

Simulations of the $\bar{p}p \rightarrow \Lambda\bar{\Sigma}^0$ reaction

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Overview

- Motivation
- Simulation parameters
- Inclusive study
- Exclusive study
- Conclusions
- Next steps



Motivation

- To update previous ¹ study on the reaction
 $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda \rightarrow \bar{\Lambda}\gamma\pi^- p \rightarrow \bar{p}\pi^+\gamma\pi^- p$
- To study the feasibility of $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$ spin observables measurement

¹Grape, S. (2009). Studies of PWO Crystals and Simulations of the $\bar{p}p \rightarrow \Lambda\bar{\Lambda}, \Lambda\bar{\Sigma}^0$ Reactions for the PANDA Experiment (PhD dissertation). Acta Universitatis Upsaliensis, Uppsala.

Simulation

- Parameters
 - 10,000 events of the reaction $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$
 - Forward-peaking distribution
 - Beam momentum: 1.771 GeV
 - Decay model by Walter Ikegami Andersson ²

²Described at

<https://indico.gsi.de/event/6953/contribution/1/material/slides/0.pdf>

Inclusive study: $\bar{p}p \rightarrow \bar{\Sigma}^0 X$

Analysis strategy

- $\bar{\Lambda}$ reconstruction
- Photon selection
- $\bar{\Sigma}^0$ reconstruction, different approaches:
 - 1 1C fit using $m_{\bar{\Sigma}}$
 - 2 Cuts on $\bar{\Sigma}$ missing mass

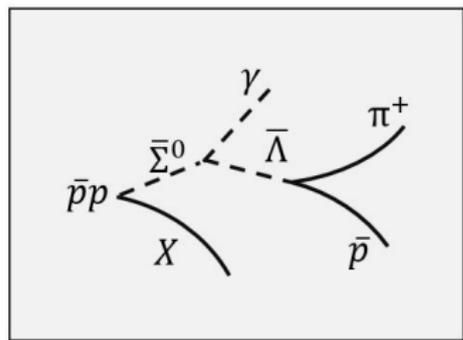


Figure: Inclusive reaction scheme.

Final state particles

From the **Total** number of reconstructed particles, the ones coming from the reaction $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda$ are referred as **True** and the rest as **False**.

Full reaction:

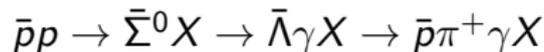


Table: Total final state particles.

Particle	Total	True	False
π^+	7,070	6,174	896
\bar{p}	7,944	7,567	377
γ	123,046	7,043	116,003

Inclusive study: $\bar{p}p \rightarrow \bar{\Sigma}^0 X$

Analysis strategy

- **$\bar{\Lambda}$ reconstruction**
- Photon selection
- $\bar{\Sigma}^0$ reconstruction, two approaches:
 - 1 1C fit using $m_{\bar{\Sigma}}$
 - 2 Cuts on $\bar{\Sigma}$ missing mass

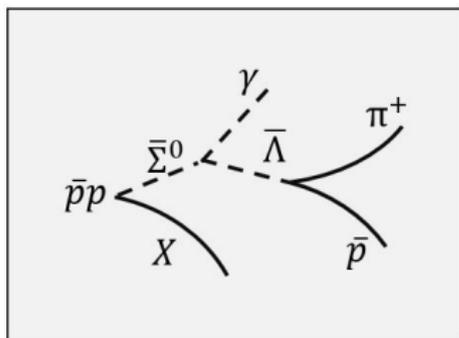


Figure: Inclusive study reaction scheme.

$\bar{\Lambda}$ reconstruction

- Take all $\bar{p}\pi^+$ combinations.
- Apply vertex fit on all $\bar{\Lambda}$ candidates, keep those with probability $p > 0.01$.
- Apply fit using $m_{\Lambda} = 1.115 \text{ GeV}/c^2$, keep candidates with $p > 0.01$.
- Choose the candidate with smallest χ^2 in vertex fit.

Table: $\bar{\Lambda}$ reconstruction.

Cut	Total	True	False	True/Total
None	5,335	4,651	684	0.87
Vertex fit	4,580	4,211	369	0.92
1C fit	3,813	3,653	160	0.96
Smallest χ^2	3,656	3,557	99	0.97

Invariant mass $\bar{\Lambda}$ after Vtx & Kin fit (all)

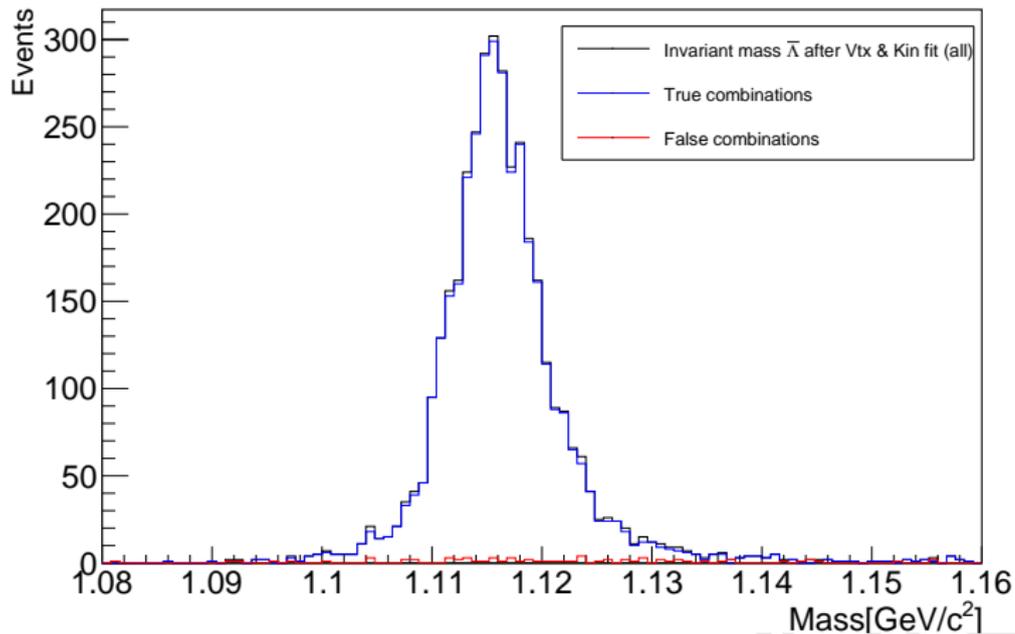


Figure: $\bar{p}\pi^+$ combinations invariant mass.

Inclusive study: $\bar{p}p \rightarrow \bar{\Sigma}^0 X$

Analysis strategy

- $\bar{\Lambda}$ reconstruction
- **Photon selection**
- $\bar{\Sigma}^0$ reconstruction, two approaches:
 - 1 IC fit using $m_{\bar{\Sigma}}$.
 - 2 Cuts on $\bar{\Sigma}$ missing mass.

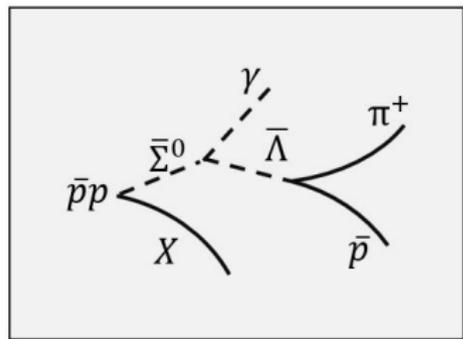


Figure: Inclusive reaction scheme.

Photon Selection

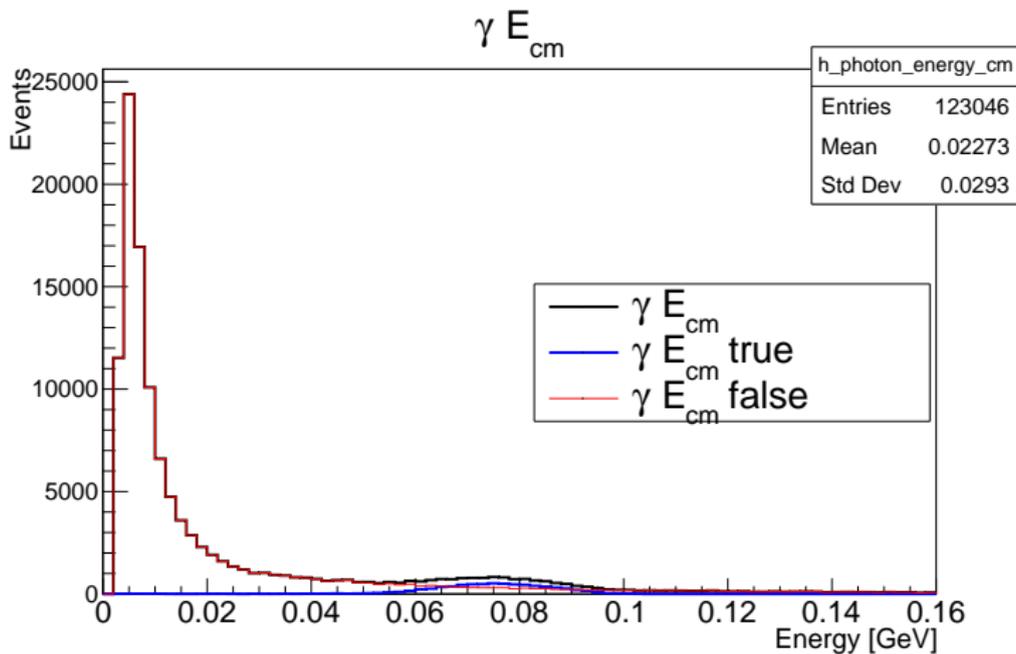


Figure: Photon candidates energy in the center of mass system. Difference between blue and red curves motivate a cut.

Photon selection

- Center of mass energy cut: $0.060 < E_{cm} < 0.091$ GeV

Table: γ selection.

Cut	Total	True	False	True/Total
None	123,046	7,043	116,003	0.05
E_{cm}	10,647	5,969	4,678	0.56

Number of γ per event

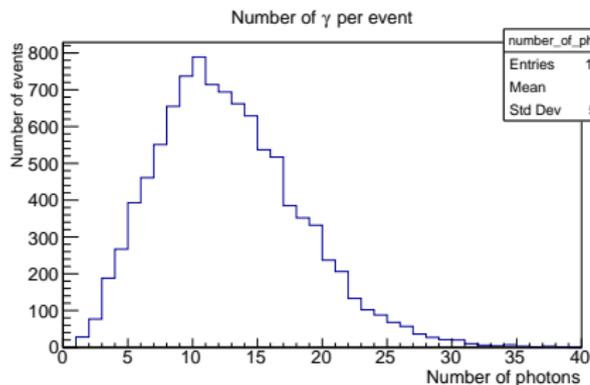


Figure: Total number of γ candidates per event before cut.

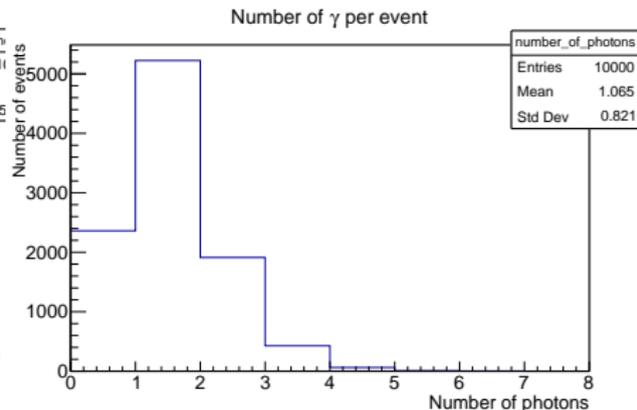


Figure: Total number of γ candidates after cut.

Inclusive study: $\bar{p}p \rightarrow \bar{\Sigma}^0 X$

Analysis strategy

- $\bar{\Lambda}$ reconstruction
- Photon selection
- $\bar{\Sigma}^0$ reconstruction:
 - 1 **1C fit using $m_{\bar{\Sigma}}$.**
 - 2 Cuts on $\bar{\Sigma}$ missing mass.

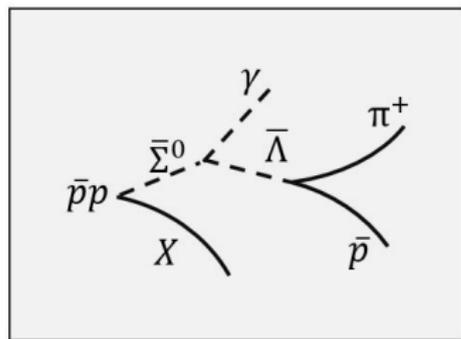


Figure: Inclusive reaction scheme.

$\bar{\Sigma}^0$ reconstruction

- Take all $\bar{\Lambda}$ and γ combinations.
- Apply 1C fit with $m(\bar{\Sigma}^0) = 1.192 \text{ GeV}/c^2$, keep candidates with $p > 0.01$
- Choose the candidate with smallest χ^2 per event.

Table: $\bar{\Sigma}^0$ reconstruction.

Cut	Total	True	False	True/Total
None	63,052	3,286	59,766	0.05
$\bar{\Lambda}_{Vtx+1C}$	43,107	2,514	40,593	0.06
γ_{sel}	3,734	2,140	1,594	0.57
1C fit	3,284	2,083	1,201	0.63
<i>Smallest</i> χ^2	2,593	1,868	725	0.72

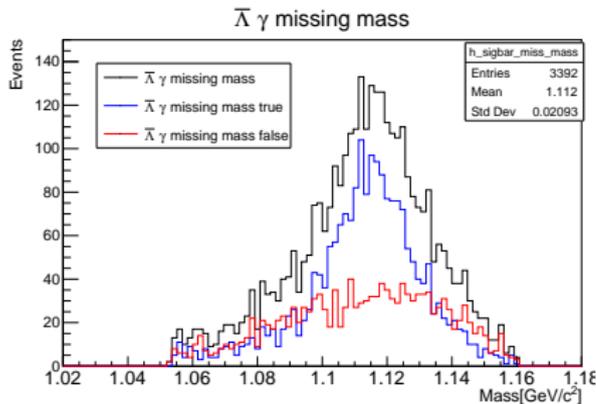


Figure: $\bar{\Lambda} \gamma$ missing mass.
Background highlighted in red and signal in blue.

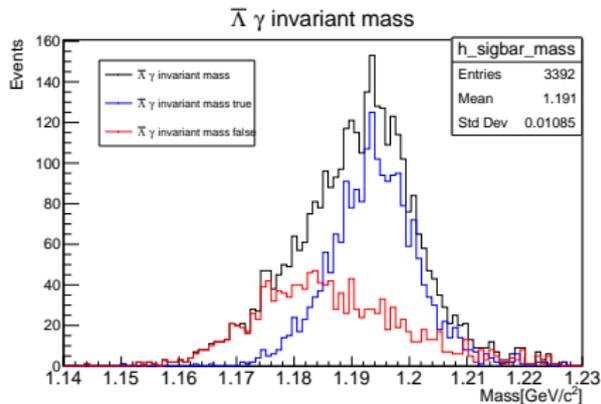


Figure: $\bar{\Lambda} \gamma$ invariant mass.
Background highlighted in red and signal in blue.

Inclusive study: $\bar{p}p \rightarrow \bar{\Sigma}^0 X$

Analysis strategy

- $\bar{\Lambda}$ reconstruction
- Photon selection
- $\bar{\Sigma}^0$ reconstruction:
 - 1 1C fit using $m_{\bar{\Sigma}}$.
 - 2 **Cuts on $\bar{\Sigma}$ missing mass.**

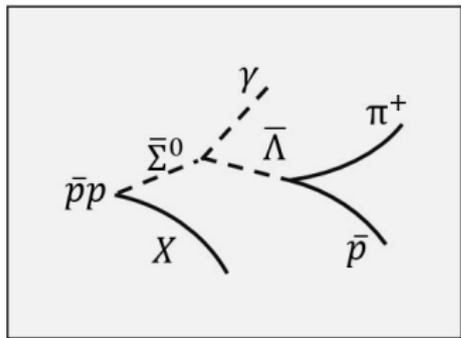


Figure: Inclusive reaction scheme.

Motivation for cuts

$$1.05 < MM(\bar{\Lambda}\gamma) < 1.16.$$

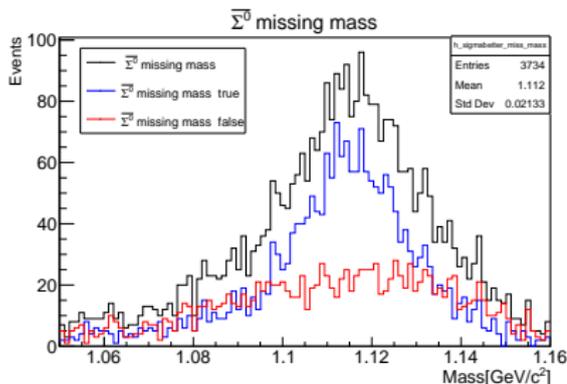


Figure: $\bar{\Lambda}\gamma$ missing mass true and false motivation cut.

Gauss fit with
 $\mu = 1.115 \text{ GeV}/c^2$ and
 $\sigma = 0.0197$, 3σ window gives
 $1.06 < MM(\bar{\Lambda}\gamma) < 1.17$ cut

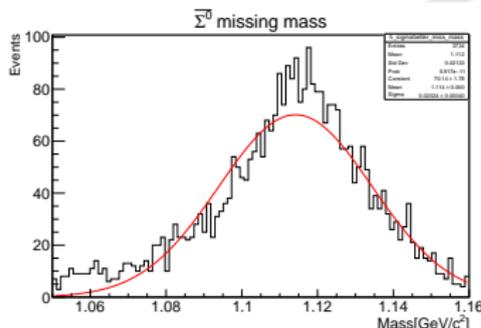


Figure: $\bar{\Lambda}\gamma$ missing mass fit.

$\bar{\Sigma}^0$ reconstruction

- Combination of $\bar{\Lambda}$ and γ candidates.
- Look at $MM(\bar{\Lambda}\gamma)$ to find possible cuts:
 - $1.05 < MM(\bar{\Lambda}\gamma) < 1.16$ according to true and false events.
 - $1.06 < MM(\bar{\Lambda}\gamma) < 1.17$ according to Gauss fit

Table: $\bar{\Sigma}^0$ reconstruction.

Cut	Total	True	False	True/Total
None	63,052	3,286	59,766	0.05
$\bar{\Lambda}_{Vtx+1C}$	44,903	2,584	42,319	0.06
γ_{sel}	3,891	2,192	1,699	0.56
$MM(\bar{\Lambda}\gamma)_{cut}$	3,392	2,022	1,370	0.60

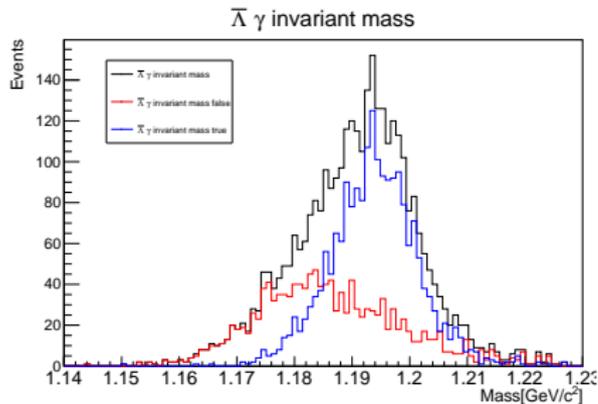


Figure: $\bar{\Lambda} \gamma$ invariant mass.
Background highlighted in red and signal in blue.

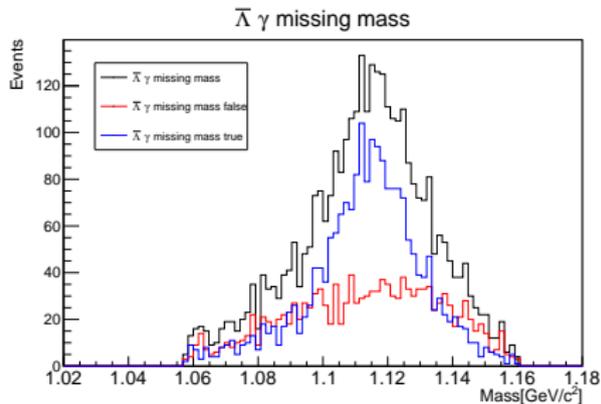


Figure: $\bar{\Lambda} \gamma$ missing mass.
Background highlighted in red and signal in blue.

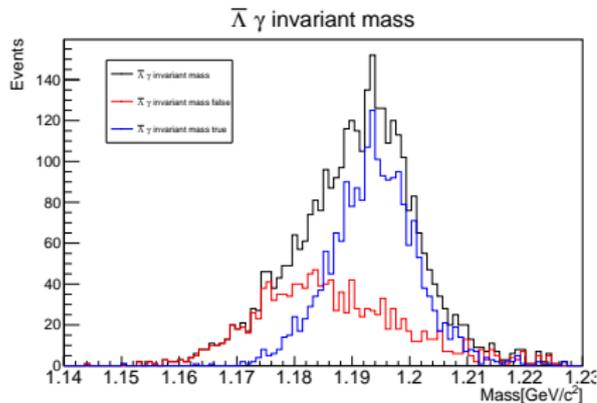


Figure: $\bar{\Lambda}\gamma$ invariant mass.
Background highlighted in red and
signal in blue.

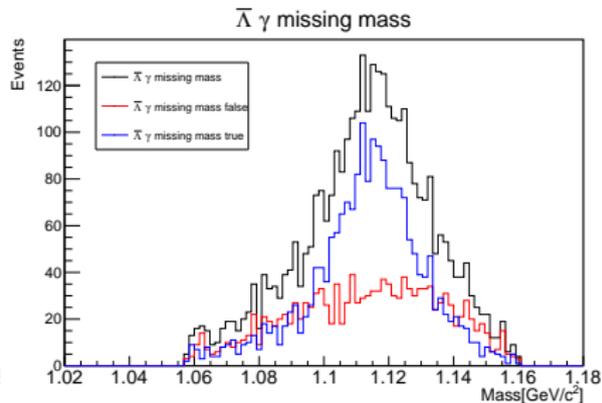


Figure: $\bar{\Lambda}\gamma$ missing mass.
Background highlighted in red and
signal in blue.

Inclusive study does not give a clean
sample

Exclusive study $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$

Analysis strategy

- Λ reconstruction
- $\bar{\Sigma}^0$ reconstruction
- Count cases when both $\bar{\Sigma}^0\Lambda$ are reconstructed.

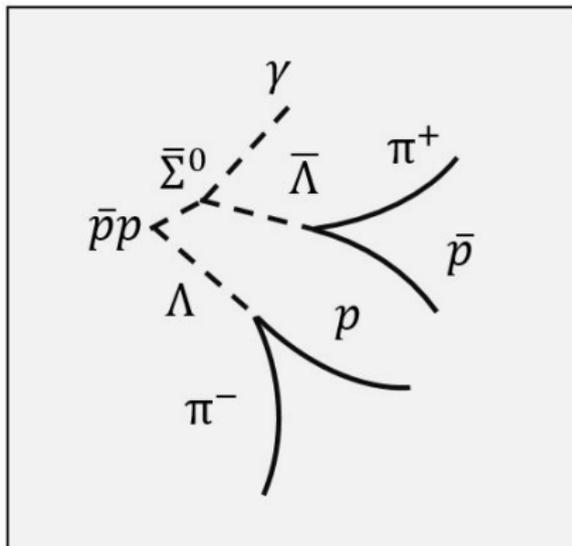


Figure: Exclusive study reaction scheme.

Final state particles

Full reaction:



Table: Total final state particles.

Particle	Total	True	False
π^-	7,033	5,900	1,133
π^+	7,070	6,174	896
p	9,594	8,073	1,521
\bar{p}	7,944	7,567	377
γ	123,046	7,043	116,003

Exclusive study $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$

Analysis strategy

- **Λ reconstruction**
- $\bar{\Sigma}^0$ reconstruction
- $\bar{\Sigma}^0\Lambda$ system reconstruction.

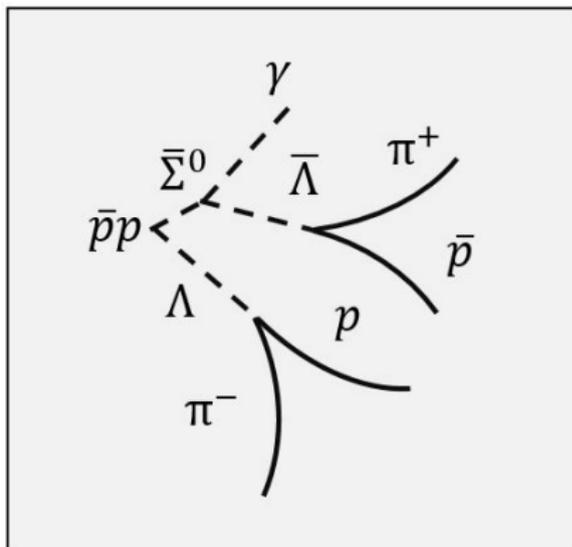


Figure: Exclusive study reaction scheme.

Λ reconstruction

- Take all $\pi^- p$ combinations.
- Apply vertex fit on all Λ candidates, keep only those with $p > 0.01$.

Table: Λ reconstruction.

Cut	Total	True	False	True/Total
None	7,046	4,693	2,353	0.67
Vertex fit	5,407	4,365	1,042	0.81

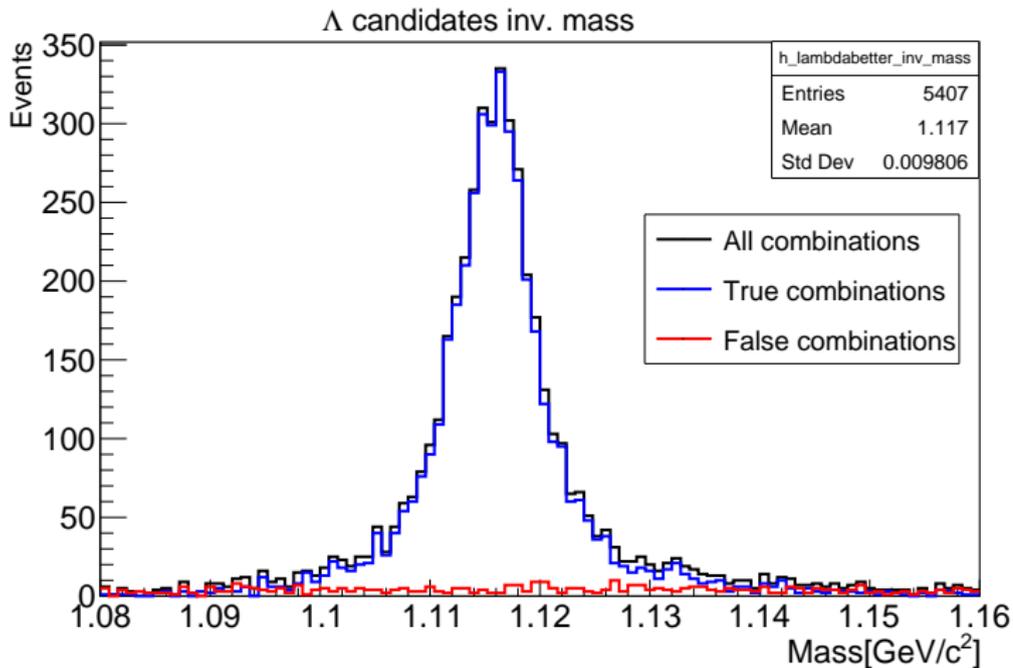


Figure: $p\pi^-$ combinations invariant mass.

Exclusive study $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$

Analysis strategy

- Λ reconstruction
- **$\bar{\Sigma}^0$ reconstruction**
- $\bar{\Sigma}^0\Lambda$ system reconstruction

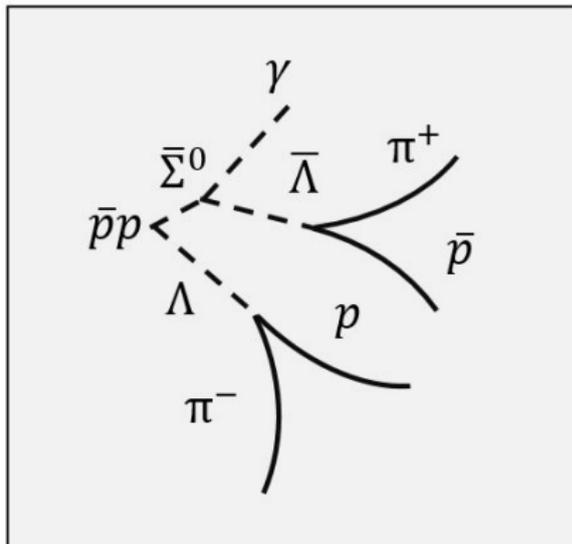


Figure: Exclusive study reaction scheme.

$\bar{\Sigma}^0$ reconstruction

- $\bar{\Lambda}$ reconstruction (same strategy as Λ)
- Choose photons with $0.060 < E_{cm} < 0.091$
- Cut on $1.06 < MM(\bar{\Lambda}\gamma) < 1.17$ (according to Gauss fit)

Table: $\bar{\Sigma}^0$ reconstruction.

Cut	Total	True	False	True/Total
None	63,052	3,286	59,766	0.05
γ_{sel}	5,509	2,794	2,715	0.51
$\bar{\Lambda}_{Vtx}$	4,745	2,588	2,207	0.55
$MM(\bar{\Lambda}\gamma)_{cut}$	3,954	2,284	1,670	0.58

Exclusive study $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$

Analysis strategy

- Λ reconstruction
- $\bar{\Sigma}^0$ reconstruction (same strategy as inclusive case)
- **$\bar{\Sigma}^0\Lambda$ system reconstruction**

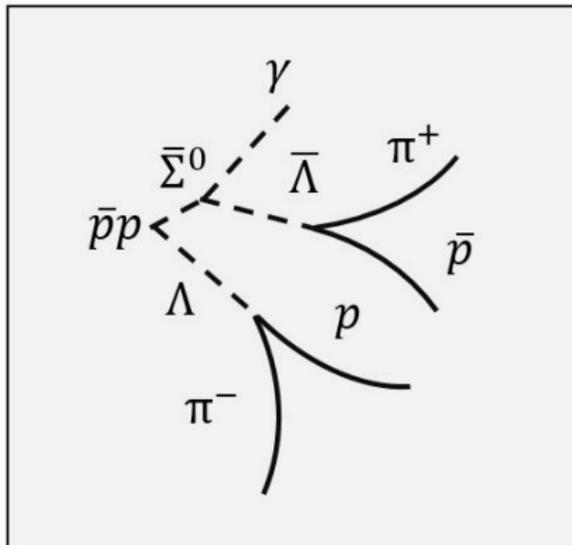


Figure: Exclusive study reaction scheme.

$\bar{\Sigma}^0\Lambda$ system reconstruction

- $\bar{\Sigma}^0$ and Λ candidates combination
- 4C fit on $\bar{\Sigma}^0\Lambda$ candidates, choose $p > 0.01$
- Keep the candidate with smallest χ^2

Table: $\bar{\Sigma}^0\Lambda$ reconstruction.

Cut	Total	True	False	True/Total
None	34,389	1,560	32,829	0.05
$\bar{\Sigma}_{Selection}^0$	2,098	1,085	1,013	0.52
$\Lambda_{Selection}$	1,793	1,005	788	0.56
4C fit	493	461	32	0.94

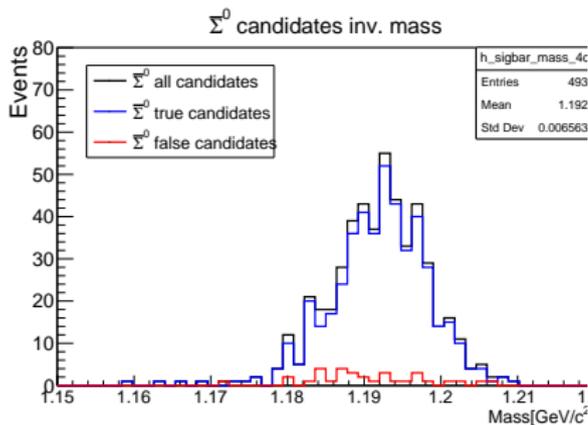


Figure: $\bar{\Sigma}^0$ inv mass after 4c fit.

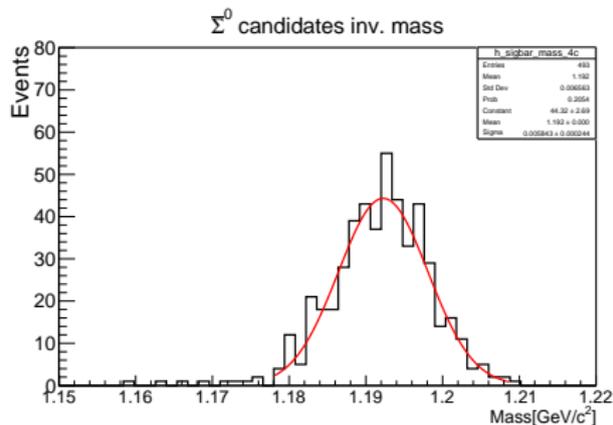


Figure: $\bar{\Sigma}^0$ inv mass after 4c fit.
Gaussian fit with $\mu = 1.192 \text{ GeV}/c^2$
and $\sigma = 0.006$

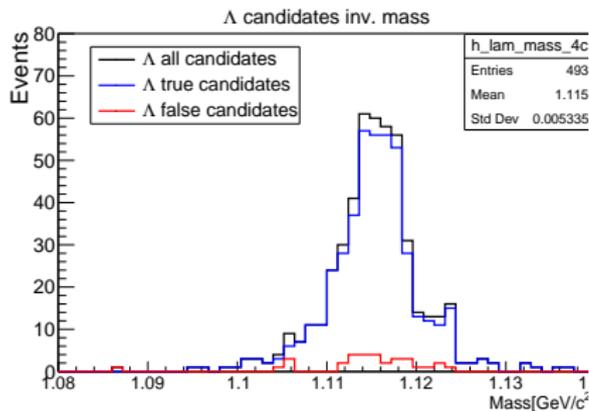


Figure: Λ inv mass after 4c fit.

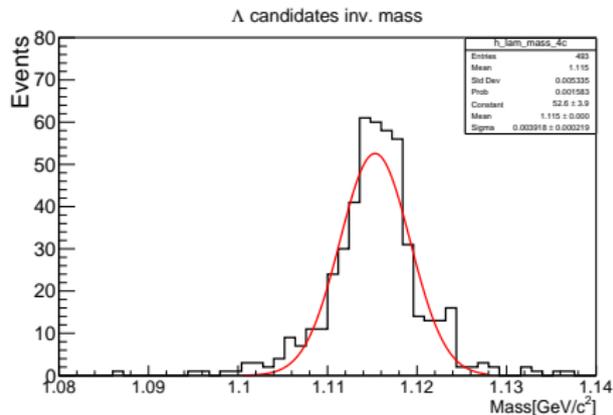
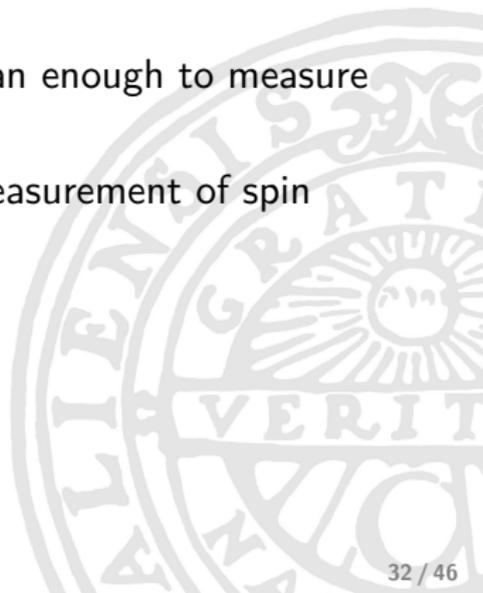


Figure: Λ inv mass after 4c fit.
Gaussian fit with $\mu = 1.115\text{GeV}/c^2$
and $\sigma = 0.004$

Conclusions

- Inclusive study shows high overlap between signal and background.
- Inclusive study does not give sample clean enough to measure spin observables.
- Exclusive study is necessary to future measurement of spin observables.



Next steps

- Same analysis at 6 GeV
- $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda, \bar{\Sigma}^0 \rightarrow \bar{\Lambda}e^+e^-$ at 6 GeV



Thank You!



Back up slides



Inclusive study



Probability and χ^2 for Vertex fit on $\bar{\Lambda}$

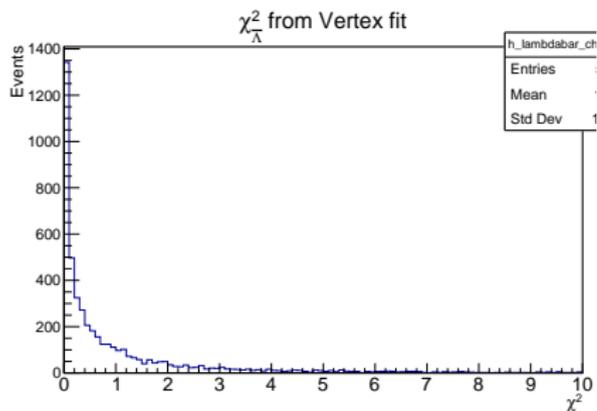


Figure: χ^2 corresponding to $\bar{\Lambda}$ vertex fit.

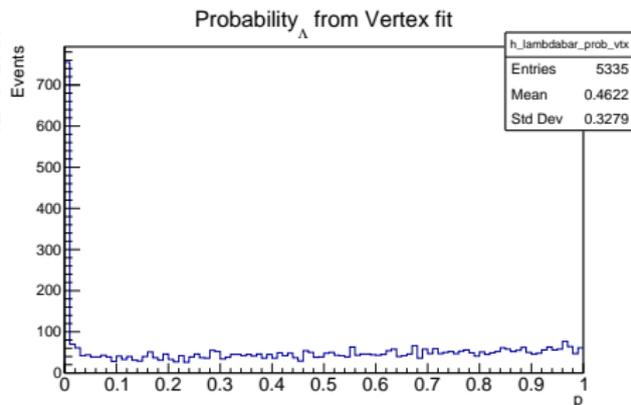


Figure: probability corresponding to $\bar{\Lambda}$ vertex fit.

Probability and χ^2 for Kin fit on $\bar{\Lambda}$

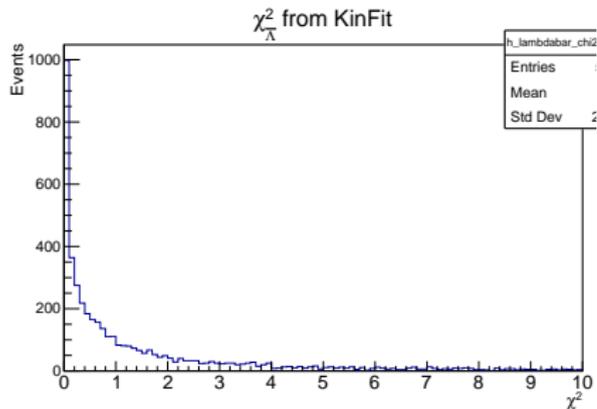


Figure: χ^0 corresponding to $\bar{\Lambda}$ kin fit.

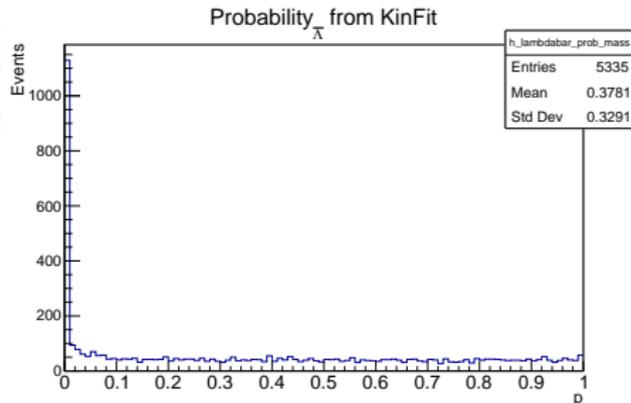


Figure: *probability* corresponding to $\bar{\Lambda}$ kin fit.

Probability and χ^2 for 1C fit on $\bar{\Sigma}^0$

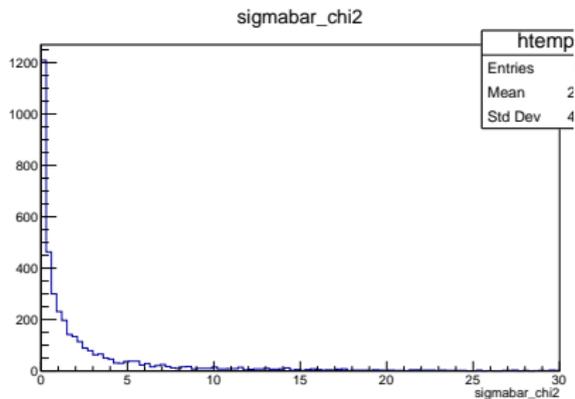


Figure: χ^2 corresponding to $\bar{\Sigma}^0$ kin fit.

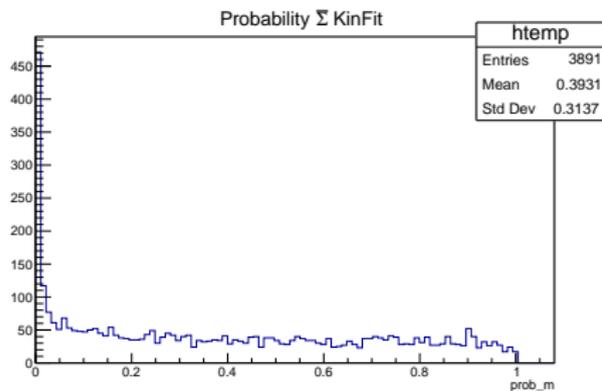


Figure: Probability corresponding to $\bar{\Sigma}^0$ kin fit.

EXCLUSIVE STUDY



Exclusive study $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$

- Λ reconstruction:
 - All $p\pi^-$ combinations
 - Vertex fit on Λ candidates, keep only those with $p > 0.01$
- $\bar{\Sigma}^0$ reconstruction:
 - $\bar{\Lambda}$ reconstruction : all $\bar{p}\pi^+$ comb. vertex fit and keep $p > 0.01$
 - Photon selection : $0.060 < E_{cm} < 0.091$ GeV
 - $\bar{\Lambda}\gamma$ combination
 - $MM(\bar{\Lambda}\gamma)$ cuts: $1.05 < MM(\bar{\Lambda}\gamma) < 1.16$
- $\bar{\Sigma}^0\Lambda$ system reconstruction:
 - $\bar{\Sigma}^0$ and Λ candidates combination
 - 4C fit on $\bar{\Sigma}^0\Lambda$ candidates, choose $p > 0.01$
 - Keep the candidate with smallest χ^2

Probability and χ^2 for Vertex fit on Λ

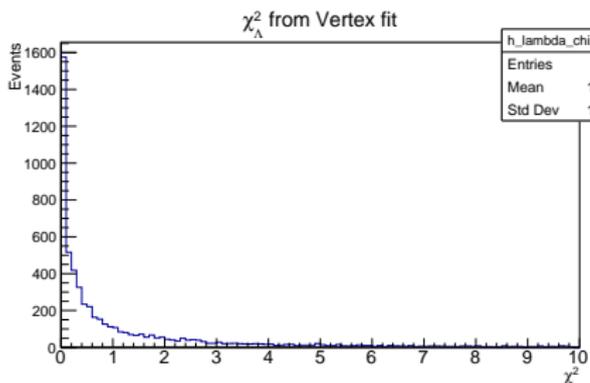


Figure: χ^2 corresponding to Λ vertex fit.

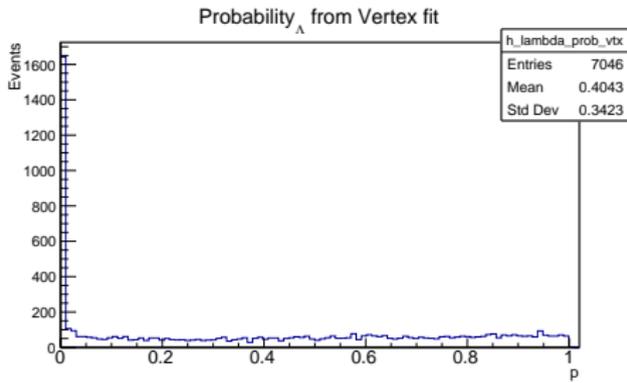


Figure: *probability* corresponding to Λ vertex fit.

Probability and χ^2 for Vertex fit on $\bar{\Lambda}$

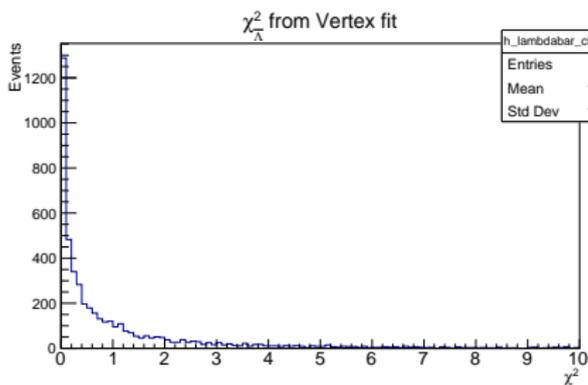


Figure: χ^2 corresponding to $\bar{\Lambda}$ vertex fit.

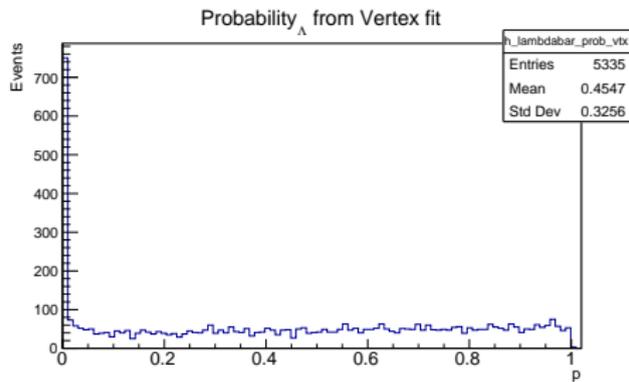


Figure: *probability* corresponding to $\bar{\Lambda}$ vertex fit.

Probability and χ^2 for Vertex fit on $\bar{\Lambda}$

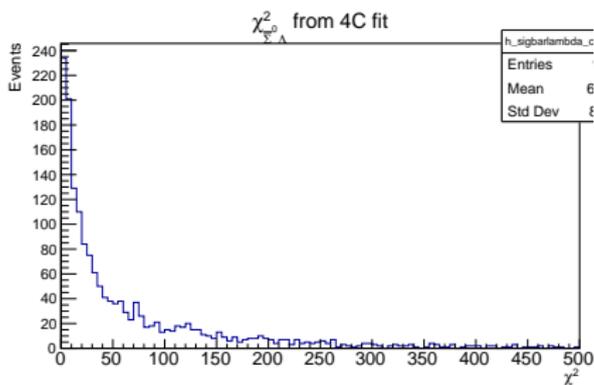


Figure: χ^2 corresponding to $\bar{\Sigma}^0 \Lambda$ 4c fit.

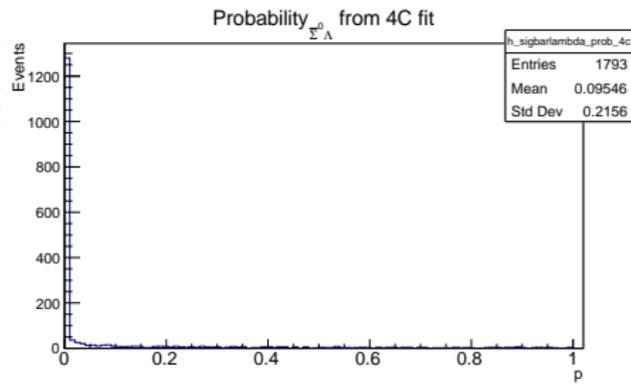


Figure: Probability corresponding to $\bar{\Sigma}^0 \Lambda$ 4c fit.

Gaussian fit on $\bar{\Lambda}\gamma$ missing mass

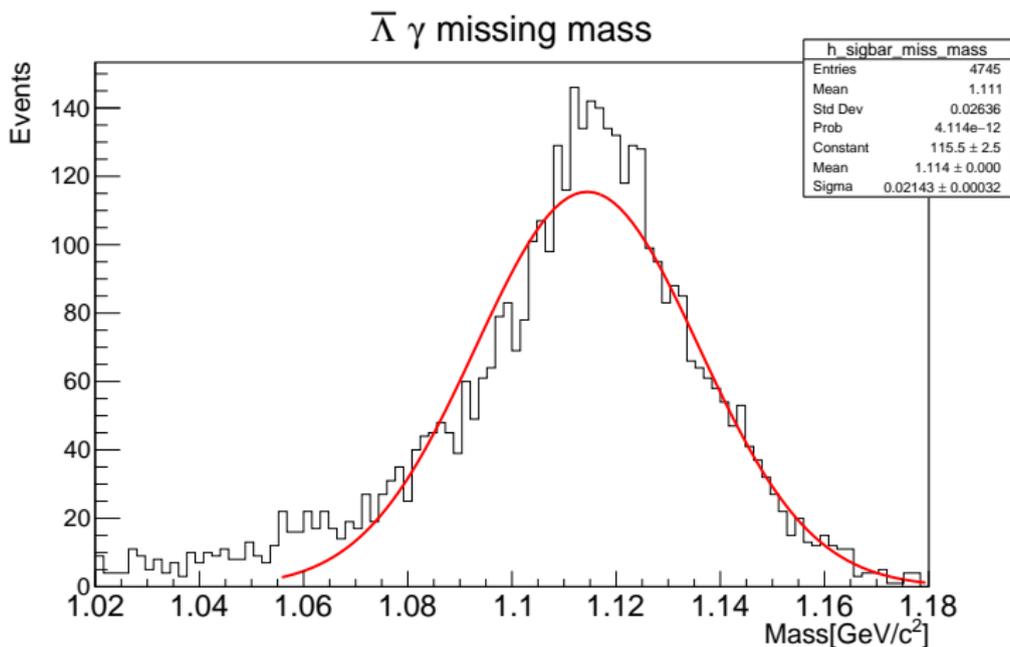


Figure: Gaussian fit to justify missing mass cut : $\mu = 1.114$ and $\sigma = 0.021$

$\bar{\Sigma}^0\Lambda$ reconstruction (1C fit on $\bar{\Sigma}^0$)

Combination of all $\bar{\Sigma}^0\Lambda$ candidates. The $\bar{\Sigma}^0$ reconstruction is done in the same way as for the inclusive analysis.

Table: $\bar{\Sigma}^0\Lambda$ reconstruction.

Cut	Total	True	False	True/Total
None	34,389	1,560	32,829	0.05
$\bar{\Lambda}(\Lambda)_{selection}$	17,485	1,000	16,485	0.06
$\gamma_{selection}$	1,483	849	634	0.57
1C fit on $\bar{\Sigma}^0$	1,308	833	475	0.64
Smallest $\chi^2_{\bar{\Sigma}^0}$	1,039	734	305	0.71