Can we use
\[ \Sigma^0 \rightarrow \Lambda \gamma \]
to study EMC response at low energy?

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The Concept

For decays of the type: $a \rightarrow b\gamma$

$$E_{\gamma}^{\text{calc}} = \frac{M^2_a - M^2_b}{2(E_b - p_b \cos \theta_{b\gamma})}$$

It is possible to compare measured photon energy to the calculated value, to check the energy scale and energy resolution.

A few modes are in use to study single photons.
$$\Sigma^0 \rightarrow \Lambda \gamma$$

Run 4 data ($\approx$100 fb$^{-1}$)

Not optimized!!!

- Use LambdaVeryVeryLoose skim
- Tight cuts to get a very clean $\Lambda$
  (e.g., flight$>2$ mm)
- Photons GoodPhotonLoose with $\pi^0$ veto

$E_\gamma > 50$ MeV

Lambda Gamma Mass
$\Sigma^0 \rightarrow \Lambda \gamma$ Mass Difference

$M_{\Sigma^0 - M_{\Lambda}} = 76.96 \pm 0.02$ MeV (PDG)

Fit - Novosibirsk + 3rd order polynomial

From fit $M_{\Sigma^0 - M_{\Lambda}} = 77.35 \pm 0.11$ MeV
Analysis Method

Compare measured gamma energy to calculated value under the \( \Sigma^0 \rightarrow \Lambda \gamma \) hypothesis. Two ways:

\[
\frac{(E_{\gamma}^{\text{meas}} - E_{\gamma}^{\text{calc}})}{E_{\gamma}^{\text{calc}}} \quad \text{or} \quad \frac{(E_{\gamma}^{\text{meas}} - E_{\gamma}^{\text{calc}})}{E_{\gamma}^{\text{meas}}}
\]

These contain the same information, but the background shape seems to behave better for one. This may help with fitting systematics.

Fit peaks to Novosibirsk and background to 3rd order polynomial. Determine both relative error on energy scale and energy resolution, in 50 MeV bins of \( E_{\gamma} \).
$50 < E_\gamma < 100$ MeV

\[
\frac{(E_{\gamma}^{\text{meas}} - E_{\gamma}^{\text{calc}})}{E_{\gamma}^{\text{calc}}}
\]

\[
\frac{(E_{\gamma}^{\text{meas}} - E_{\gamma}^{\text{calc}})}{E_{\gamma}^{\text{meas}}}
\]

Fit results will follow (in a plot).
Note that the backgound seems to peak under the signal in the left plot, but has simple shape in the right plot.
$150 < E_\gamma < 200 \text{ MeV}$

Again, the background is changing under the peak in the left plot, but not in the right plot.
$200 < E_{\gamma} < 250$ MeV

\[
\frac{(E_{\gamma}^{\text{meas}} - E_{\gamma}^{\text{calc}})}{E_{\gamma}^{\text{calc}}}
\]

\[
\frac{(E_{\gamma}^{\text{meas}} - E_{\gamma}^{\text{calc}})}{E_{\gamma}^{\text{meas}}}
\]
Energy Scale

\[
\frac{(E^\text{meas}_\gamma - E^\text{calc}_\gamma)}{E^\text{calc}_\gamma}
\]

\[
\frac{(E^\text{meas}_\gamma - E^\text{calc}_\gamma)}{E^\text{meas}_\gamma}
\]

Both show about 1% scale shift over most of the energy range covered.

Errors are from the fit.
Energy Resolution

Parameterization in BaBar NIM article

Note: the contribution to resolution from $E_{\text{calc}}$ smearing has NOT been addressed yet.

Errors are from the fit.
Conclusions

• $\Sigma^0 \rightarrow \Lambda \gamma$ looks promising for low-energy single photon studies.

• The background shape changes with photon energy for one of the two (apparently equivalent) variables, but not the other.
  - May reduce bin-to-bin systematic on fit(?)
  - May carry over to other decay modes(?).