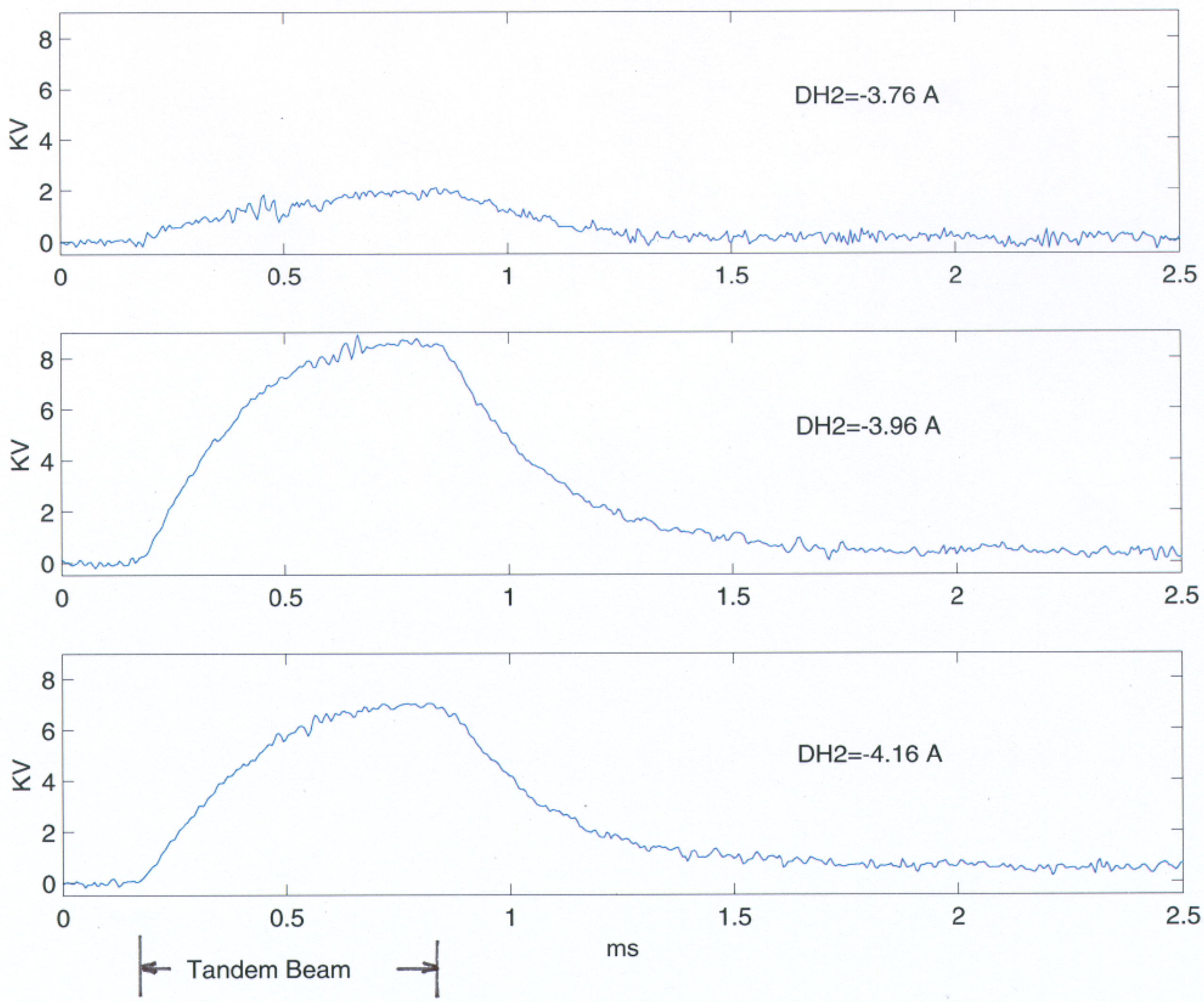
$$Y = 1.11 \left(\frac{E_{ek}}{E^{em}}\right)^{-0.35} \left(1 - \exp\left(-2.3 \left(\frac{E_{ek}}{E^{em}}\right)^{1.35}\right)\right)$$

   E^{em} is the projectile energy with maximum yield.

3. For the prediction of SE production at high energy, Seiler model has better fit.

4 Booster Study

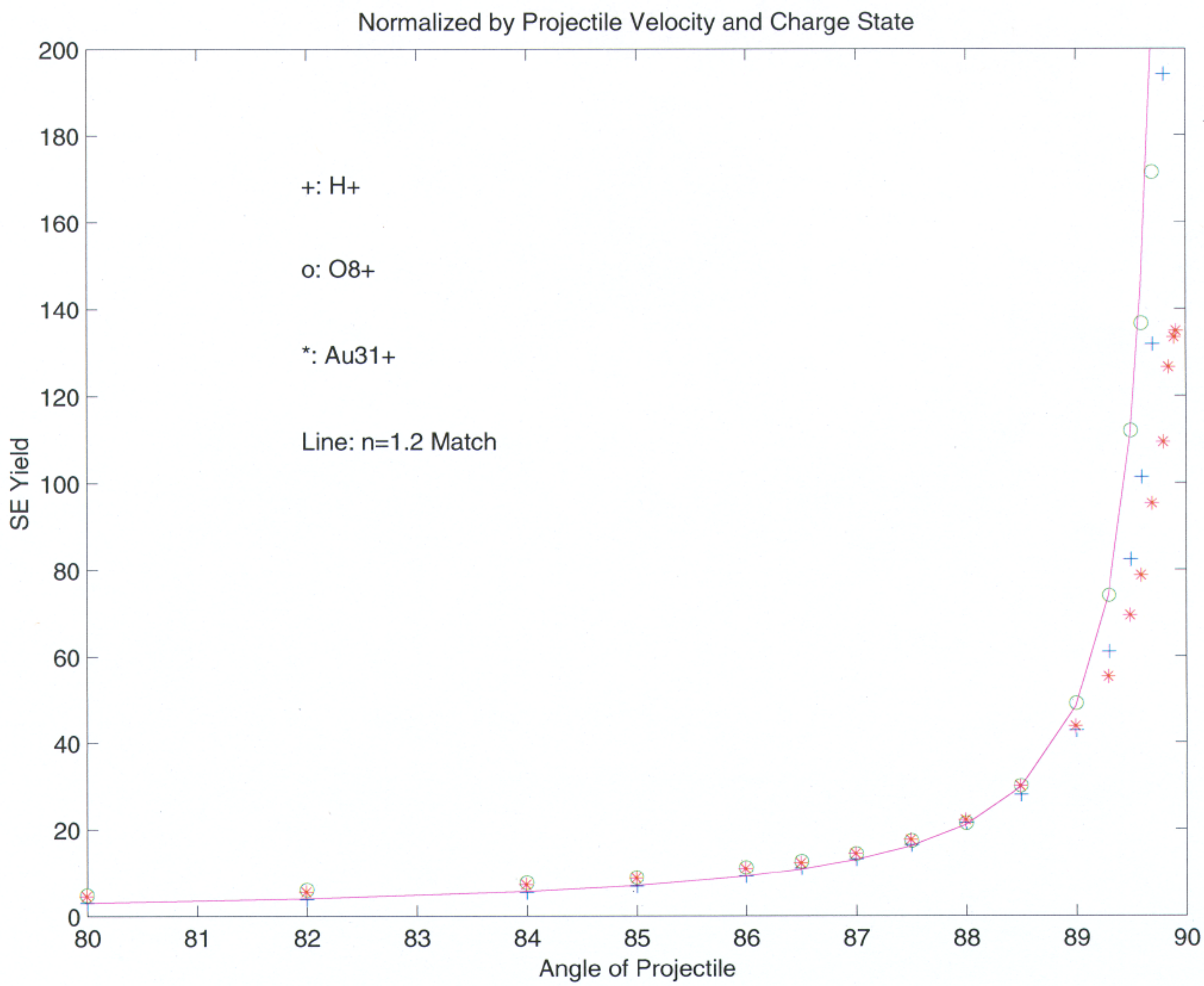
- By steering 3×10^9 Au^{31+} ions into Booster injection inflector cathode (-24 KV), a voltage increase of 8.5 KV was observed.
- The large SE production is due to the scraping effect. The estimated SE yield is 94,000 per lost Au^{31+} ion ($\beta = 0.044$).
- Beam size was large, FWHM size is 4 mm. Each 0.2 A of steering magnet corresponds to 0.5 mm horizontal position shift.
- The translated SNS yield is $\sim$ 27 per lost proton, about 100 times higher than the one without scraping effect. Actual yield should be higher.
- Geometry of the inflector does not allow accurate measurement in terms of incident angle, even use a collimator.
- Biased target is used in study to overcome the difficulties in scraping study using electron collectors.


DH2=-3.76 A
DH2=-3.96 A
DH2=-4.16 A
KV
ms
Tandem Beam

5 Tandem Study

- Using biased target, H^+, O^{8+}, and Au^{31+} ions scraping effect is studied. (P. Thieberger et. al., Physical Review A, in press).
- Faraday cup and collimator are used to improve the accuracy.
- In all 3 cases, data up to 89 degrees are fitting well into $\cos\theta^{-n} = \cos\theta^{-1.2}$.
- Scaling the yield.

  1. Using Seiler model, the H^+ ($\beta = 0.24$) yield is scaled by factor of 1/0.32, and O^{8+} ($\beta = 0.13$) by a factor of 1/0.52.
  2. Using the charge state factor of $q^{1.7}$, the O^{8+} yield is scaled by a factor of 1/34, and the Au^{31+} yield by a factor of 1/343.
  3. These scalings are found acceptable.



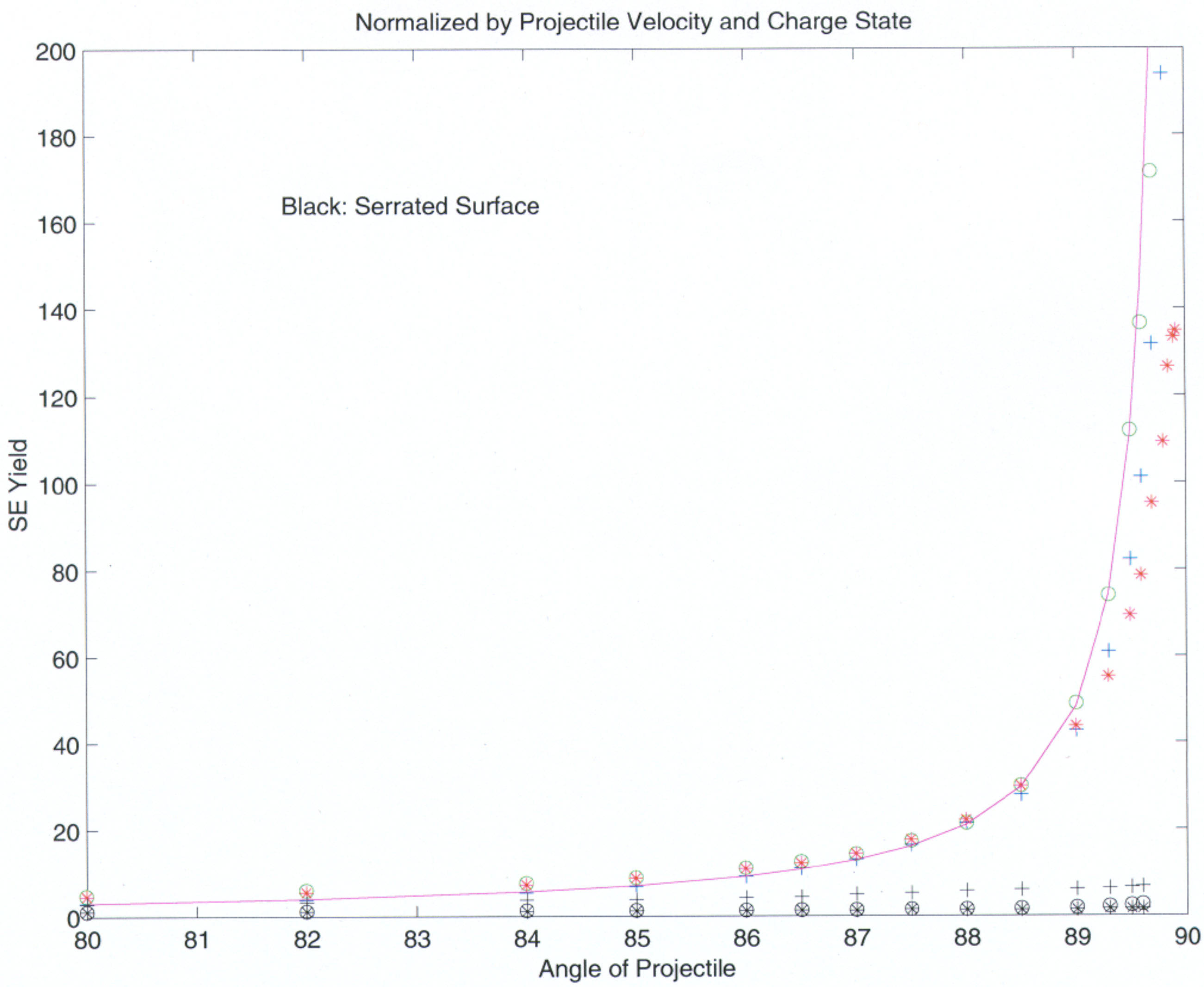
Normalized by Projectile Velocity and Charge State
+: H+
o: O8+
*: Au31+
Line: n=1.2 Match
SE Yield
Angle of Projectile
0
20
40
60
80
100
120
140
160
180
200
80
81
82
83
84
85
86
87
88
89
90

- Above 89 degrees, the yield is smaller than $\cos\theta^{-1.2}$ curve predicted. Among the possible reasons are:

  1. Potential deflection at the target.
  2. Sputtering effect, positive ions generated, note the Au^{31+} case is the worst one in the fitting.
  3. Electron depletion, only electrons in a few nm layer could escape.
  4. Other secondary effects.

6 Collimator Surface

- Use serrated surface, at > 89 degrees, the SE yield is reduced to 2% for 126 MeV O^{8+} and 182 MeV Au^{31+} ions, and 6% for 28 MeV protons.
- Studying design and impedance issues.


Normalized by Projectile Velocity and Charge State
Black: Serrated Surface
SE Yield
Angle of Projectile
0
20
40
60
80
100
120
140
160
180
200
80
81
82
83
84
85
86
87
88
89
90

7 Further Studies

- Scraping effect on TiN coated surface.
- Further study for the collimator surface design.
- Possible effect of beam scrubbing study.