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Measurement of Hyper-Triton Lifetime at STAR

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Outline

- Motivation
- RHIC and STAR
- Dataset
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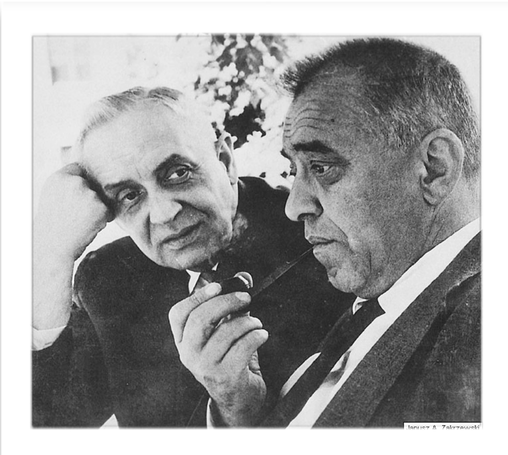
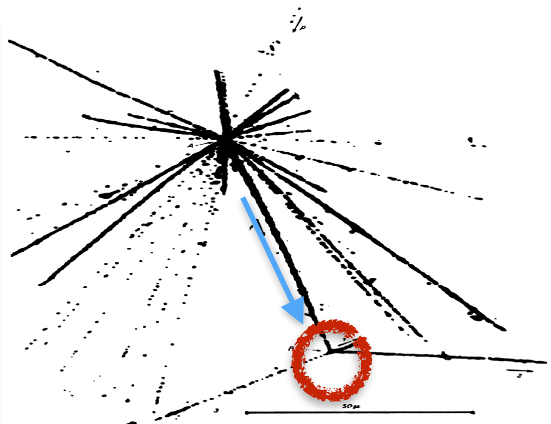
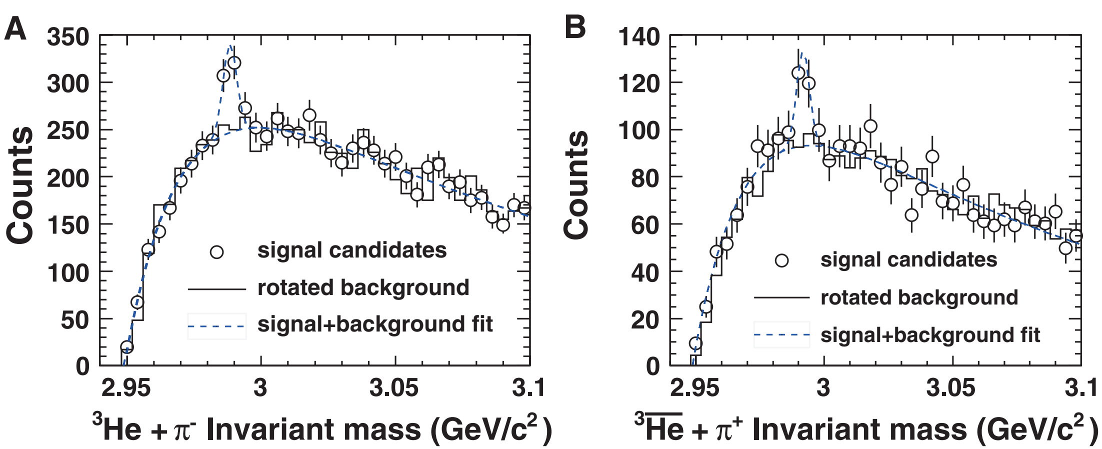
Motivation

The first hyper nucleus was observed in 1952.





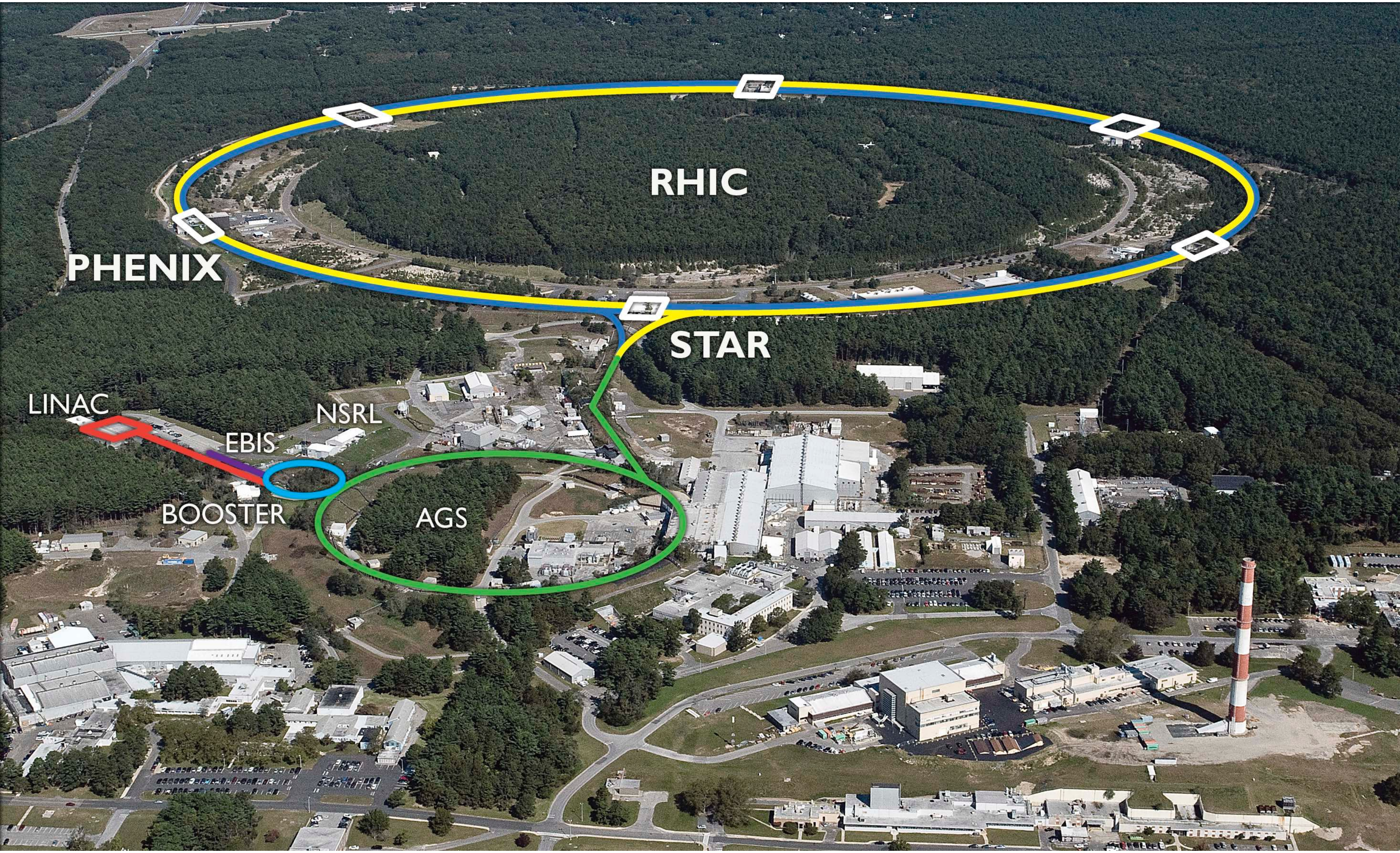
M. Danysz and J. Pniewski, Phil. Mag. 44 (1953) 348



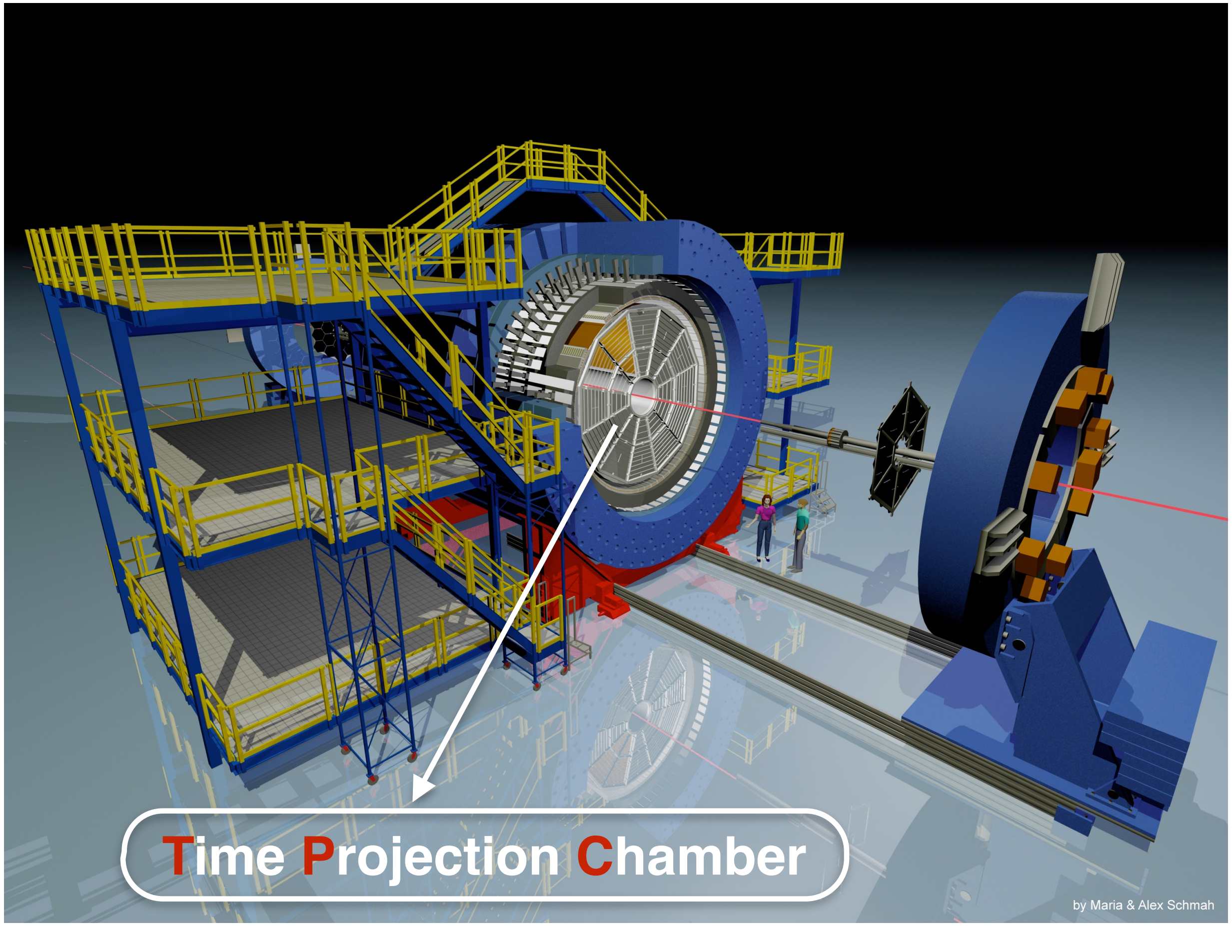
STAR Collaboration, SCIENCE 328, 58 (2010)

- ★ YN interaction will help to understand strong interactions and neutron stars.
- ★ Binding energy and lifetime are sensitive to YN interaction.
- ★ Hypertriton is the hyper nucleus with lowest A.
- ★ Hypertriton could be abundantly produced at RHIC.
- ★ Measurement of hypertriton lifetime at STAR.

Relativistic Heavy Ion Collider

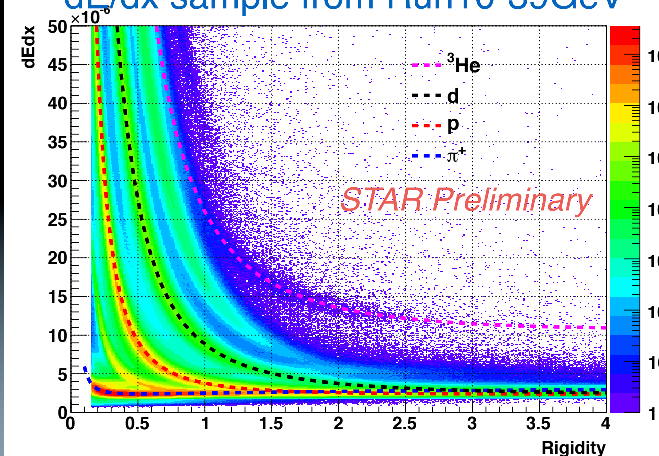


Solenoid Tracker At RHIC



STAR TPC provides momentum and energy loss information.

dE/dx sample from Run10-39GeV



^{3}He, d, p and π can be identified well at STAR, which makes it possible to reconstruct hyper-tritons through its 2 main decay channels:

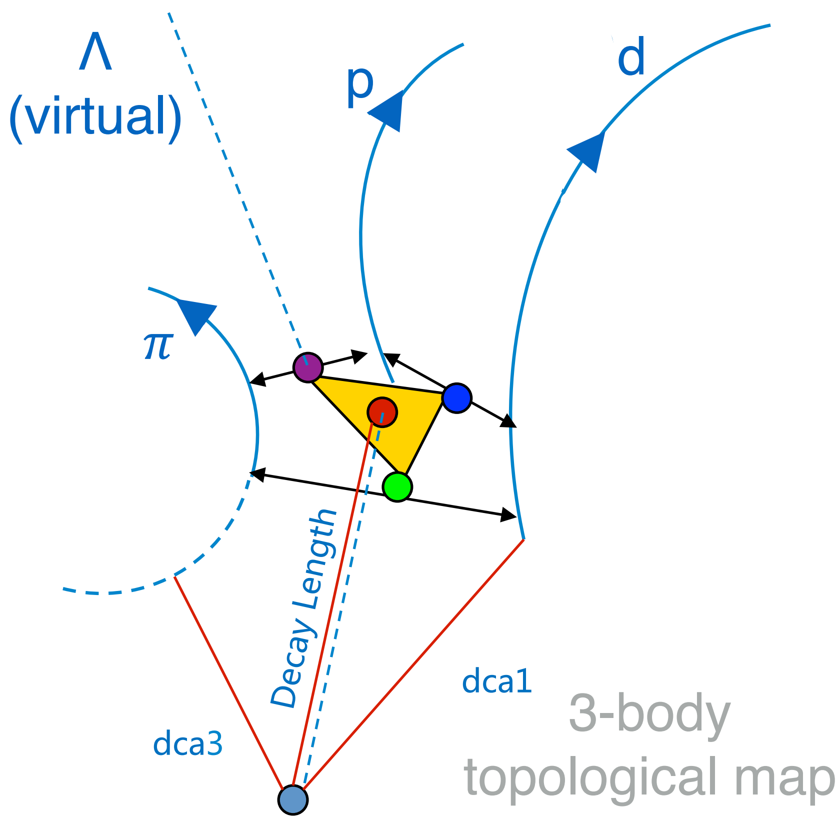
$$^{3}_{\Lambda}H \rightarrow {}^{3}He + \pi^{-}$$

$$^{3}_{\Lambda}H \rightarrow d + p + \pi^{-}$$

Dataset

Channel	Theoretical B.R.
$^3He+\pi^-$	24.88%
$d+p+\pi^-$	40.15%

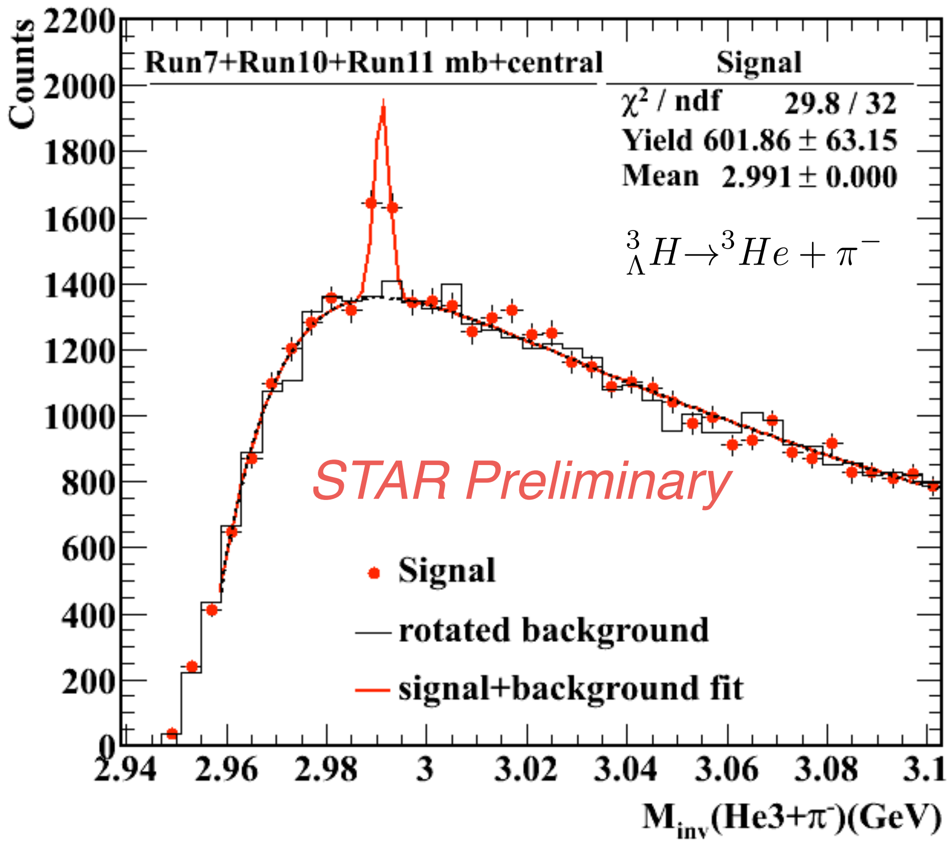
Physical Review C.57.1595(1998)

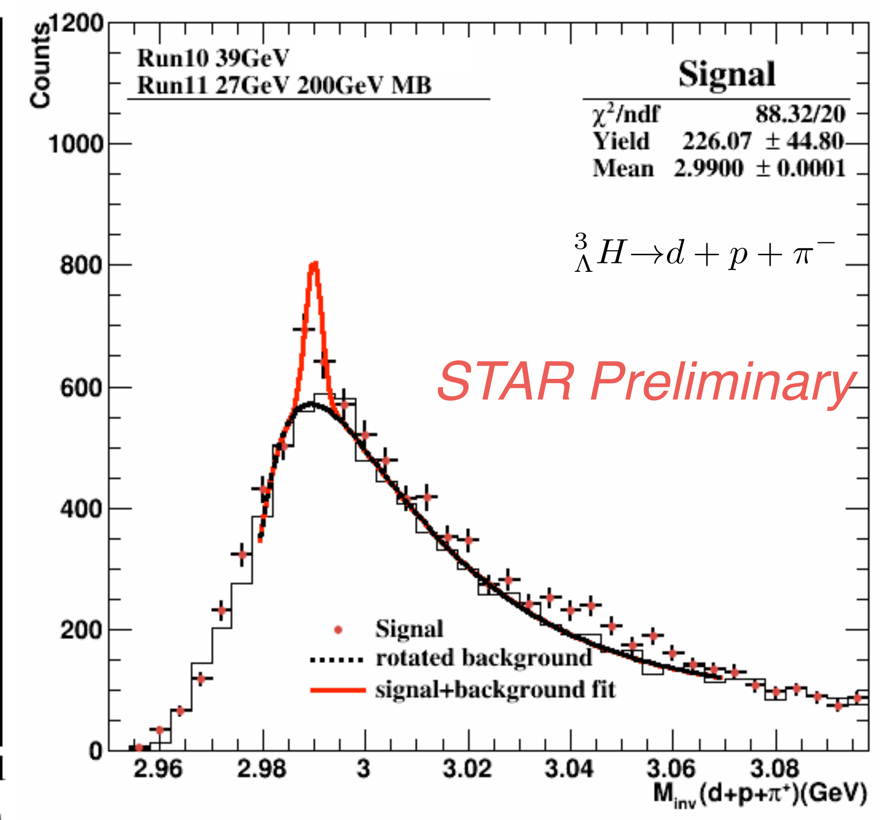


2-body	Event #
Run10 7.7	3.98 M
Run10 11.5	10.98 M
Run11 19.6	31.15 M
Run11 27	48.65 M
Run10 39	118.02 M
Run10 200	222.73 M
Total	**435.51 M**

3-body	Event #
Run11 27	53.31 M
Run10 39	134.41 M
Run11 200	516.87 M
Total	**704.59 M**

Invariant Mass

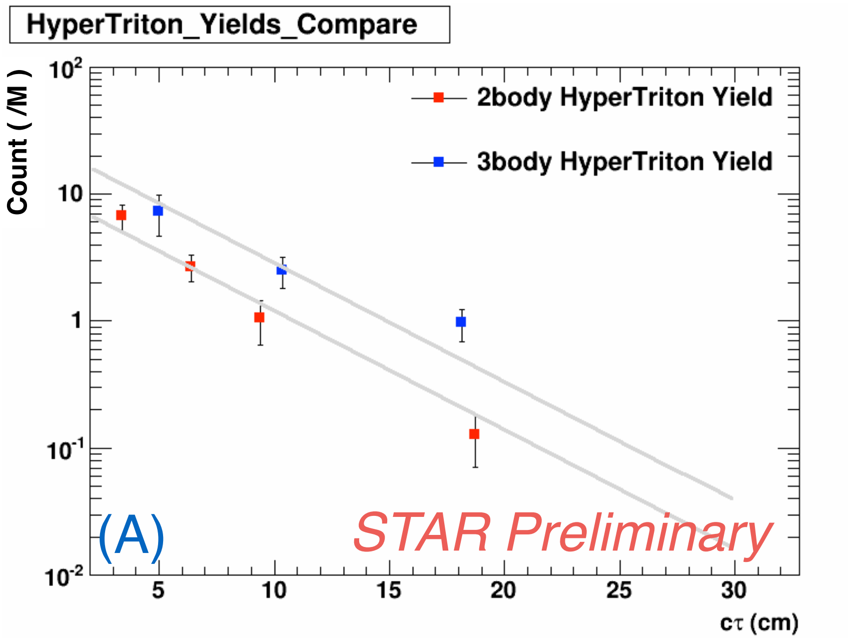


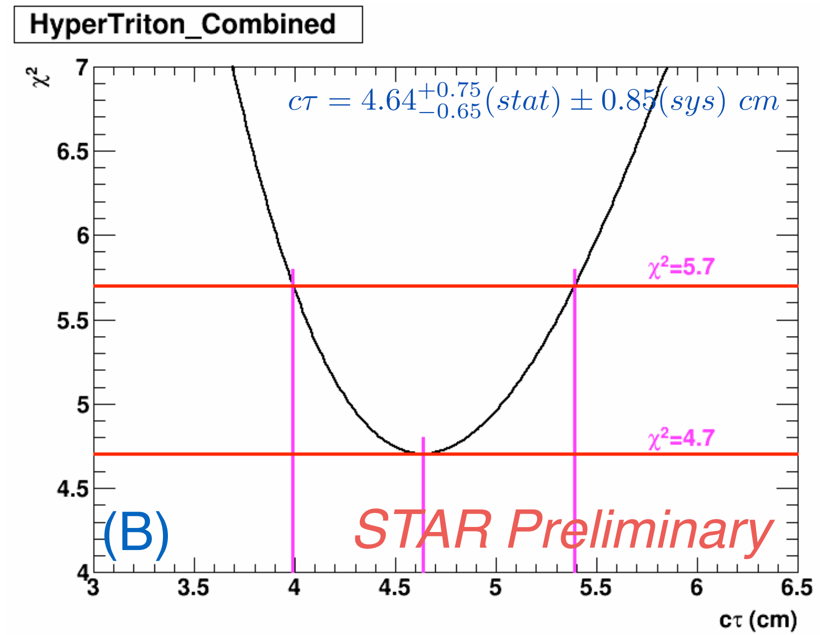


Invariant mass results for 2-body and 3-body analyses.

Measured Lifetime

With 2-body and 3-body data, we can calculate χ^2 distribution with $c\tau$.





Hypertriton lifetime from combined channels :

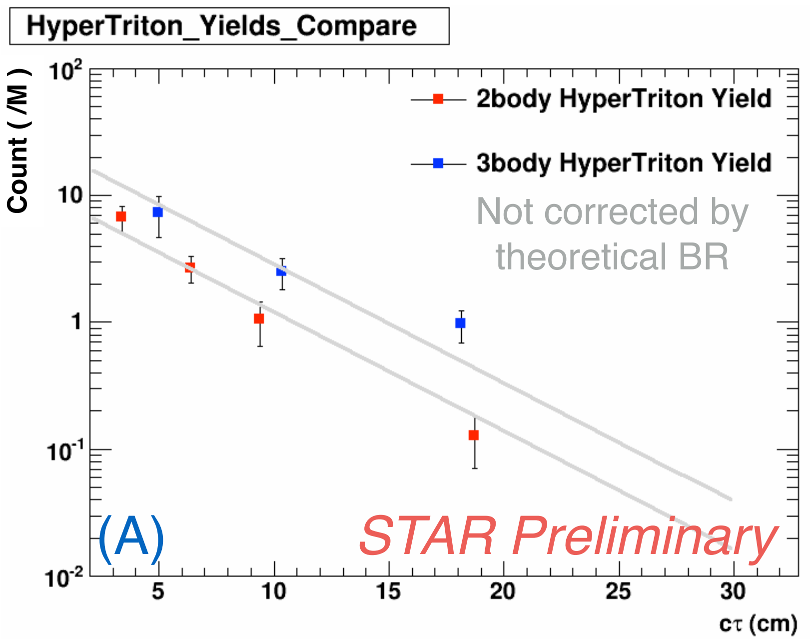
$$\tau = 155^{+25}_{-22}(stat) \pm 29(sys)\ ps$$

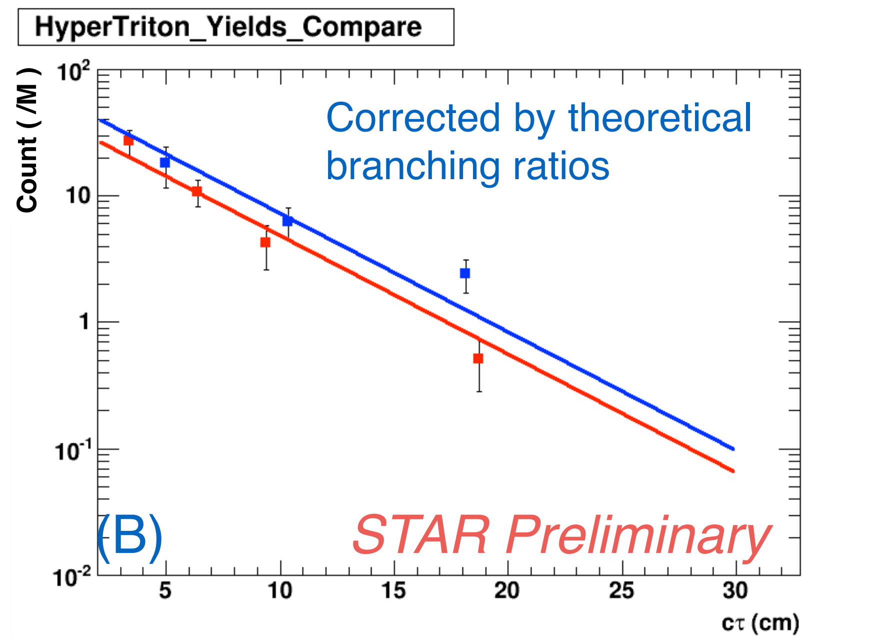
We take into account two kinds of contributions to systematic errors:

- binning effect
- different (V0) cuts.

Measured Branching Ratio

Branching ratio can be calculated by decay law : $f(t) = N_0 B r e^{-\frac{t}{\tau}}$



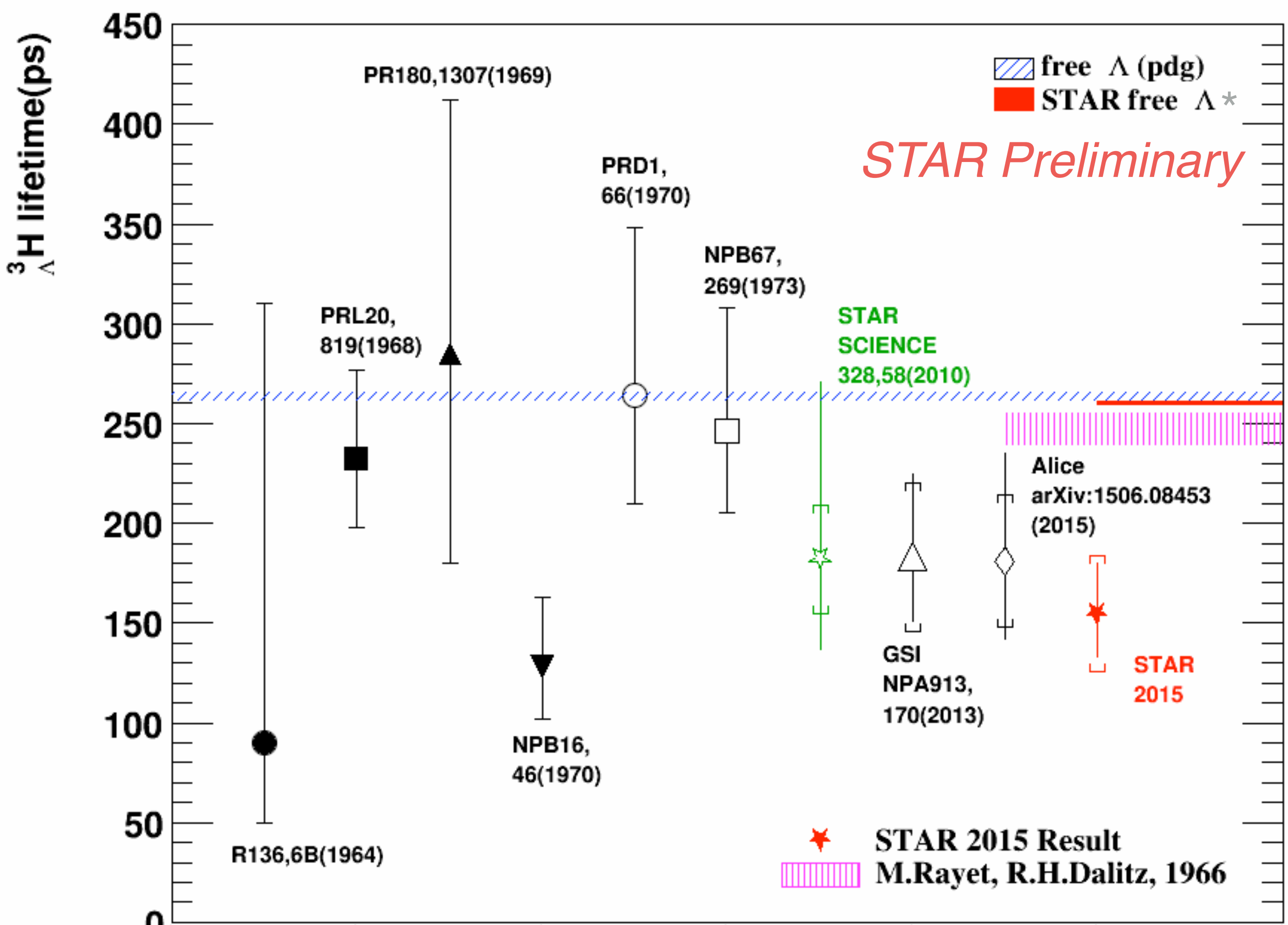


$$\frac{B.R.(d+p+\pi^-)}{B.R.(^3He+\pi^-)} = 2.41^{+0.39}_{-0.34}$$

Theoretical : $\left(\frac{40.15}{24.88} = 1.61\right)$

**Physical Review C.57.1595(1998)*

World Data



* The same method is applied for calculation of STAR free Λ lifetime.

Summary

In this analysis, with 2-body and 3-body decay channels, we calculated the lifetime of hyper triton as well as the ratio of 2 branching ratios.

For lifetime result :

$$\tau = 155^{+25}_{-22}(stat) \pm 29(sys)\ ps$$

For branching ratio result :

$$\frac{B.R.(d+p+\pi^-)}{B.R.(^3He+\pi^-)} = 2.41^{+0.39}_{-0.34}$$

Theoretical : $\left(\frac{40.15}{24.88} = 1.61\right)$

*Physical Review C.57.1595(1998)

Backup

Theoretical Decay Modes*

	Channel	Γ(S-1)	BR(%)	Lifetime(ps)
Mesonic Decay	$^3He+\pi^-$	9.73E+08	**24.88**	-
	$^3H+\pi^0$	4.87E+08	12.45	-
	$d+p+\pi^-$	1.57E+09	**40.15**	-
	$d+n+\pi^0$	7.83E+08	20.02	-
	$p+p+n+\pi^-$	2.45E+07	0.63	-
	$p+n+n+\pi^0$	1.23E+07	0.31	-
Non-Mesonic Decay	d+n	6.70E+06	0.17	-
	p+n+n	5.70E+07	1.46	-
Total		**3.91E+09**	**100**	**256**

**Physical Review C.57.1595(1998)*

Topological Cuts — 2body

	Run10 7.7GeV	Run10 11.5GeV	Run11 19.6GeV	Run11 27GeV	Run10 39GeV	Run10 200GeV
dca2	>0.9	>0.8	>1.2	>1.0	>0.7	>1.0
dca12	<1.0	<0.8	<0.9	<1.0	<1.0	<0.8
LambH3 DCA	<1.0	<0.8	<1.0	<1.0	<0.9	<1.0
LambH3 DL	>2.4	>2.1	>3.8	>3.5	>2.0	>3.3

In 2-body: dau1 = helium3 ; dau2 = pion
In 3-body: dau1 = deuteron; dau2 = proton; dau3 = pion

Topological Cuts — 3body

	27GeV	39GeV	200GeV
dca2*	≥1.0;≥0.75;≥0.5	≥1.0;≥0.75;≥0.5	≥1.0;≥0.75;≥0.5
dca3*	≥2.5;≥2.00;≥0.8	≥2.5;≥2.00;≥0.8	≥2.5;≥2.00;≥0.8
dca12	<1.0	<1.0	<0.8
dca13	<1.0	<1.0	<0.8
dca23	<0.8	<0.8	<0.8
dca1-xv0123	<1.2	<1.2	<1.0
dca2-xv0123	<1.2	<1.2	<1.0
dca3-xv0123	<1.2	<1.2	<1.0
Lambda DL	[2.4,150]	≥2.4	[2.4,150]
Lambda DCA	[0,0.9]	[0,1.0]	[0.6,1.6]
Lambda Mass	<1.112	<1.110	<1.111
LambH3 DL	[2.4,150]	[2.4,150]	[2.4,150]
LambH3 DCA	<1.0	<1.0	<0.6

*Depends on momentum of virtual lambda.(<0.8;[0.8,3.6];>3.6)

Scale Number of Events

	Helium-3 Yield (/M)
Run10 7.7	5101
Run10 11.5	1530
Run11 19.6	504
Run11 27	272
Run10 39	134
Run11 200	61.6

2-body	Event #	Scaled #
Run10 7.7	3.98 M	151.51 M
Run10 11.5	10.98 M	125.37 M
Run11 19.6	31.15 M	117.16 M
Run11 27	48.65 M	98.75 M
Run10 39	118.02 M	118.02 M
Run10 200	222.73 M	102.39 M
Total	**435.51 M**	**713.20 M**

3-body	Event #	Scaled #
Run11 27	53.31 M	108.21 M
Run10 39	134.41 M	134.41 M
Run11 200	516.87 M	237.61 M
Total	**704.59 M**	**480.23 M**

The analysis for 2 channels are using different dataset. So helium-3 yield data are used to scale the total number of events.

Systematic Uncertainty

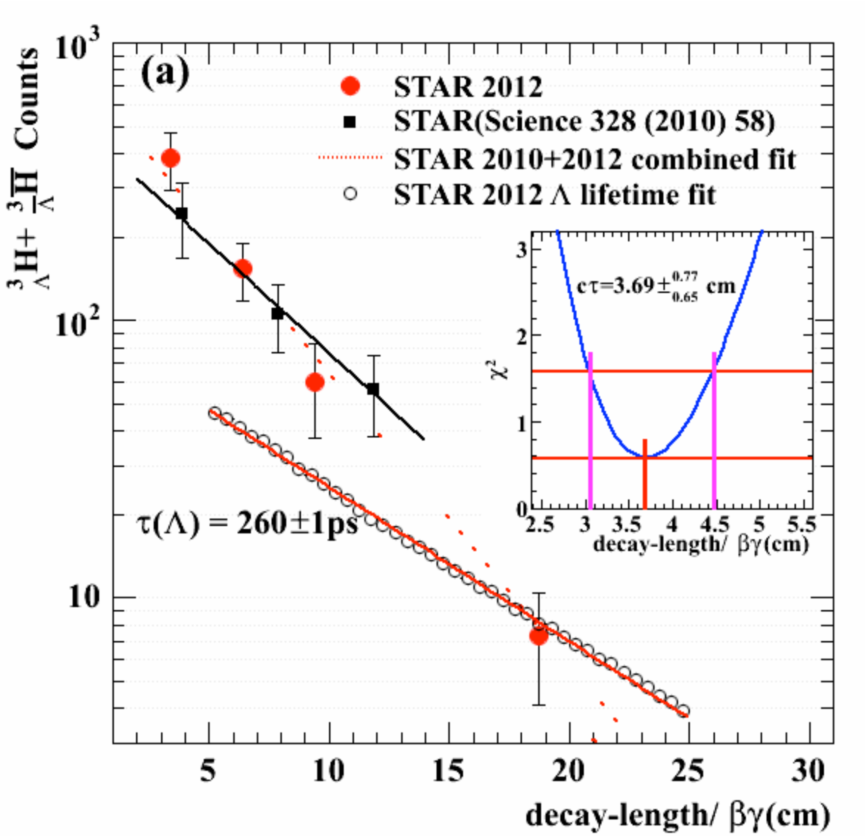
We take into account two kinds of contributions to systematic errors: binning effect and different cuts.

2-Body	Original	Current	cτ(cm)	lifetime(ps)	Uncertainty(%)
			3.69	123	
Binning	4MeV	2MeV		116	5.7
DL & dca(pi)	>2.4&>0.8	>4.0&>1.2		120	2.4
dca12 & v0dca	<1.0&<1.0	<0.7&<0.7		130	5.7
					8.4

3-Body	Original	Current	cτ(cm)	lifetime(ps)	Uncertainty(%)
			6.84	229	
Binning	4 MeV	2 MeV	7.00	234	2.2
dca 23	up-limit	up-limit -0.3	7.97	266	16.2
dca Lambda	up-limit	up-limit -0.2	6.72	225	1.7
					16.4

Combined systematic uncertainty : 18.4%

STAR Free Λ Lifetime



Measurement of lifetime of free lambda using same method as hyper triton.

Result from 2-body analysis.