Group 4 Final Presentation

Fernando Montes, Nabin Rijal, Jaclyn Schmitt

JINA-CEE Ion Optics Summer School

September 14, 2018

Emittance calculation

- Quadrupole → drift → beam spot size

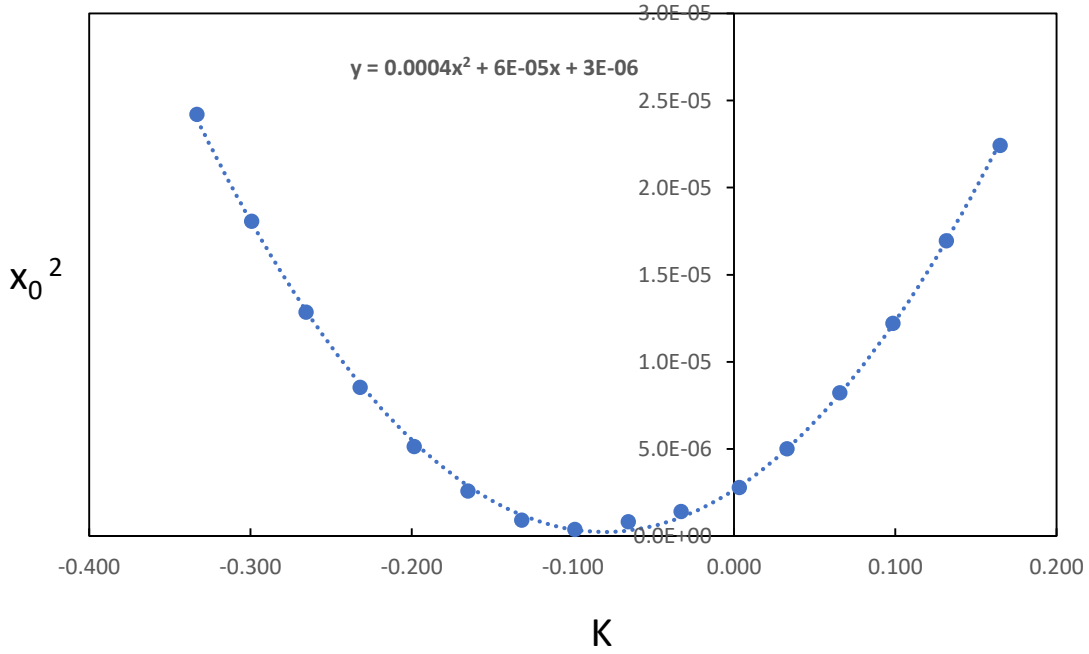
Simplification for 'thin lens approximation':

$$\mathbf{R_{focus}}(K) = \begin{pmatrix} 1 & 0 \\ -1/f & 1 \end{pmatrix} \equiv \begin{pmatrix} 1 & 0 \\ K & 1 \end{pmatrix}$$

Where K [1/Length] = Quad gradient*Quad EFL/Brho

$$\Rightarrow \mathbf{R}(K) = \mathbf{R_{drift}} \cdot \mathbf{R_{focus}} = \begin{pmatrix} 1+LK & L \\ K & 1 \end{pmatrix}. \qquad \sigma(1,K) = \mathbf{R}(K)\sigma(0)\mathbf{R}^T(K)$$

$x_0^2 = \sigma_{11}(1,K) = f(\sigma_{11}(0)\ ,\ \sigma_{12}(0)\ ,\ \sigma_{22}(0),\ K\ )$ Emittance = $\sqrt{\sigma_{11}(0)\sigma_{22}(0) - \sigma_{12}^2(0)}$



ε_{cosy} =	8.43E-07	m rad
ε_{th} =	6.28E-07	m rad

Emittance calculation

First-order quadrupole matrix $\frac{dB}{dx} \neq 0 \quad \frac{dB}{dy} \neq 0$

$$\begin{pmatrix}
\cos k_q L & \frac{1}{k_q}\sin k_q L & 0 & 0 & 0 & 0 \\
-k_q \sin k_q L & \cos k_q L & 0 & 0 & 0 & 0 \\
0 & 0 & \cosh k_q L & \frac{1}{k_q}\sinh k_q L & 0 & 0 \\
0 & 0 & k_q \sinh k_q L & \cosh k_q L & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}$$

Problem: 1/kq *sinh kq L is not zero

Thin less approximation is not valid!

```
In[363]:= L = 5.915;
          LL = 0.3401;
          Rfocus = {{Cosh[k LL], 1 / k Sinh[k LL]}, {k Sinh[k LL], Cosh[k LL]}};
          Rdrift = {{1, L}, {0, 1}};
          R = Rdrift.Rfocus;
          sig0 = {{s11, s12}, {s12, s22}};
          sig1 = R.sig0.Transpose[R];
          x[s11_, s12_, s22_, k_] = sig1[[1, 1]]
```

Out[370]=

$$(\text{Cosh}[0.3401\,k] + 5.915\,k\,\text{Sinh}[0.3401\,k])\left(s12\left(5.915\,\text{Cosh}[0.3401\,k] + \frac{\text{Sinh}[0.3401\,k]}{k}\right) + s11\,(\text{Cosh}[0.3401\,k] + 5.915\,k\,\text{Sinh}[0.3401\,k])\right)\left(5.915\,\text{Cosh}[0.3401\,k] + \frac{\text{Sinh}[0.3401\,k]}{k}\right)\left(s22\left(5.915\,\text{Cosh}[0.3401\,k] + \frac{\text{Sinh}[0.3401\,k]}{k}\right) + s12\,(\text{Cosh}[0.3401\,k] + 5.915\,k\,\text{Sinh}[0.3401\,k])\right)$$

Simplification for 'thin lens approximation':

$$\mathbf{R_{focus}}(K) = \begin{pmatrix} 1 & 0 \\ -1/f & 1 \end{pmatrix} \equiv \begin{pmatrix} 1 & 0 \\ K & 1 \end{pmatrix}$$

$$\Rightarrow \mathbf{R}(K) = \mathbf{R_{drift}} \cdot \mathbf{R_{focus}} = \begin{pmatrix} 1+LK & L \\ K & 1 \end{pmatrix}.$$

ε_{cosy} =	9.72E-07	m rad
ε_{th} =	6.28E-07	m rad

Mass Resolution Study

Parameter	Change that results in 5% decrease in mass resolution	
XX	12	%
AX	3	%
Pitch	0.19	degrees
Yaw	0.08	degrees
Roll	0.25	degrees
DX	0.82	mm
DY	0.35	mm

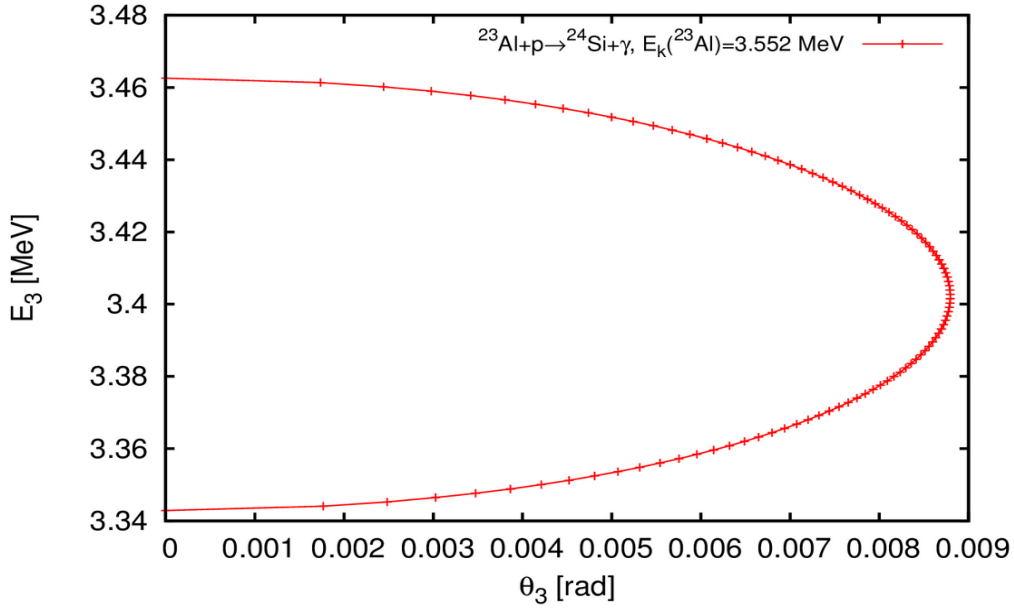
Lessons Learned:

- Mass resolution is more sensitive to beam angle than beam position.
- Mass resolution is extremely sensitive to quadrupole alignment.
- The resolution can be recovered by tuning the fields of the magnets.

$p(^{23}Al,\gamma)^{24}Si$ with SECAR

Projectile Energy = 3.552 MeV

The max-min ^{24}Si energy is 3.463-3.343 MeV.

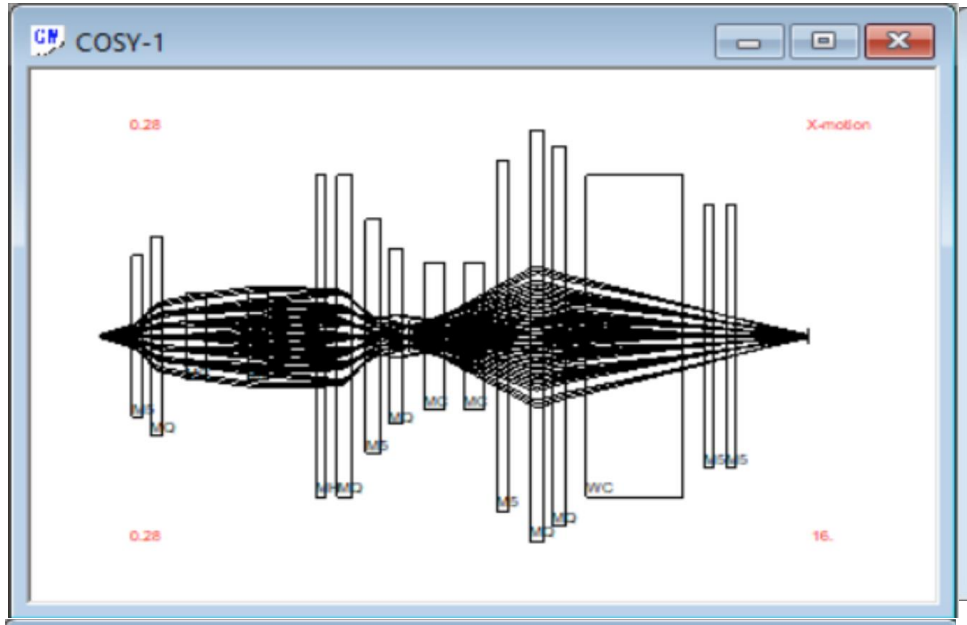


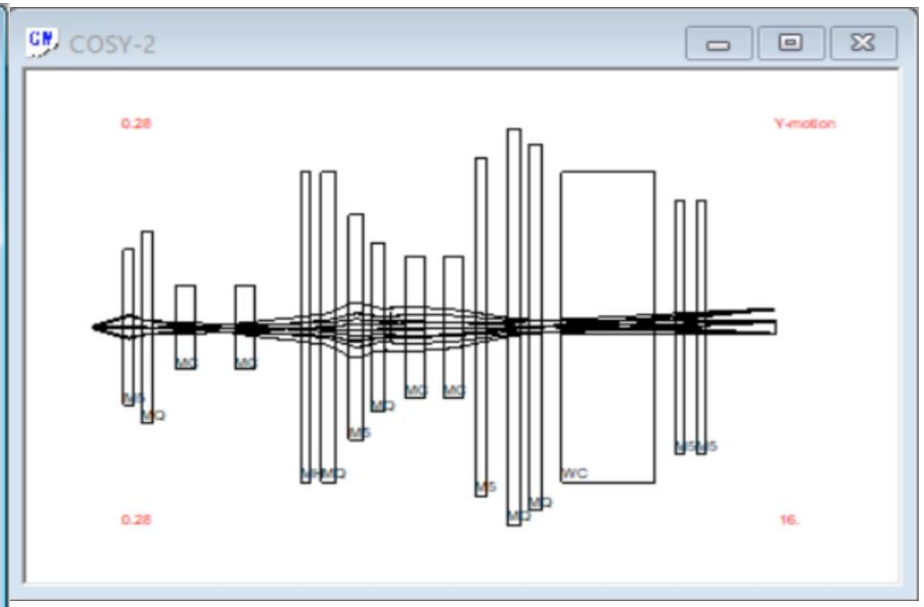
The max angle is ~9 mrad, which is well within the SECAR's acceptance of 25 mrad..

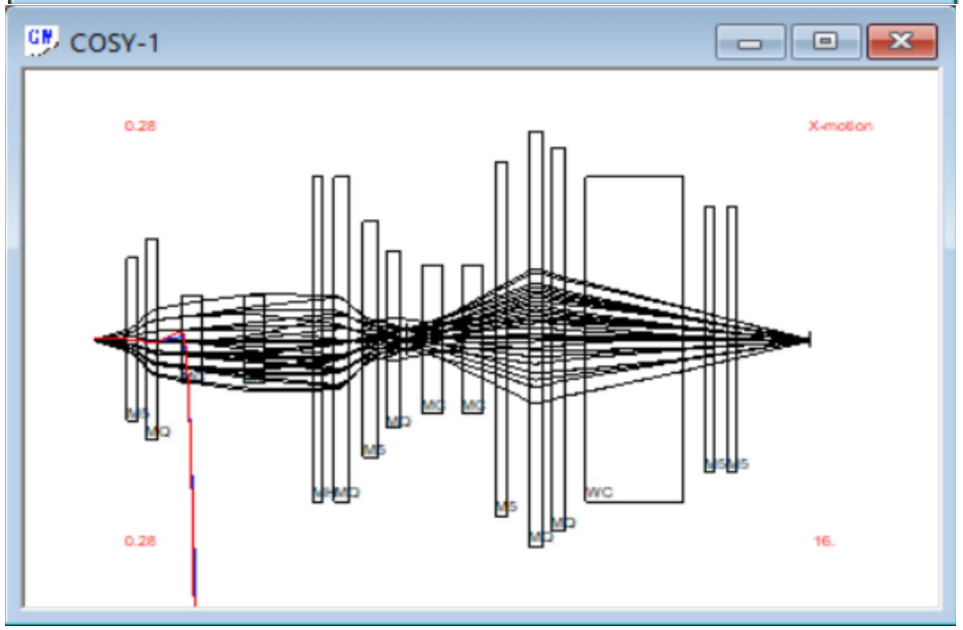
The energy spread is +/- 1.76%, which fits the SECAR's energy acceptance of 3.1%

The max-min γ energy is 3.492-3.372 MeV.

Charge state selection







How charge states are selected?

Charge = 5, Resolution = 593.5

Charge = 4 is blue, 6 is red,
Resolution = 5.9E-05