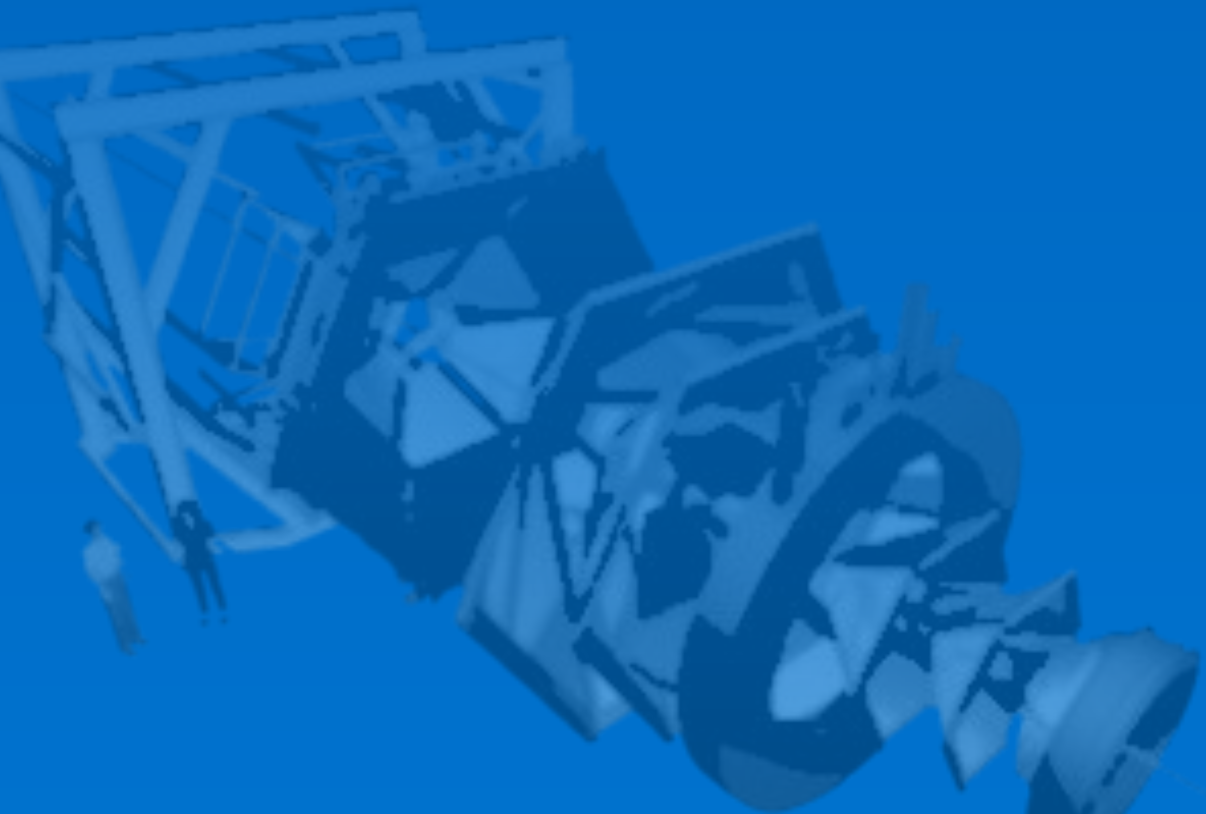
Technische Universität München

Σ^0 Production in p + Nb Reactions at E = 3.5 GeV



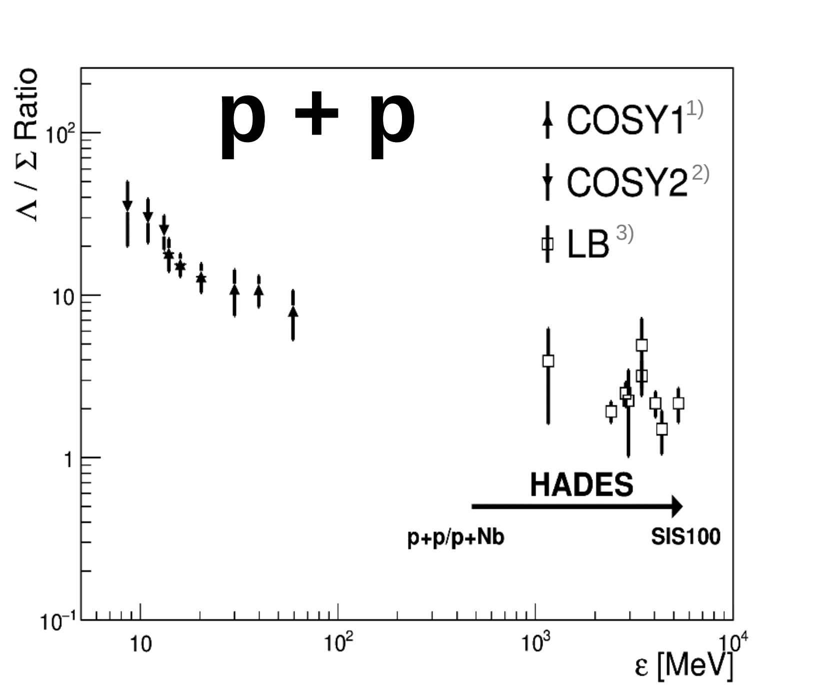
Tobias Kunz
for the HADES Collaboration

Strangeness in Quark Matter, 09-15 July 2017, Utrecht

Role of the Σ^0 Hyperon

$m_{\Sigma^0} = 1192.642 \pm 0.07$ MeV/c^2
I(J^P) = 1(1/2$^+$)
$c\tau = 2.2 \cdot 10^{-11}$ m
$\Sigma^0 \rightarrow \Lambda^0\gamma$ (99.0 %)
$\Sigma^0 \rightarrow \Lambda^0 e^+ e^-$ (0.5 %)

Σ^0



Can we detect Σ^0 in HADES?

K^0, K*, K$^\pm$, Λ, Σ$^+$, Ξ production in p + p, p + A, A + A

Hypernuclei for Λ but not for Σ^0?

Hyperon transition form factors?

Σ-N Interaction

No $\frac{\Lambda}{\Sigma^0}$ data available for p + A

1) P. Kowina et al. Eur. Phys. J., A22:293–299, 2004
2) S. Sewerin et al., Phys. Rev. Lett., 83:682–685, 1999
3) Landolt-Boernstein, Springer, 409 P., New Series 12, 1988

Role of the Σ^0 Hyperon

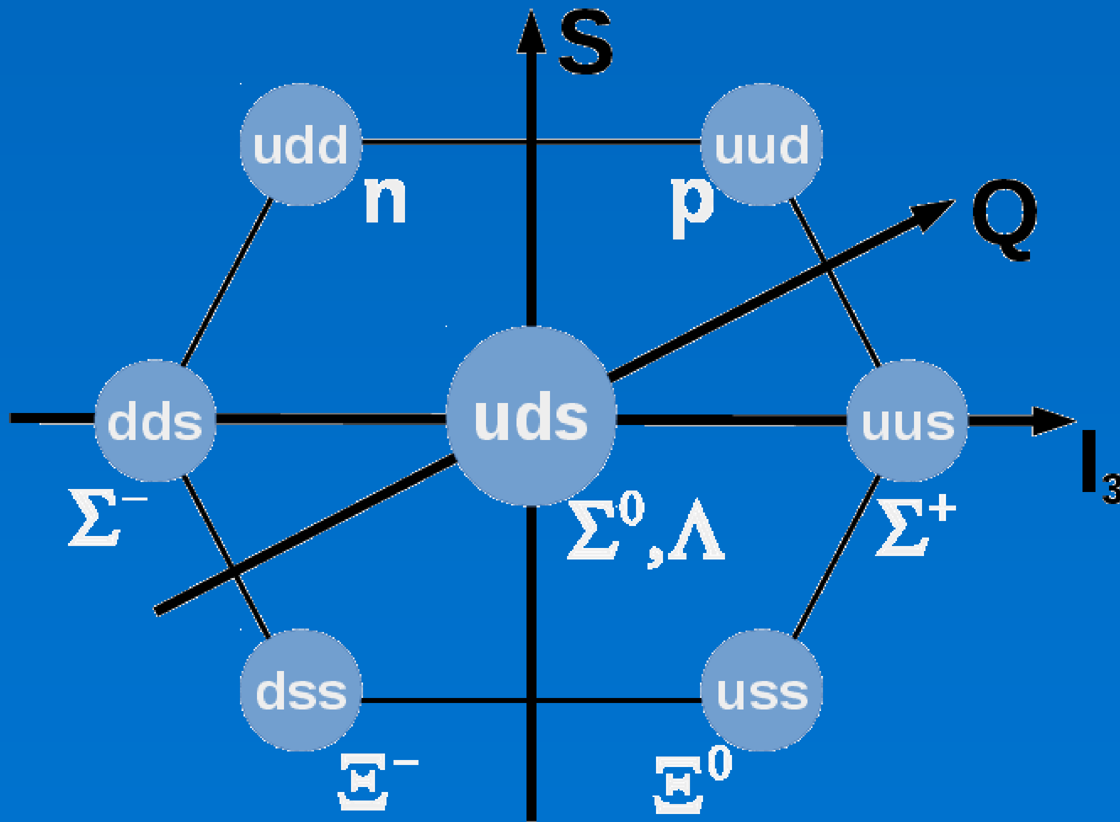
Λ_{dir}: Direct production

Λ_{Σ^0}: Λ originating from Σ^0 decays

UrQMD
GiBUU

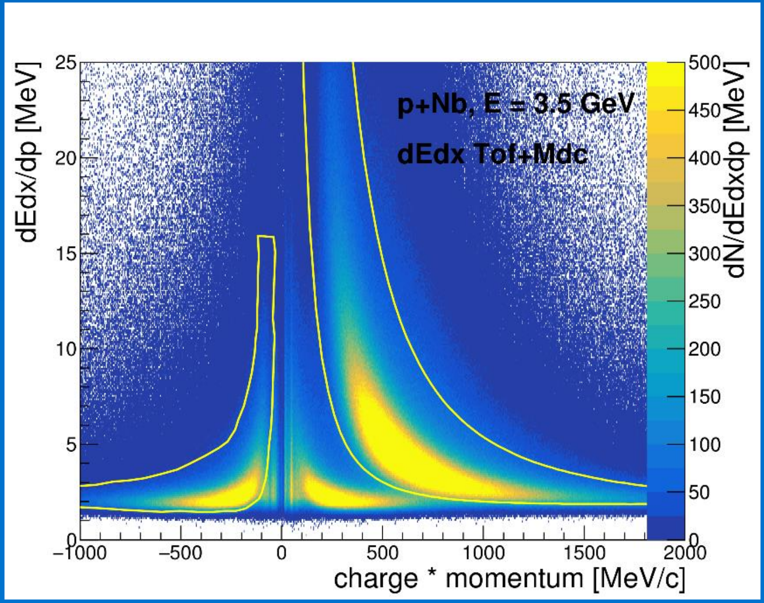
THERMUS

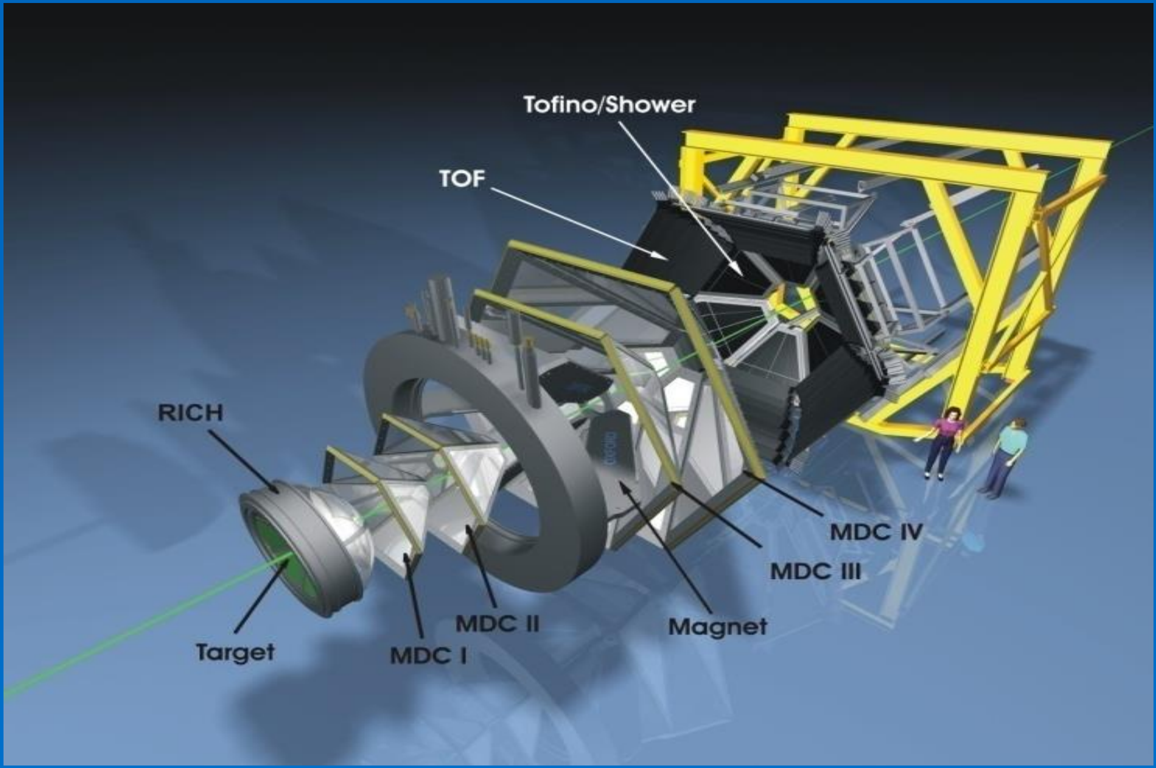
Data for
p + p



The HADES Experiment

Observable	Detector
p	MDC (Magnet)
β	TOF(ino)
dE/dx	MDC / TOF(ino)
e^+/e^-	RICH / Pre-Shower

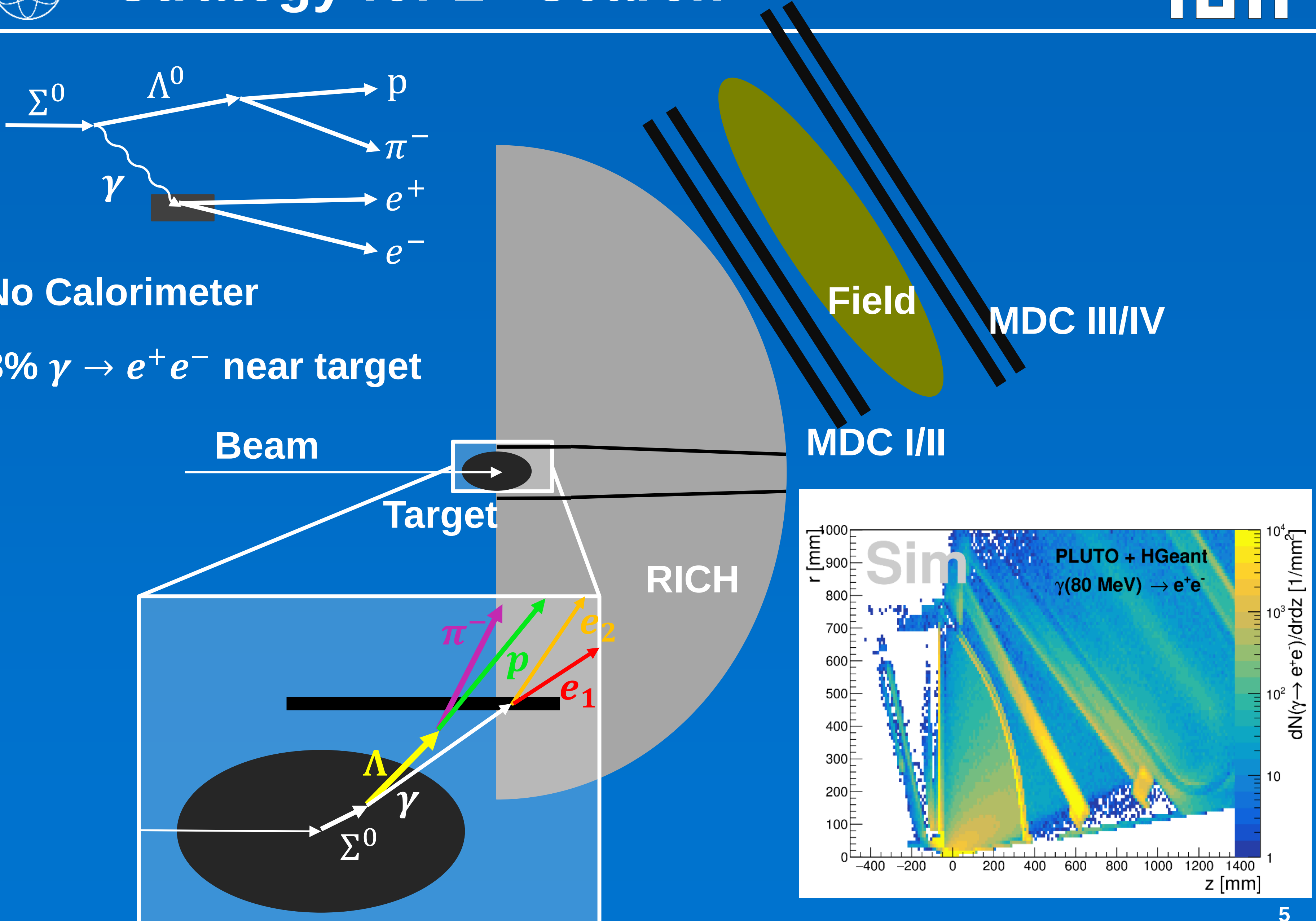




p + Nb, E_{kin} = 3.5 GeV   N = $4.21 \cdot 10^9$ evt

reconstructed   N = 1.3 $\cdot$ 10^6 Λ

Strategy for Σ^0 Search

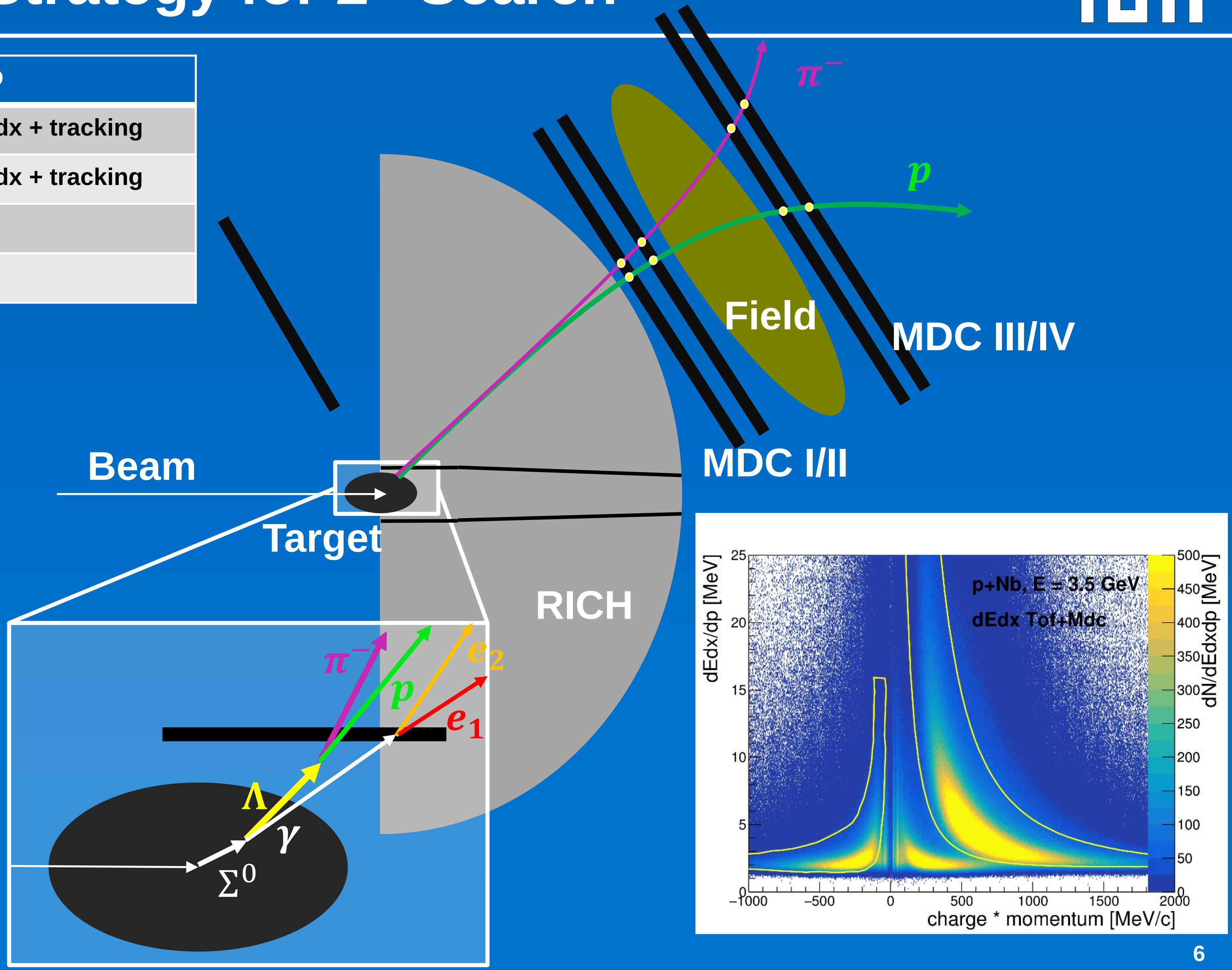


No Calorimeter

3% $\gamma \rightarrow e^+e^-$ near target

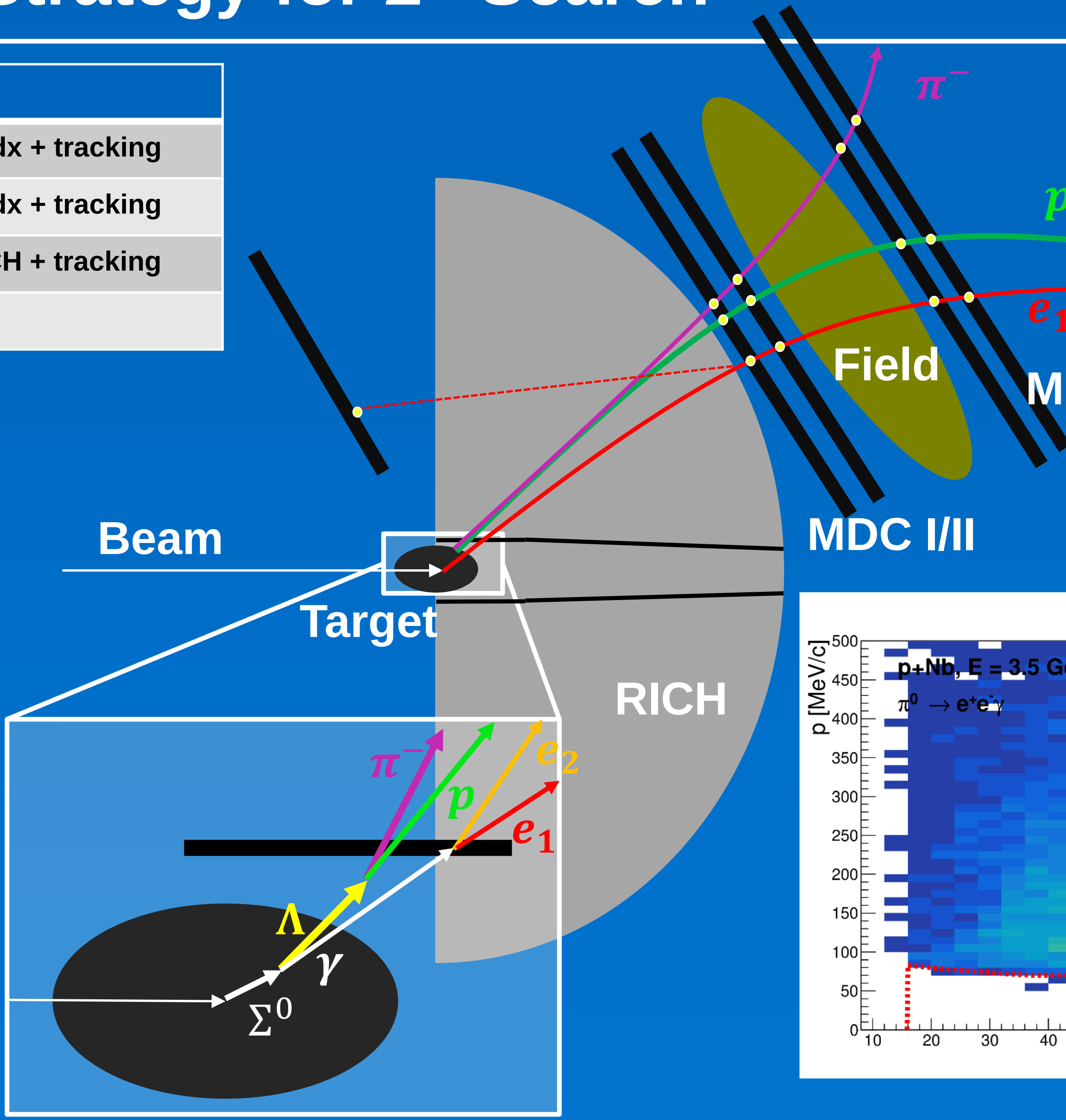
Strategy for Σ^0 Search

Particle	PID
p	dEdx + tracking
π^-	dEdx + tracking

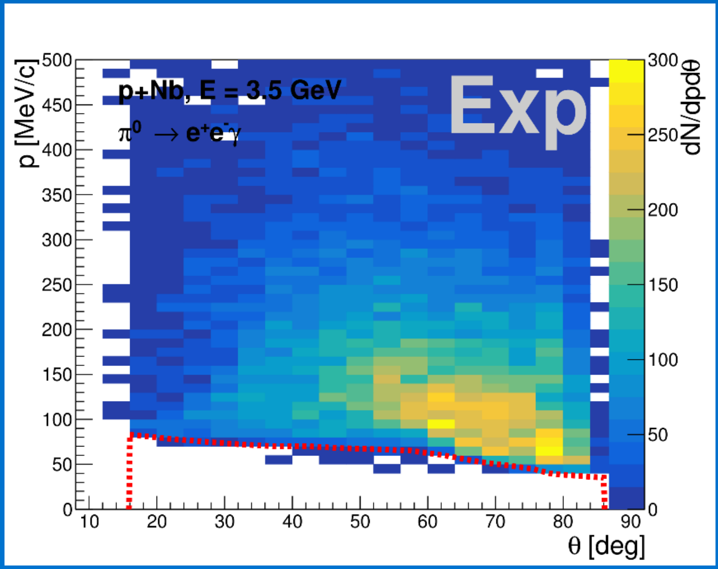


Strategy for Σ^0 Search

Particle	PID
p	dEdx + tracking
π^-	dEdx + tracking
e_1	RICH + tracking

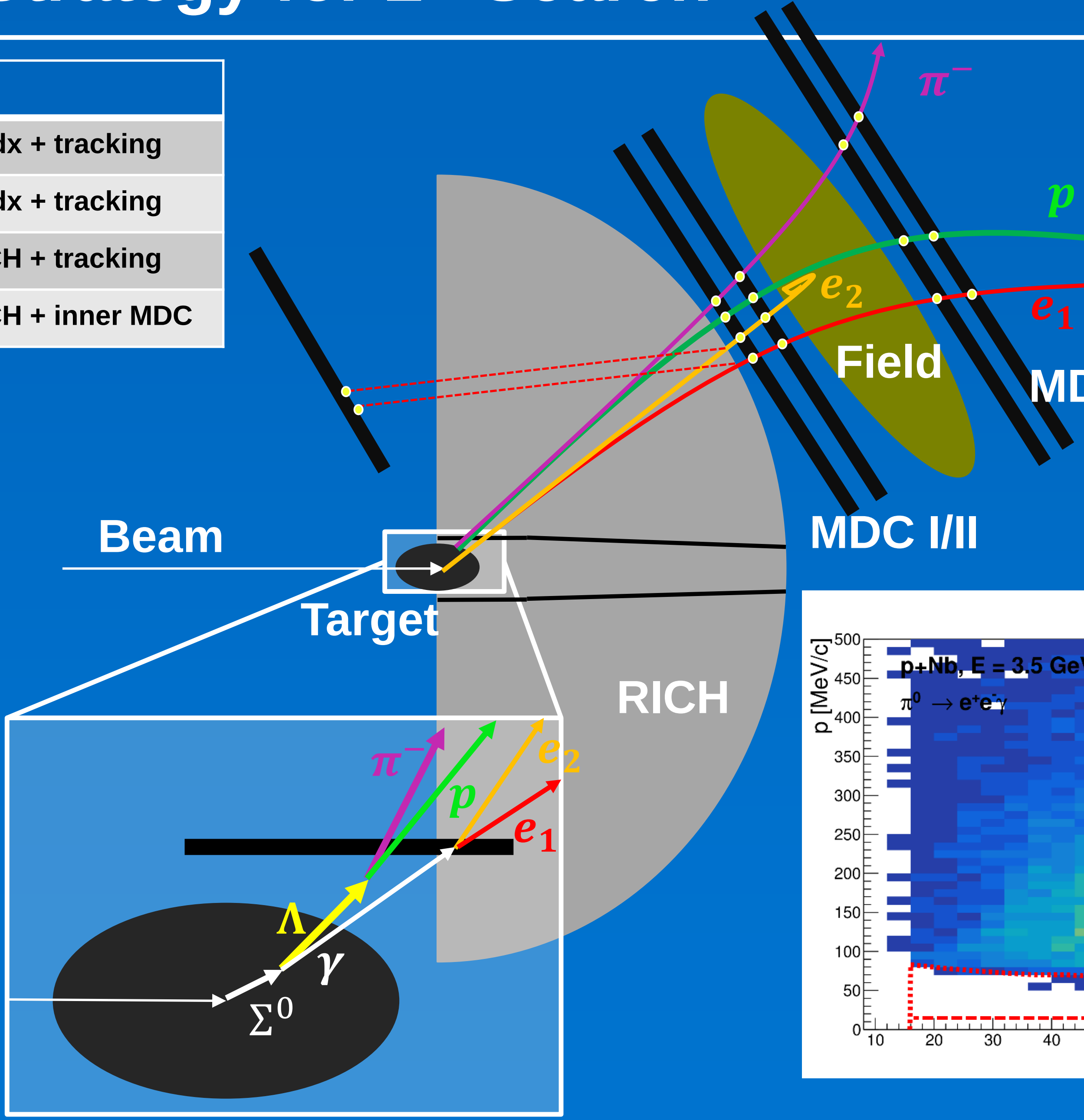


Slow e cannot be tracked!



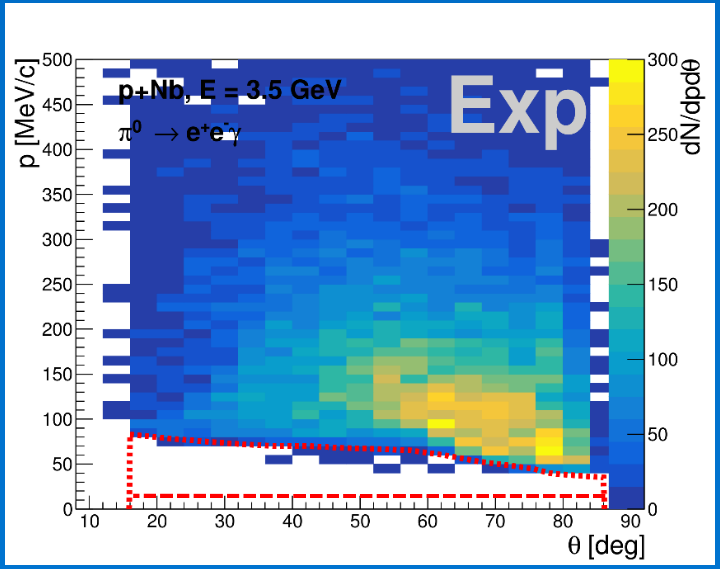
Strategy for Σ^0 Search

Particle	PID
p	dEdx + tracking
π^-	dEdx + tracking
e_1	RICH + tracking
e_2	RICH + inner MDC

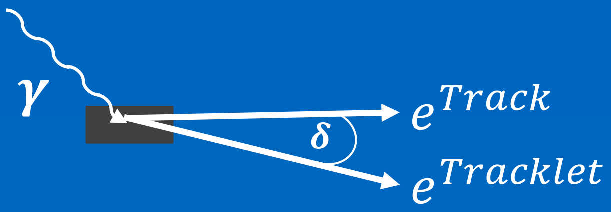


Tracklet ≠ Track

Slow e cannot be tracked!



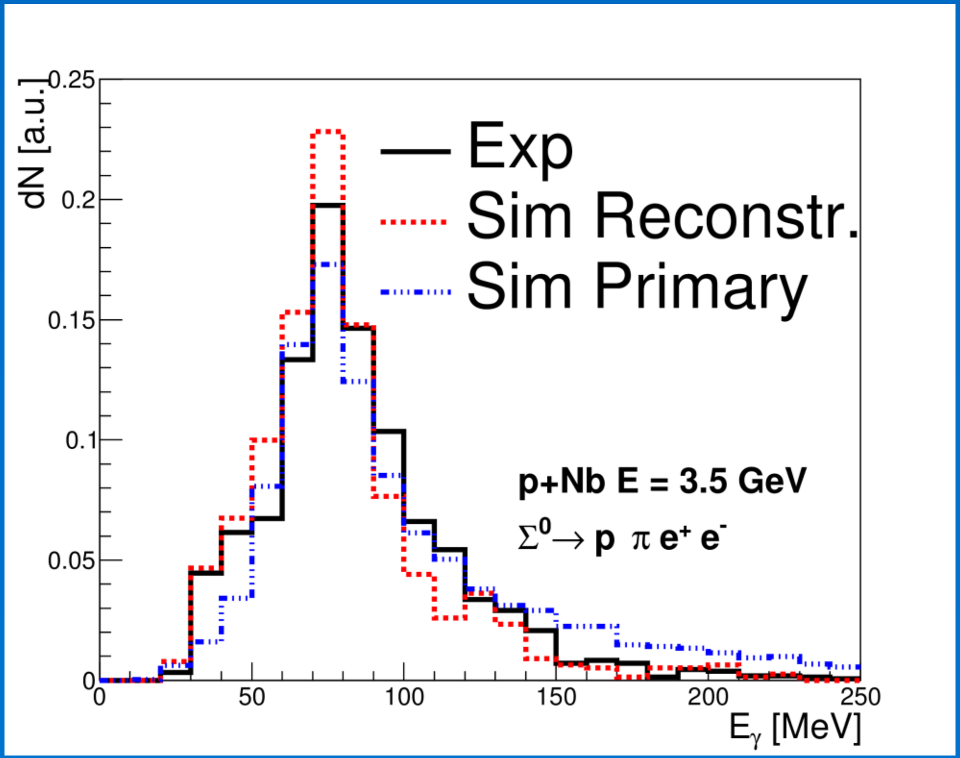
Track/Tracklet Reconstruction

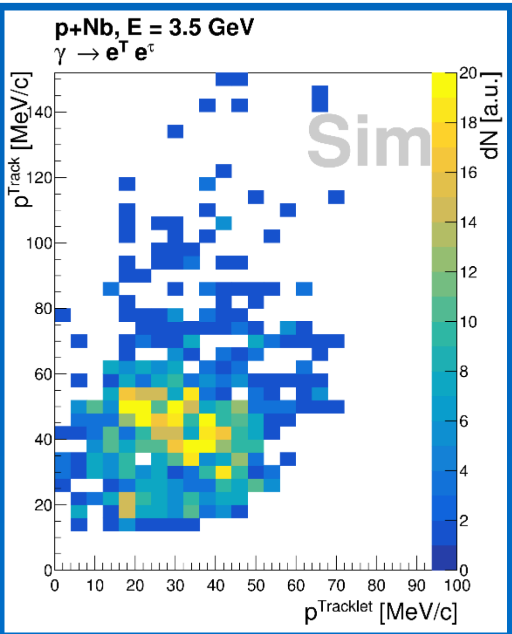


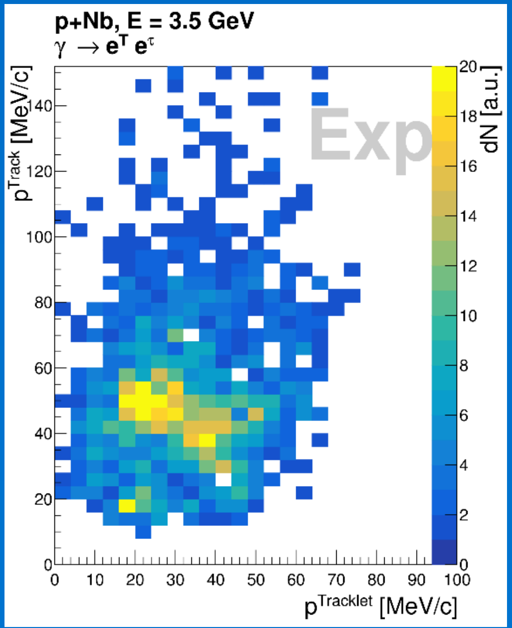
e^{Track}: θ,ϕ,p,E
$e^{Tracklet}$: θ,ϕ
Opening Angle δ

Event Hypothesis: $E_\gamma \approx 77$ MeV, e^{Track}, $e^{Tracklet}$, δ

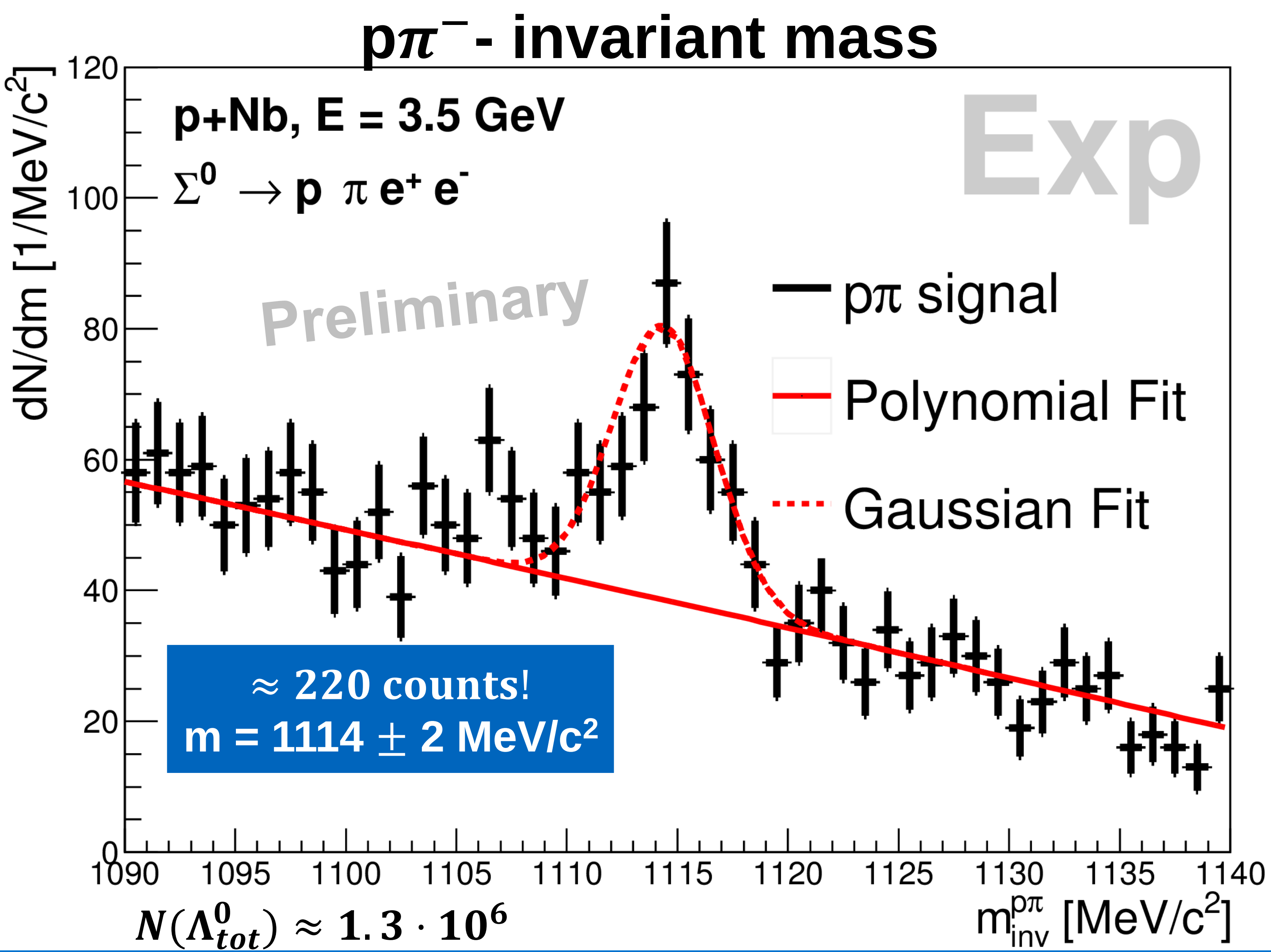
⟶ **Calculate $p^{Tracklet}$**





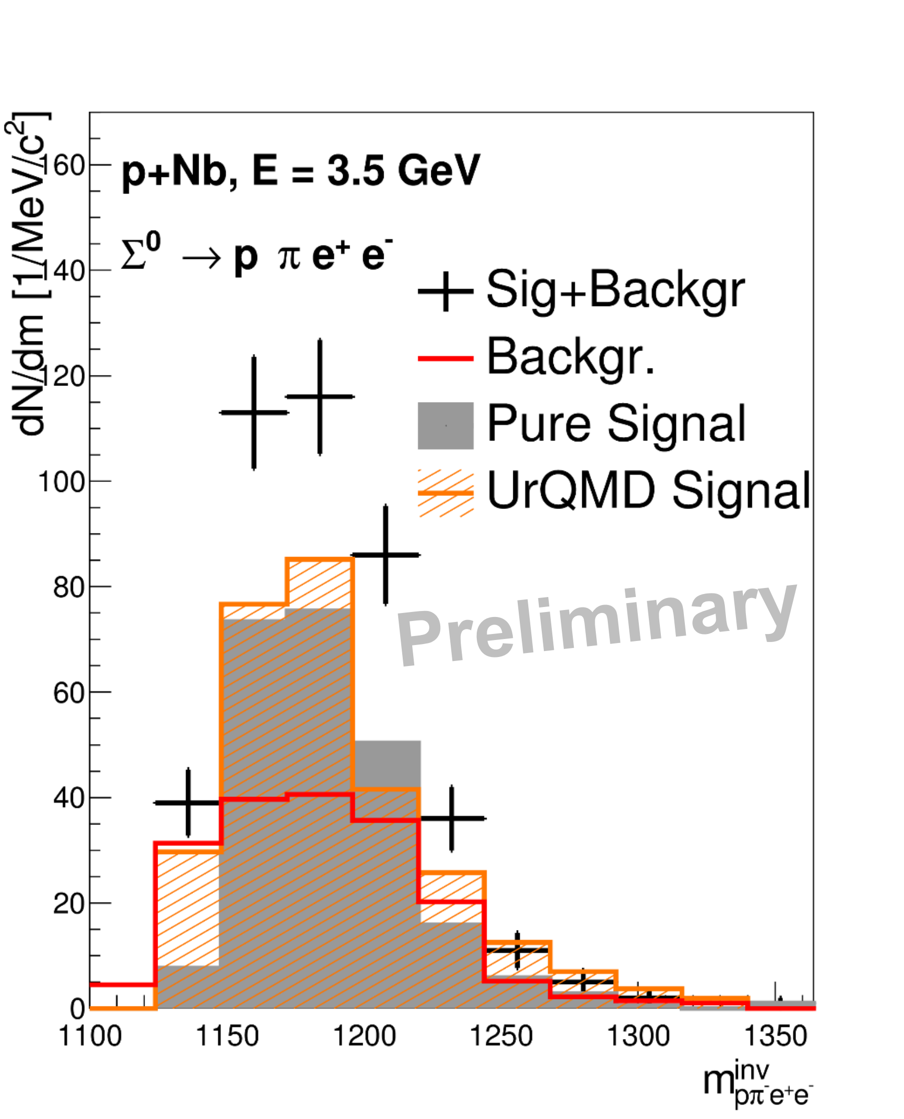


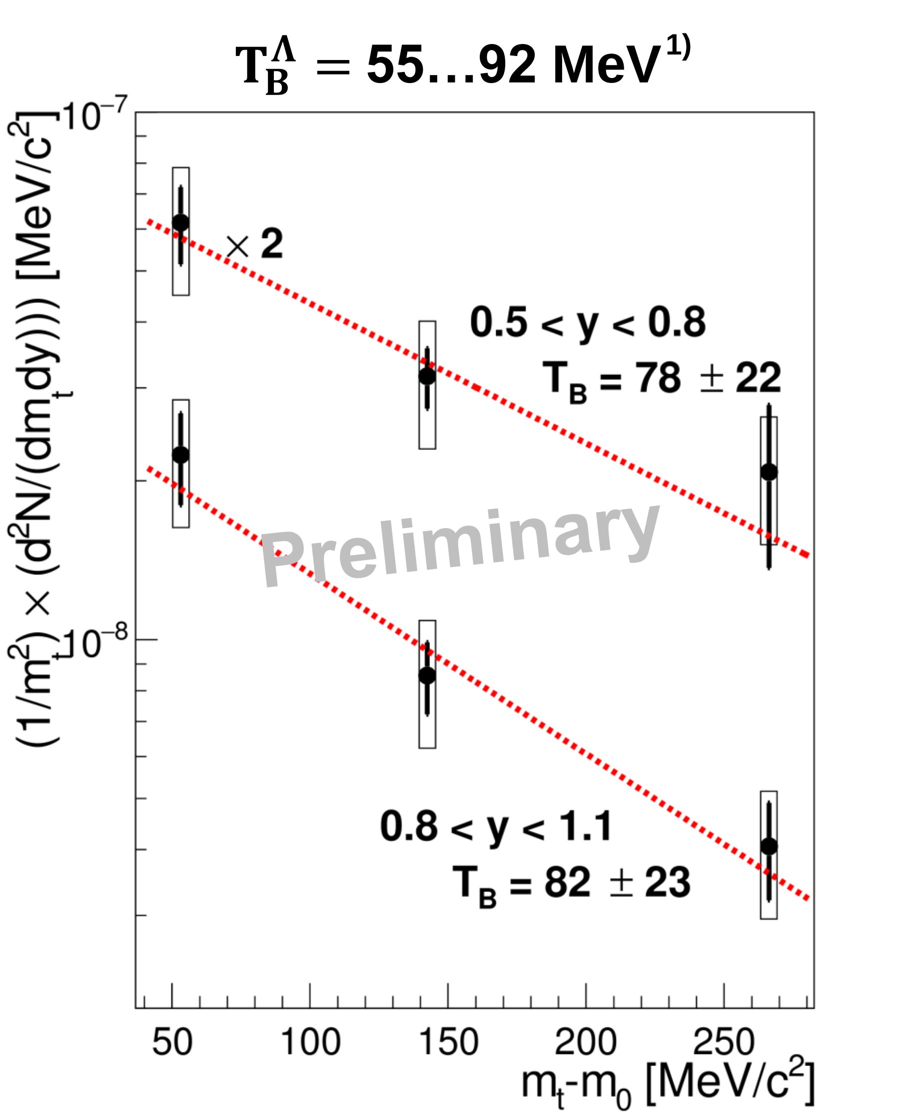
Λ^0 Candidates with Coincident $e^{\pm}$



$N(\Lambda^0_{tot}) \approx 1.3 \cdot 10^6$

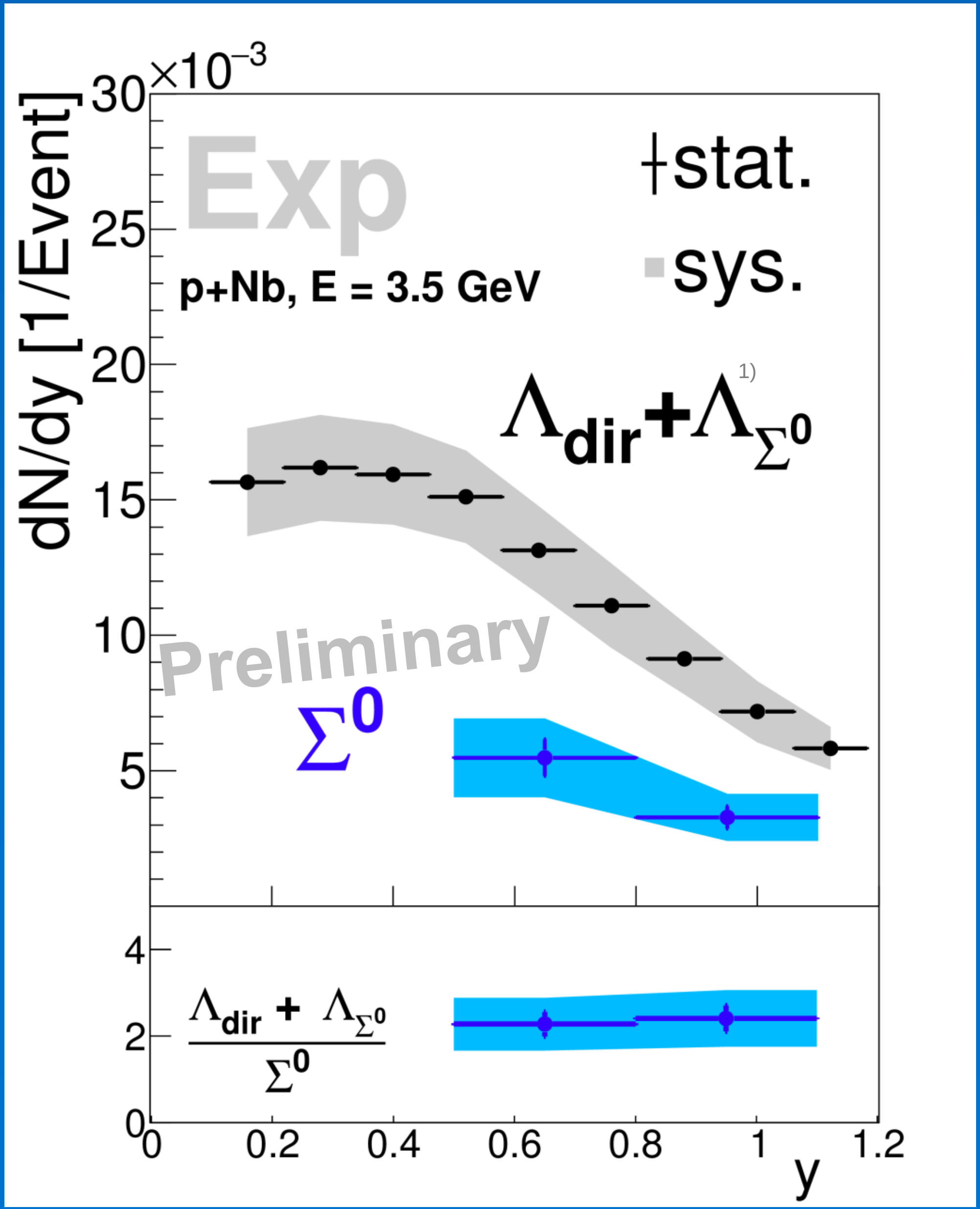
Σ^0 Signal





1) HADES Collaboration, Eur.Phys.J. A50 (2014)

$\Lambda_{dir} + \Lambda_{\Sigma^0} / \Sigma^0$ - Ratio



Measured in acceptance:

$$\frac{\Lambda_{dir}+\Lambda_{\Sigma^0}}{\Sigma^0} = 2.3$$

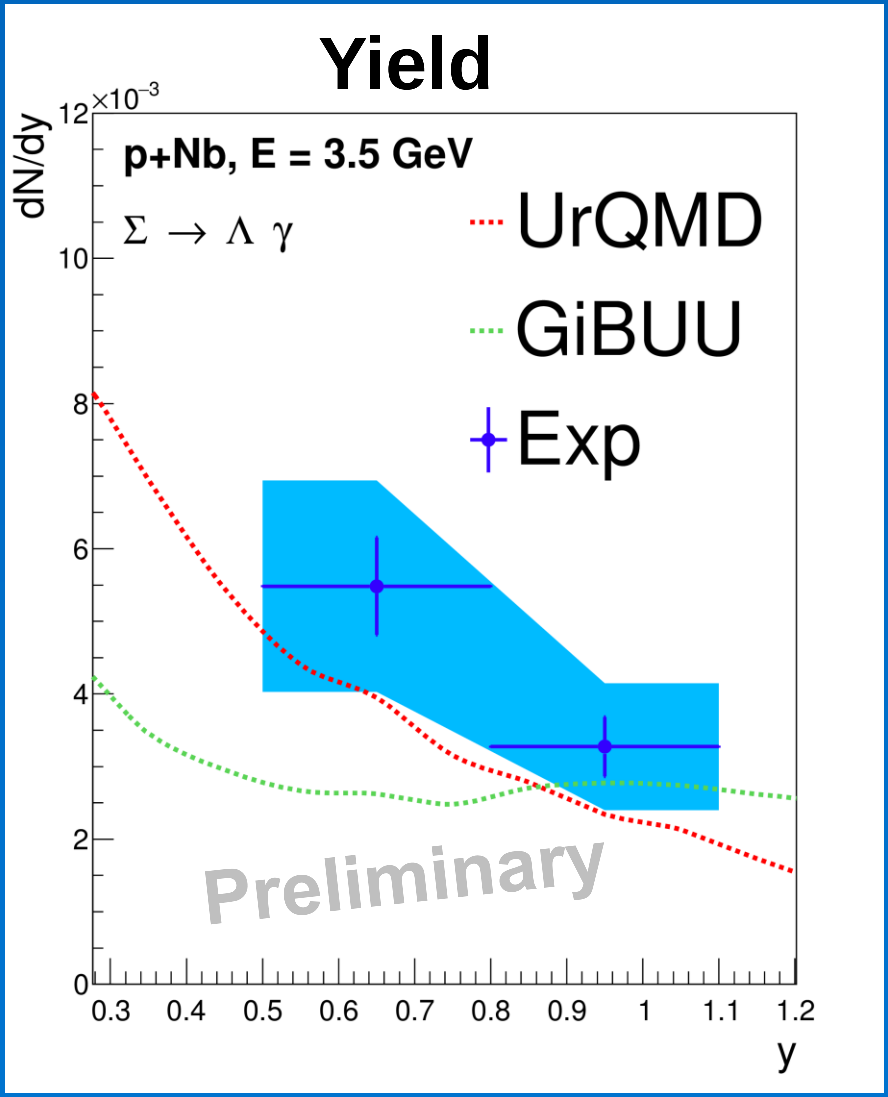
$$\pm(0.2)^{stat}$$
$$\pm(0.7)^{sys}$$

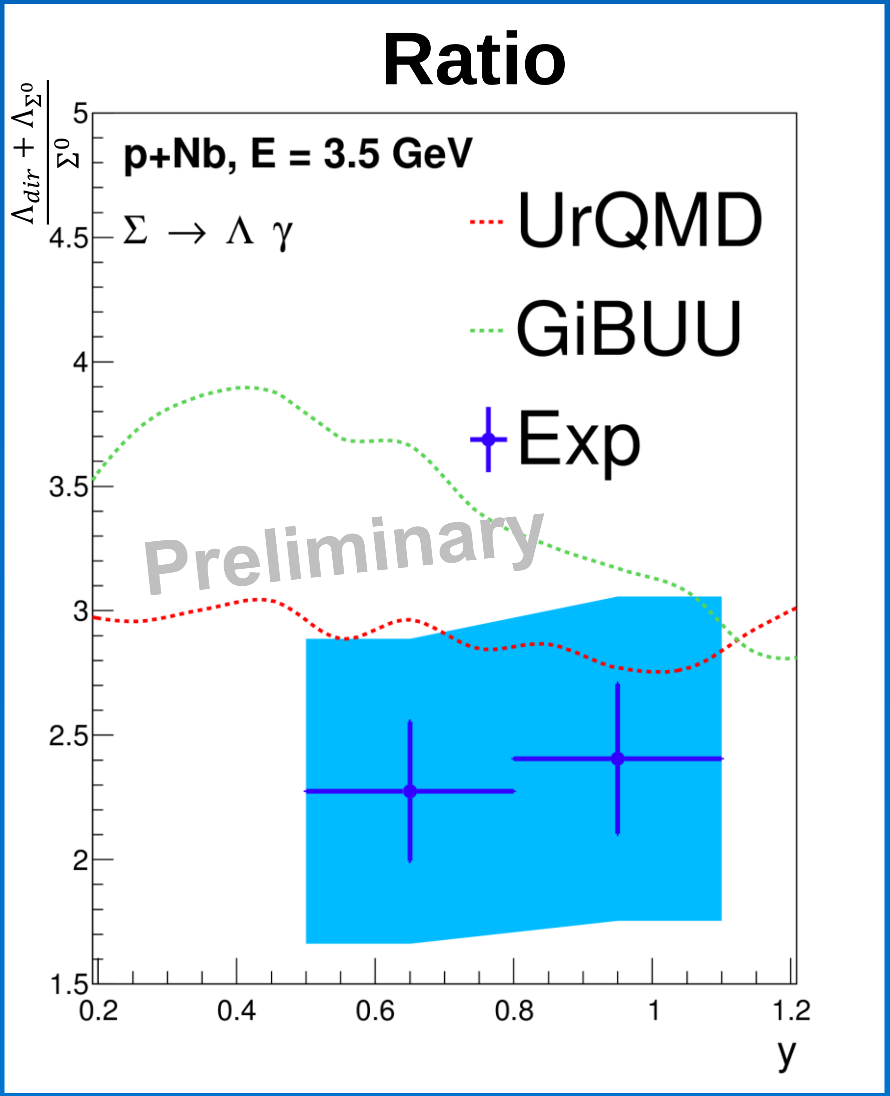
$$\sigma_{\Sigma^0} = 2.3$$

$$\pm(0.2)^{stat}$$
$$\pm(0.6)^{sys}$$
$$\pm(0.2)^{norm}$$

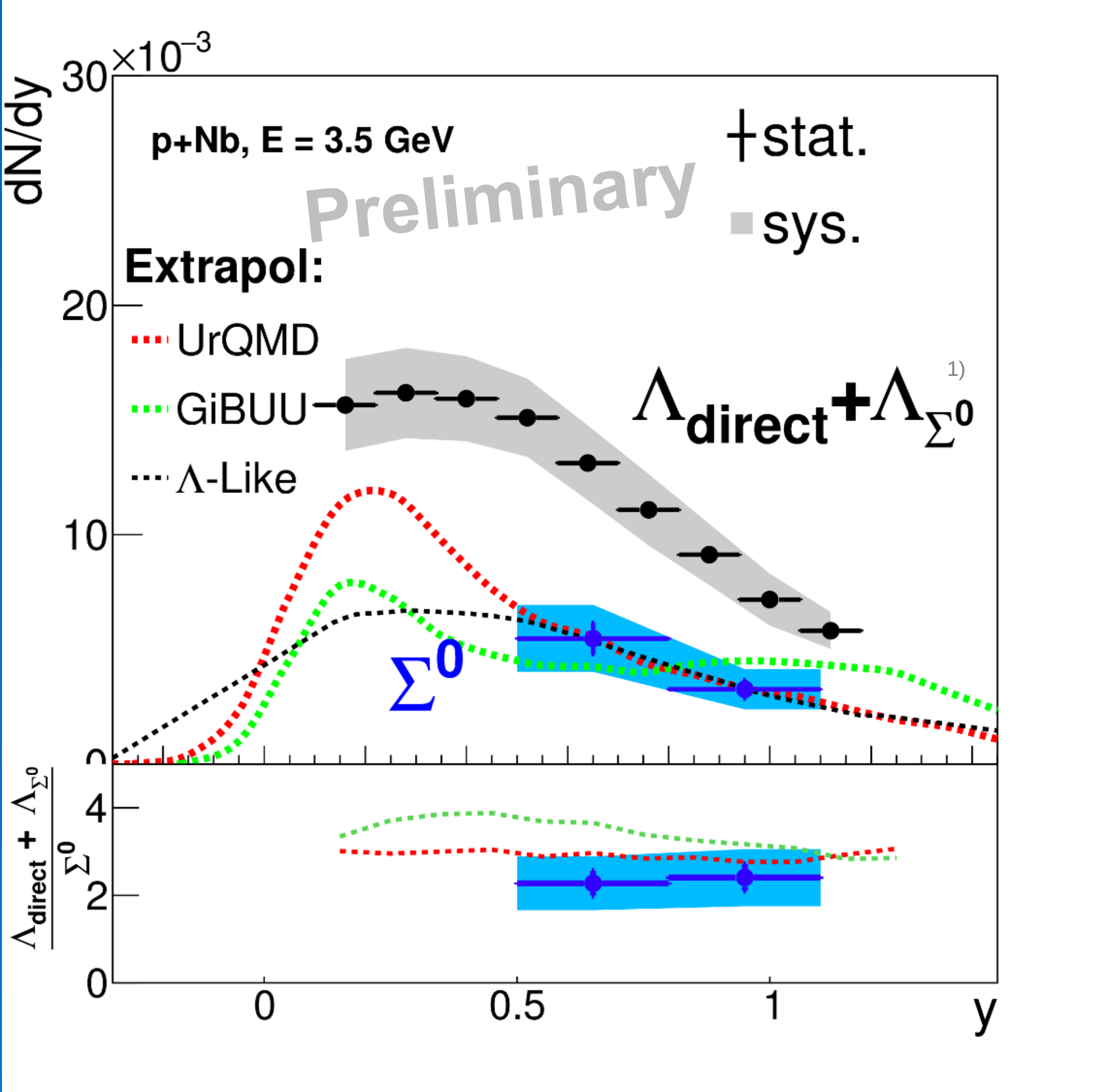
1) HADES Collaboration, Eur.Phys.J. A50 (2014)

Compare to Transport Models





Extrapolation

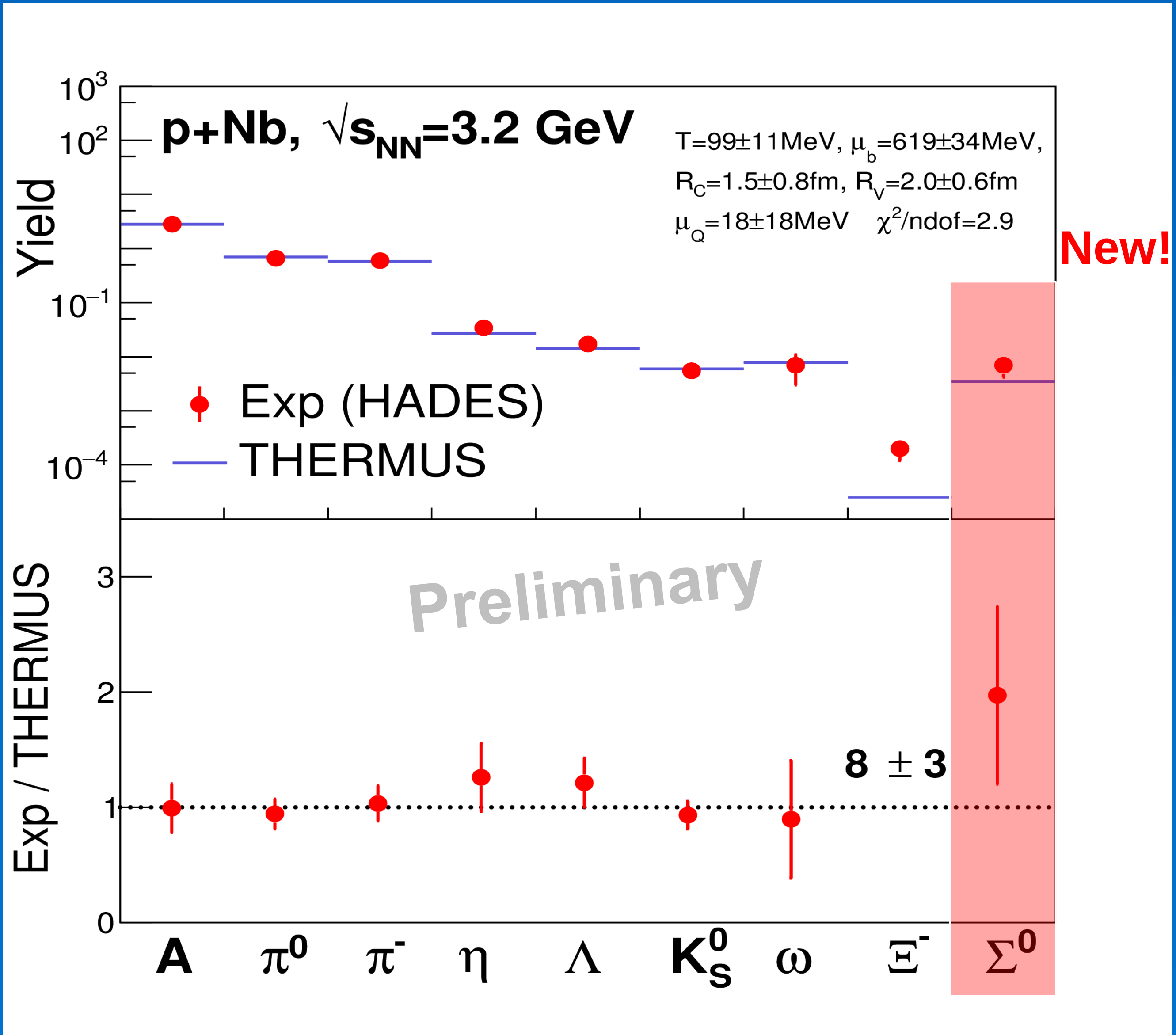


χ^2-Fit for different shapes to Exp

	Yield / 10^3	Scaling
UrQMD	8.6	1.4
GiBUU	7.3	1.6
Λ-Like	5.2	0.4

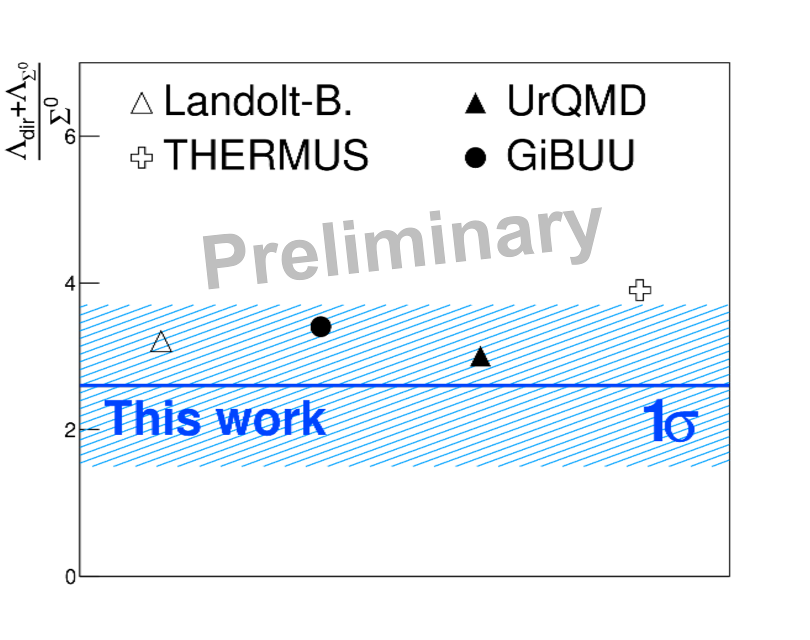
1) HADES Collaboration, Eur.Phys.J. A50 (2014)

Compare to THERMUS



Results and Uncertainties

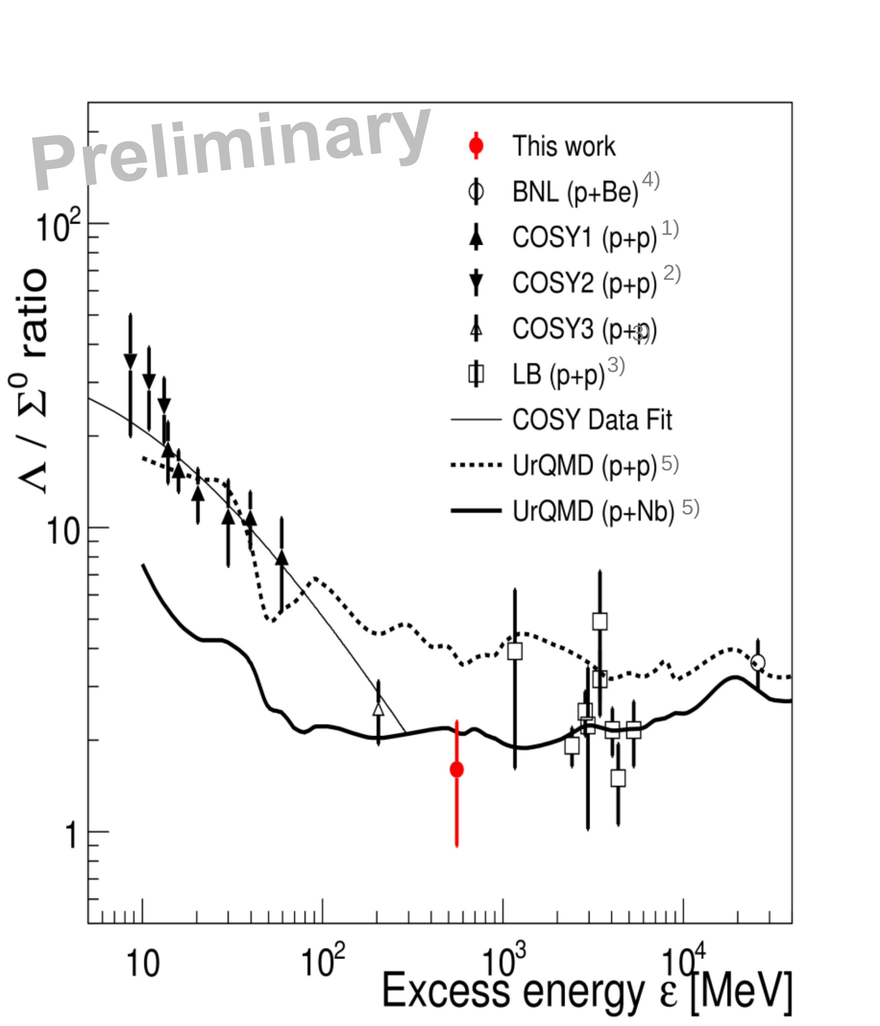
	$0.5 < y < 1.1$	Full y
Yield / 10^3	2.7 ± 0.7	6.2 ± 2.5
σ_{Σ^0} [mb]	2.3 ± 1.2	5.8 ± 2.3
Ratio $\frac{\Lambda_{dir}+\Lambda_{\Sigma^0}}{\Sigma^0}$	2.3 ± 0.6	2.6 ± 1.1



UrQMD [1]	$\frac{\Lambda_{dir}+\Lambda_{\Sigma^0}}{\Sigma^0} = 3.0$
GiBUU [2]	$\frac{\Lambda_{dir}+\Lambda_{\Sigma^0}}{\Sigma^0} = 3.4$
THERMUS [3]	$\frac{\Lambda_{dir}+\Lambda_{\Sigma^0}}{\Sigma^0} = 3.9$

1) S. A. Bass et al. Prog. Part. Nucl. Phys., 41:255–369, 1998
2) O. Buss et al., Phys. Rept., 512:1–124, 2012
3) S. Wheaton et al., Co. Phys. Com., 180:84–106, 2009

World Data



N(Σ^0) reconstructed: ≈ 220

$$\sigma_{p+A}^{tot}\left(\Sigma^0\right) = 5.8 \pm 2.3 \text{ mb}$$

$$\frac{\Lambda_{\text{dir}}}{\Sigma^0} = 1.6 \pm 0.7$$

New data point for p + A!

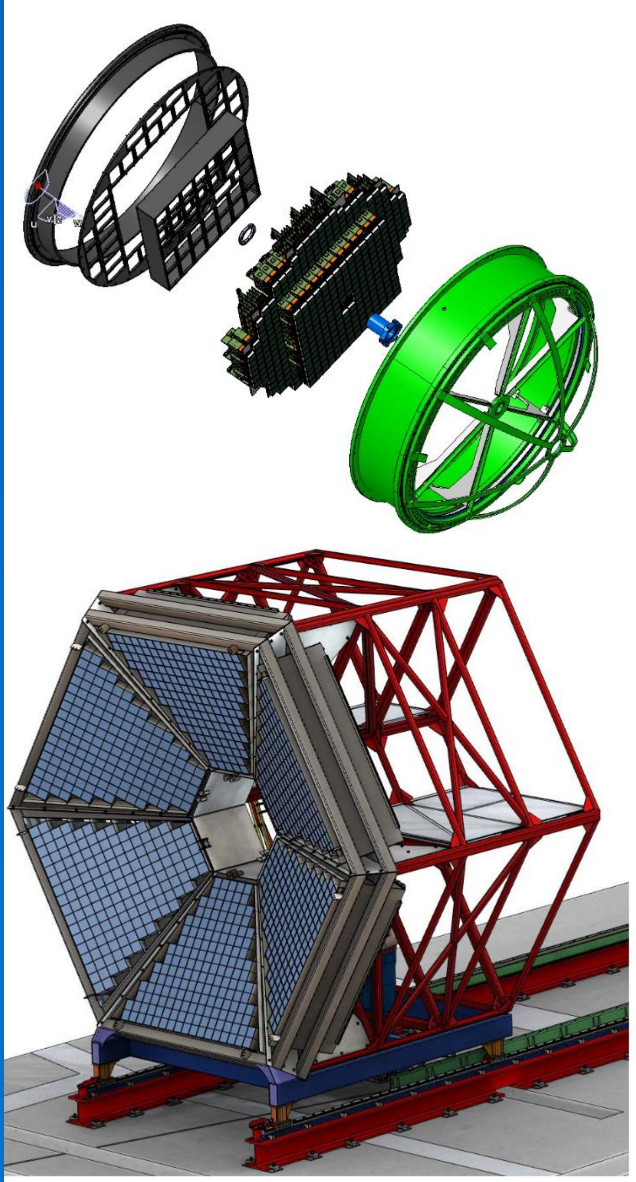
1) P. Kowina et al. Eur. Phys. J., A22:293–299, 2004
2) S. Sewerin et al., Phys. Rev. Lett., 83:682–685, 1999
3) Landolt-Boernstein, Springer, 409 P., New Series 12, 1988
4) M.W. Sullivan et al., Phys. Rev., D36:674, 1987
5) S. A. Bass et al. Prog. Part. Nucl. Phys., 41:255–369, 1998

Outlook: HADES Upgrade

Photon detector for RICH
→ **MAPMTs**
→ **Close pair eff.** ↗
→ **Single e eff.** ↗
→ $\Sigma^0 \rightarrow \Lambda e^+ e^-$ **(Line shape)**

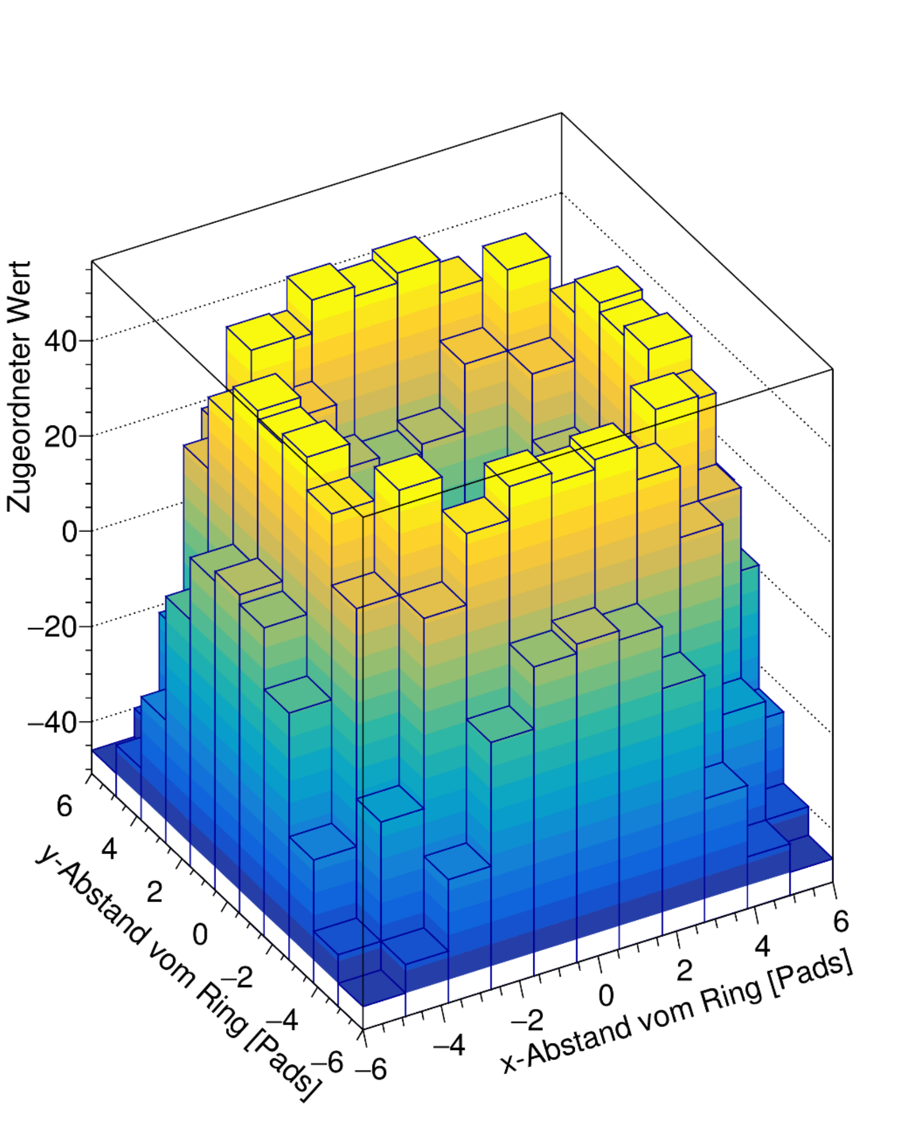
Electromagnetic Calorimeter
→ **Direct detection of** $\Sigma^0 \rightarrow \Lambda\gamma$

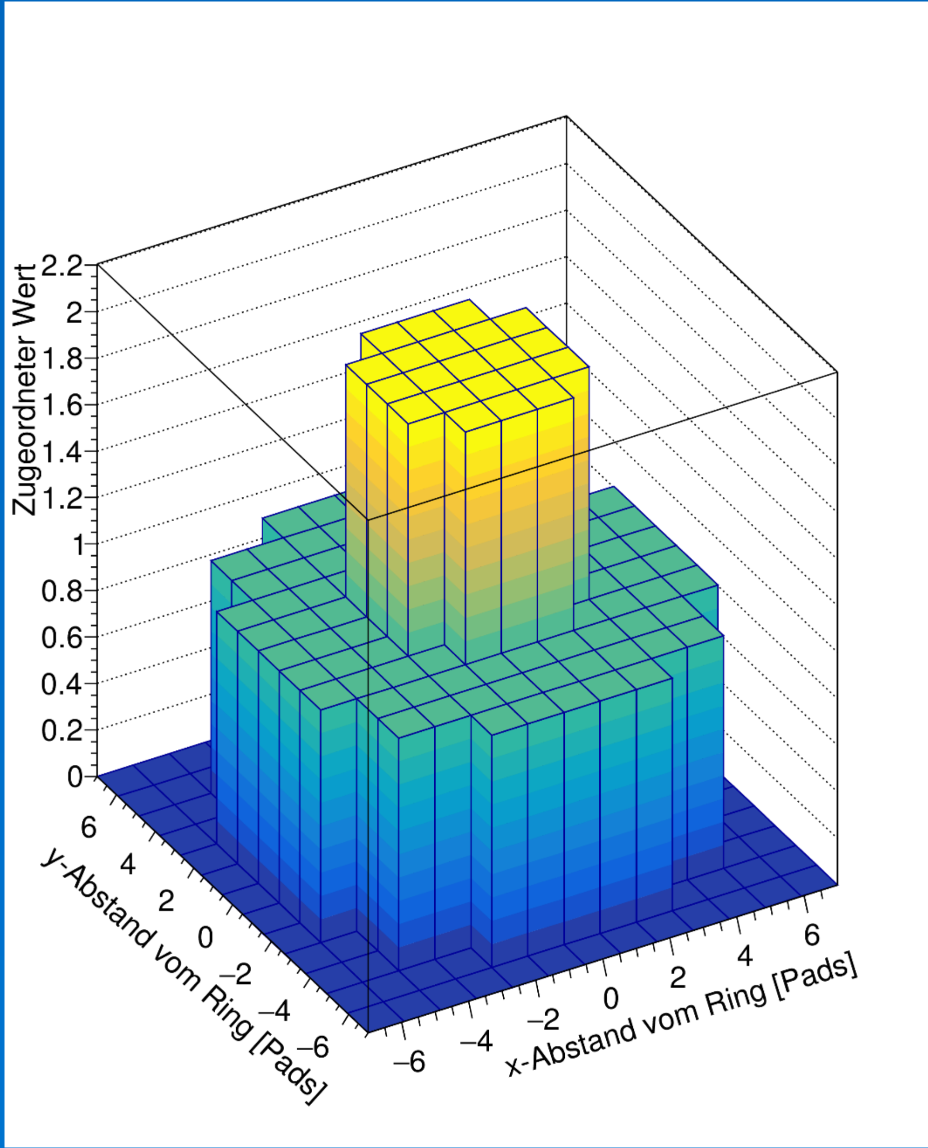
Forward Straw Tube Tracker
→ **Bigger acceptance for** Λ



Thank you for your attention

Ring Mask


Zugeordneter Wert
40
20
0
−20
−40
6
4
2
0
−2
−4
−6
y-Abstand vom Ring [Pads]
−6
−4
−2
0
2
4
6
x-Abstand vom Ring [Pads]

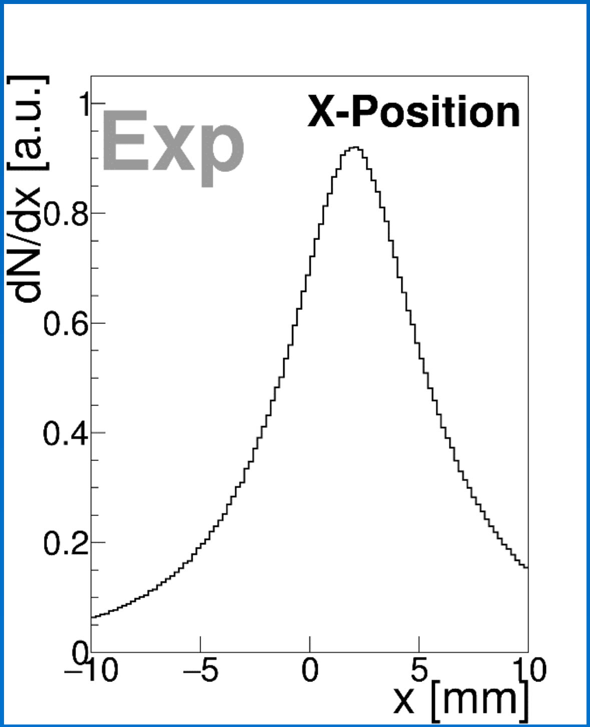

Zugeordneter Wert
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
6
4
2
0
−2
−4
−6
y-Abstand vom Ring [Pads]
−6
−4
−2
0
2
4
6
x-Abstand vom Ring [Pads]

Uncertainties

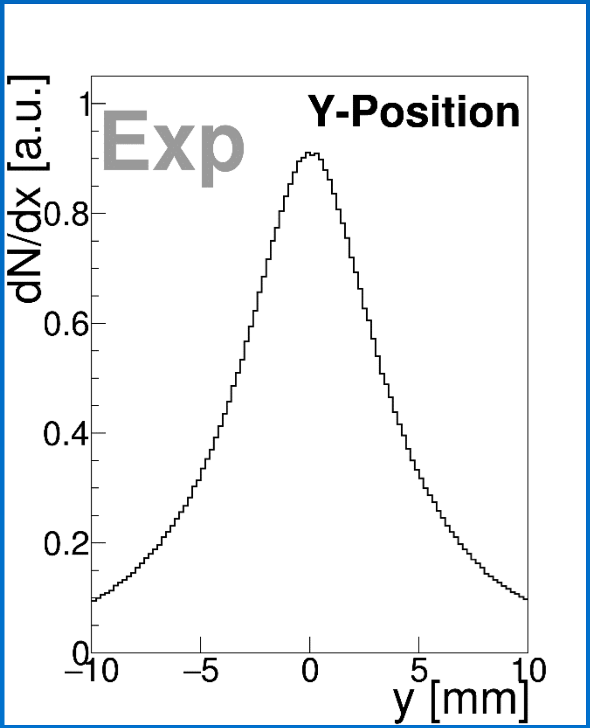
Errors	Value [%]
Normalization	11.2
e^{+}/ e^{-} ID[1)]	25
Λ ID[2)]	4.4 - 4.9
Backgr. subtr.	7.7
Extrapolation	28.1
Statistical	8.6

1) HADES Coll., Phys. Lett. B 731 (2014)
2) HADES Coll., Eur. Phys. J. A 50 (2014) 81

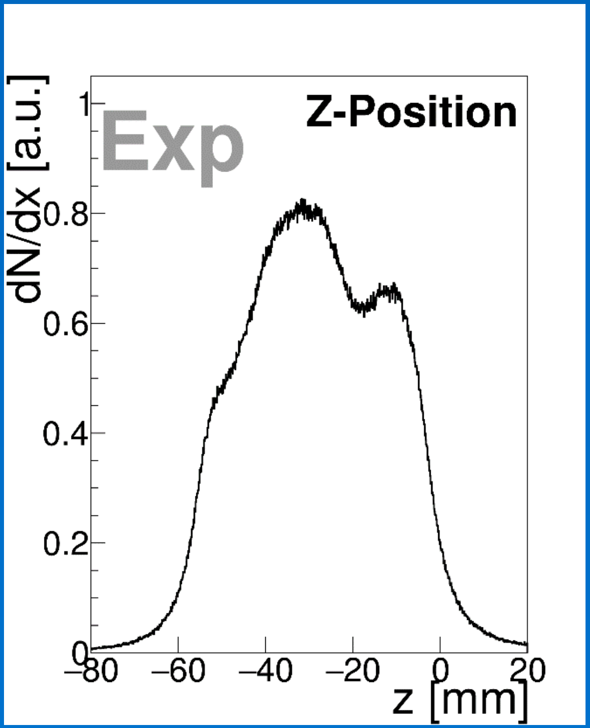
Vertex XYZ



Exp
X-Position
dN/dx [a.u.]
x [mm]
0
0.2
0.4
0.6
0.8
1
−10
−5
0
5
10

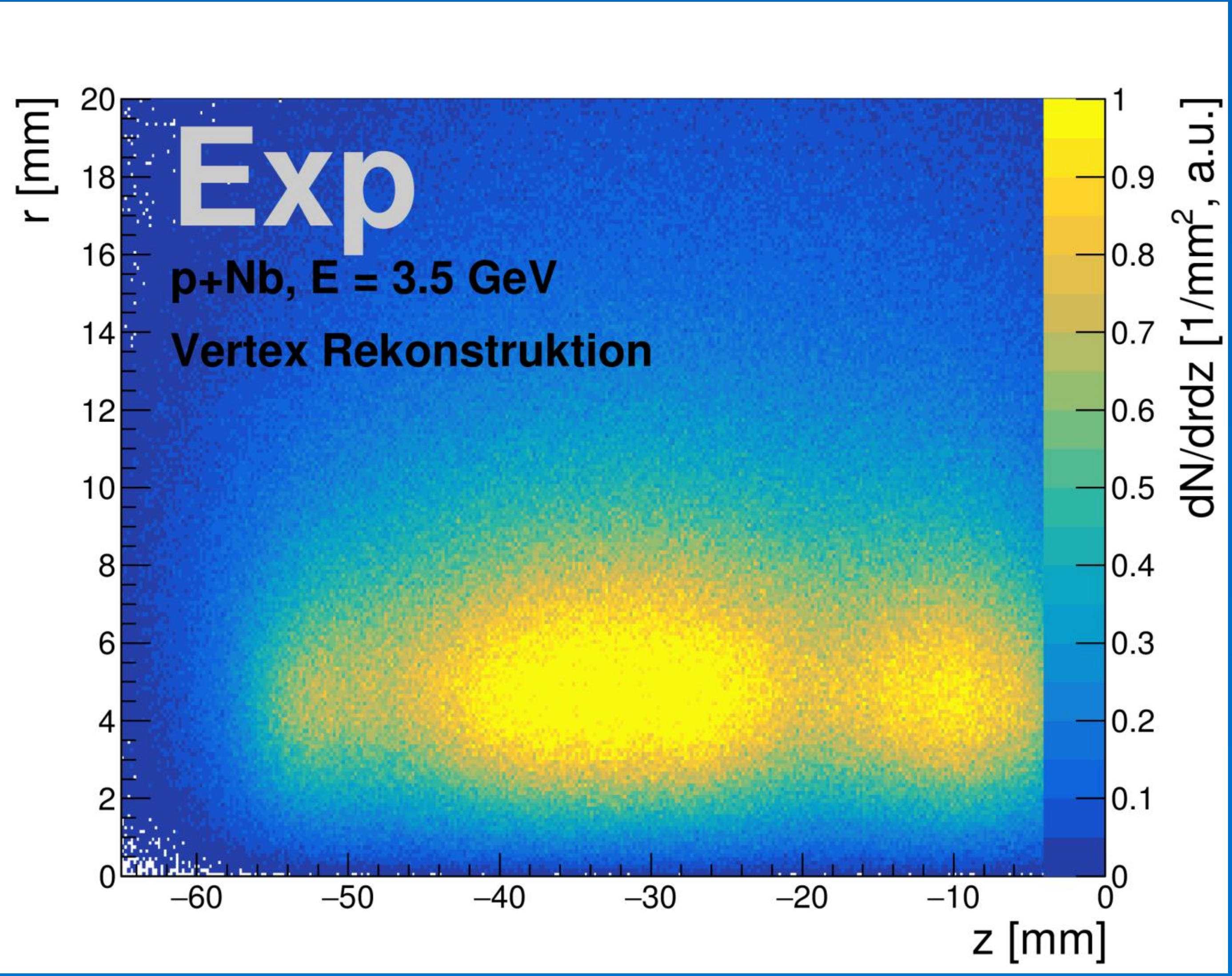


Exp
Y-Position
dN/dx [a.u.]
y [mm]
0
0.2
0.4
0.6
0.8
1
−10
−5
0
5
10



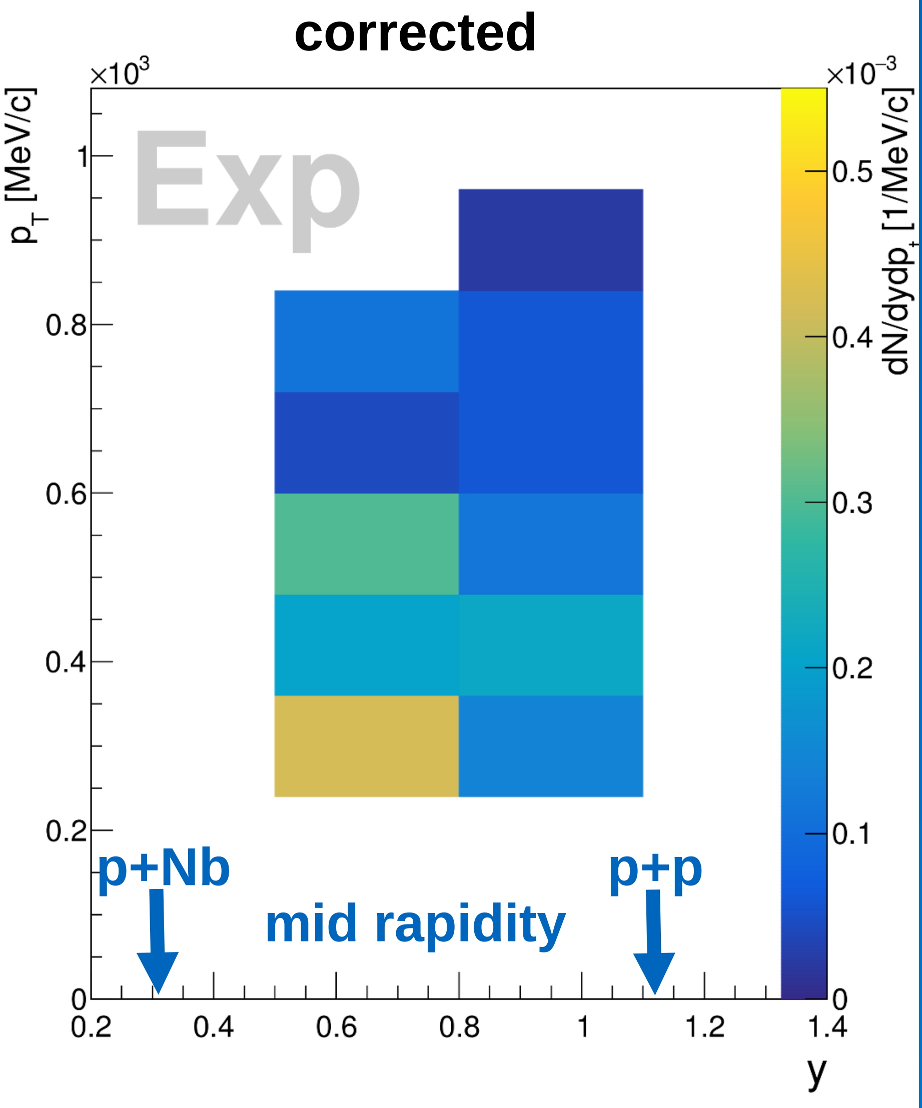
Exp
Z-Position
dN/dx [a.u.]
z [mm]
0
0.2
0.4
0.6
0.8
1
−80
−60
−40
−20
0
20

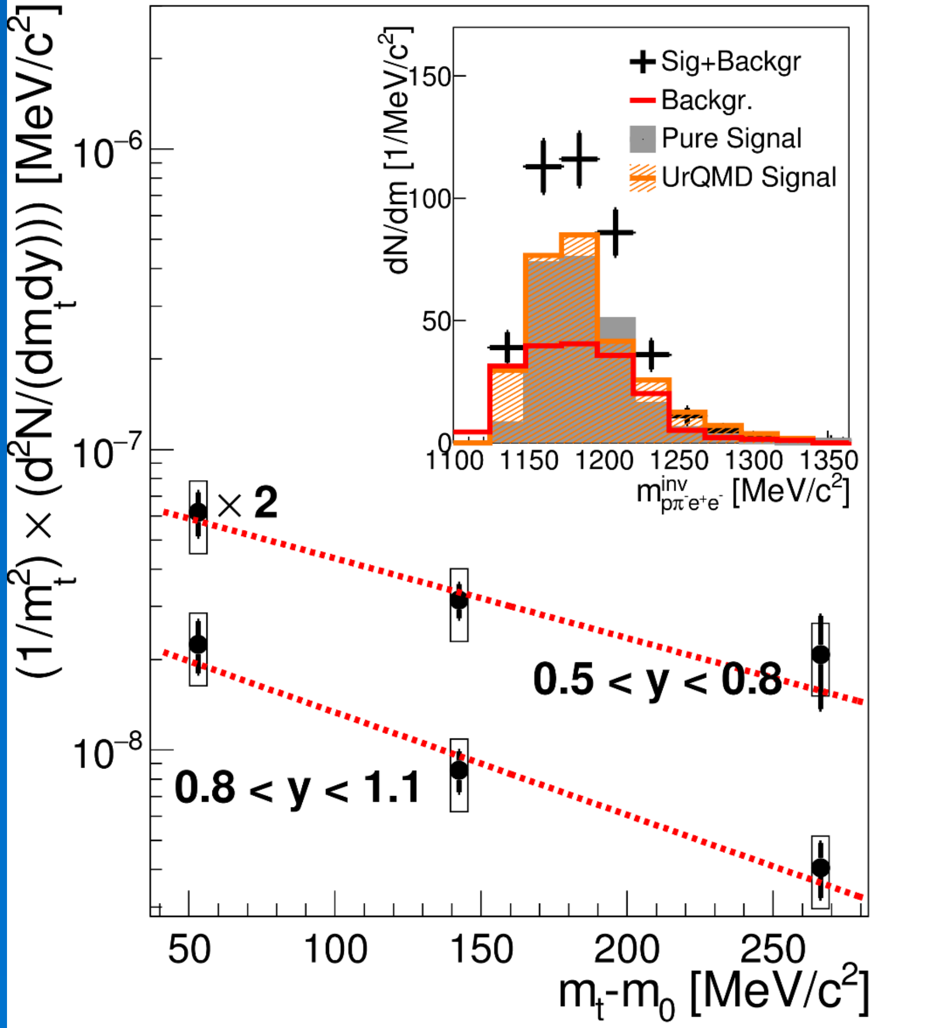
Vertex 2D



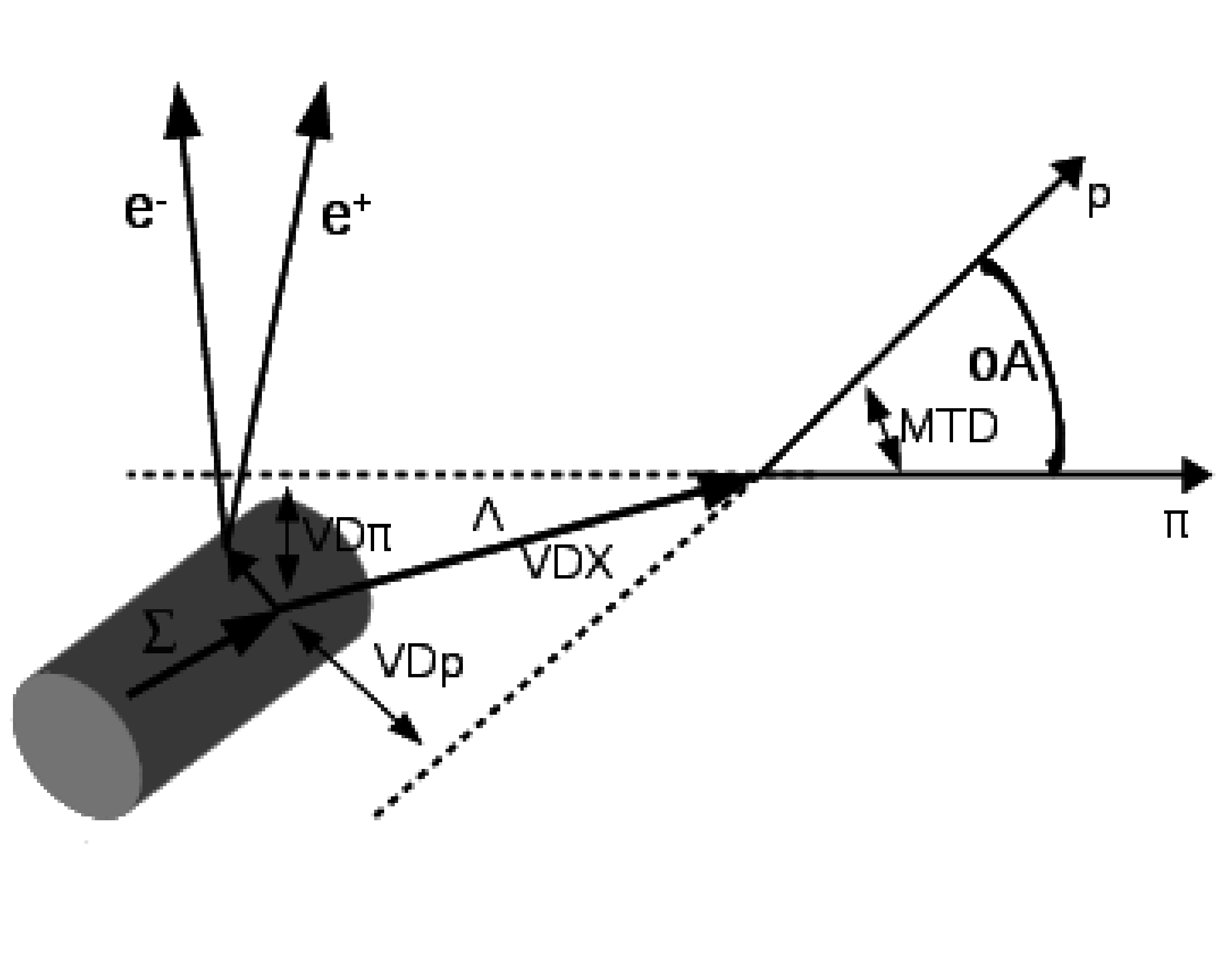
Exp
p+Nb, E = 3.5 GeV
Vertex Rekonstruktion
r [mm]
20
18
16
14
12
10
8
6
4
2
0
−60
−50
−40
−30
−20
−10
0
z [mm]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
dN/drdz [1/mm², a.u.]

Σ^0 Signal

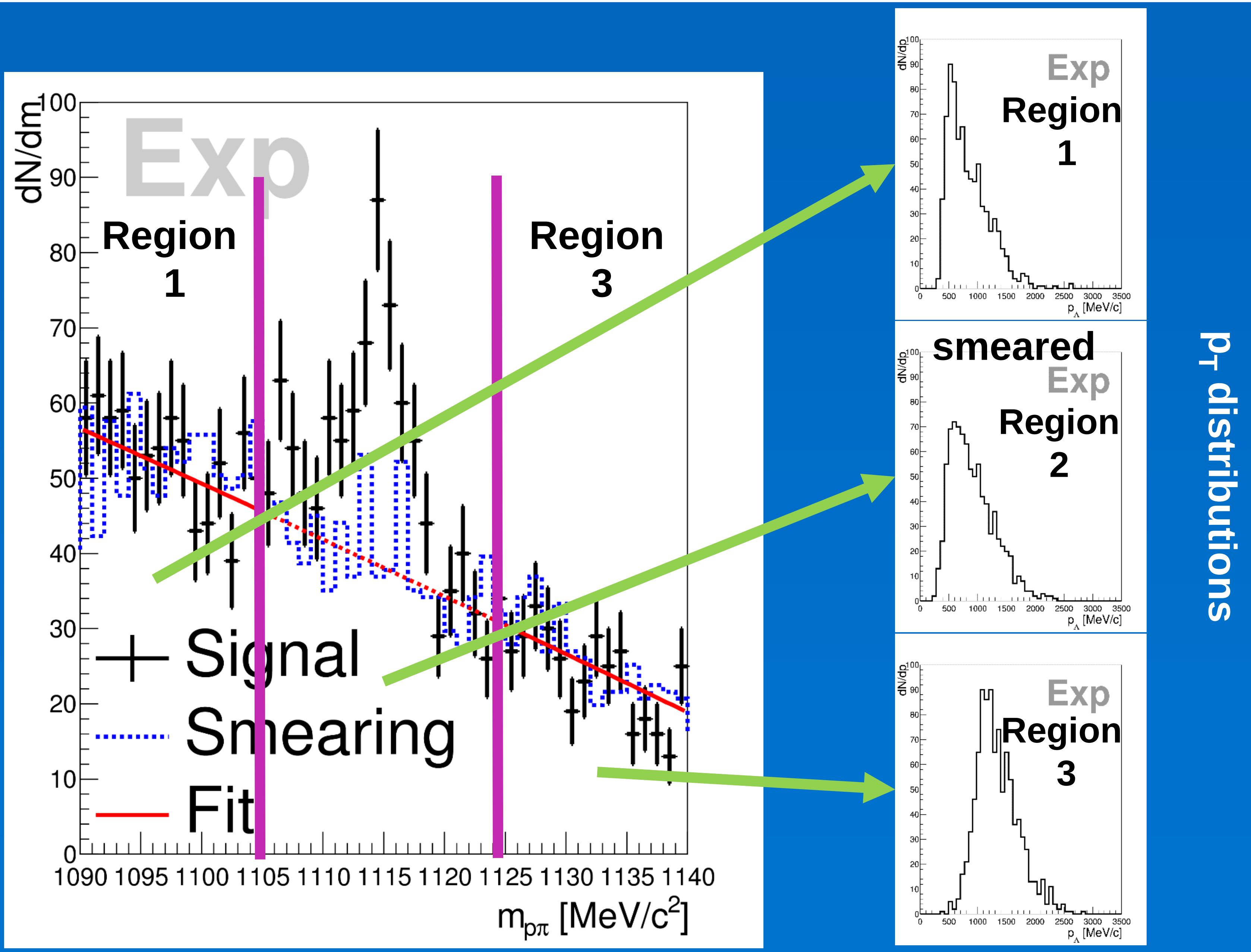




Topological Cuts

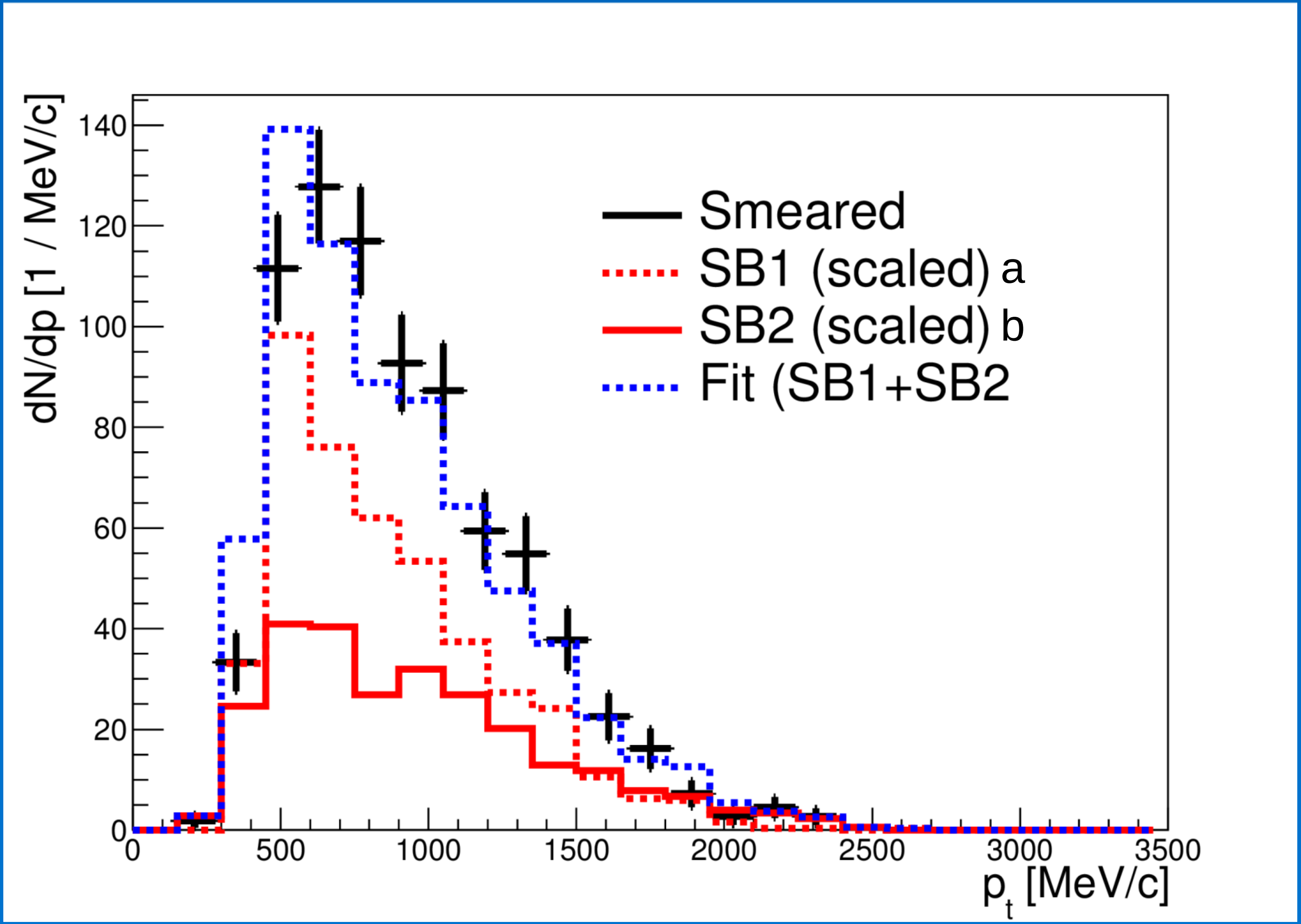


Background



Exp
Region 1
Region 3
Signal
Smearing
Fit
dN/dm
$m_{p\pi}$ [MeV/c^2]
Exp
Region 1
smeared
Exp
Region 2
Exp
Region 3
dN/dp
p_Λ [MeV/c]
p_T distributions

Background



dN/dp [1 / MeV/c]
0
20
40
60
80
100
120
140
0
500
1000
1500
2000
2500
3000
3500
p$_t$ [MeV/c]
Smeared
SB1 (scaled) a
SB2 (scaled) b
Fit (SB1+SB2

Background

same a / b factors apply!