Current status of search for muon catalyzed d^3He fusion

Kravchenko Polina

HEPD seminar, March 6, 2018

$$d + {}^3He \rightarrow {}^4He(3.66MeV) + p(14.64MeV)$$

PAUL SCHERRER INSTITUT

PSI

Motivation

December, 2017
E.M. Maev
HEPD Seminar

Ядерная реакция синтеза

d + ^{3}He → ^{4}He(3.66 MeV) + p(14.64 MeV), Q=18.3 MeV

представляет интерес по следующим причинам :

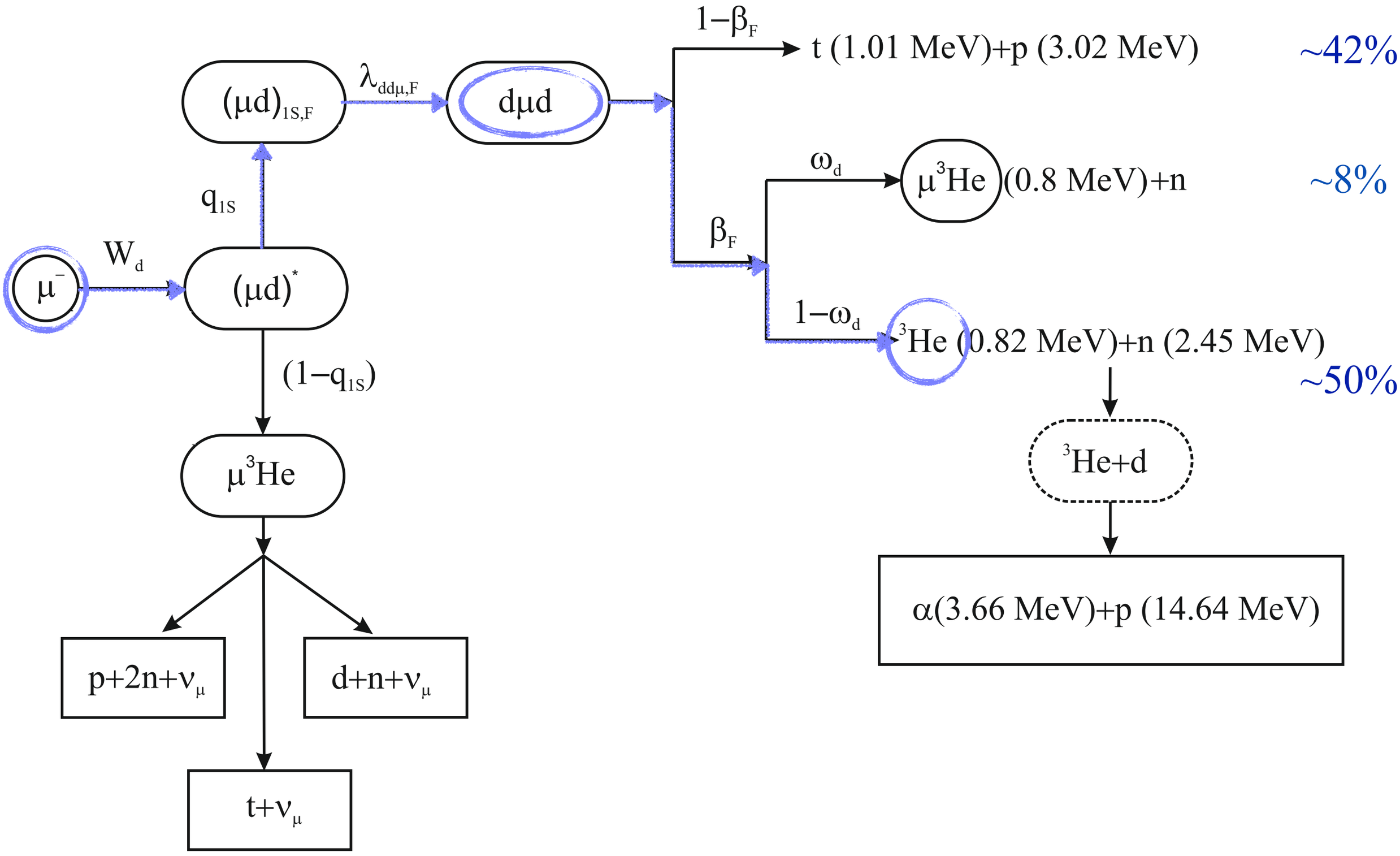
1. Зеркальная реакция по отношению к реакции ядерного d+t → ^{4}He+n синтеза (Q=17.6 MeV).
2. Перспективный источник термоядерной энергии.
3. Процесс первичного ядерного синтеза легких элементов в ранней вселенной (астрофизика).

Для всех этих процессов важно знать сечение этой реакции при очень низких энергиях столкновения (E < 10keV).

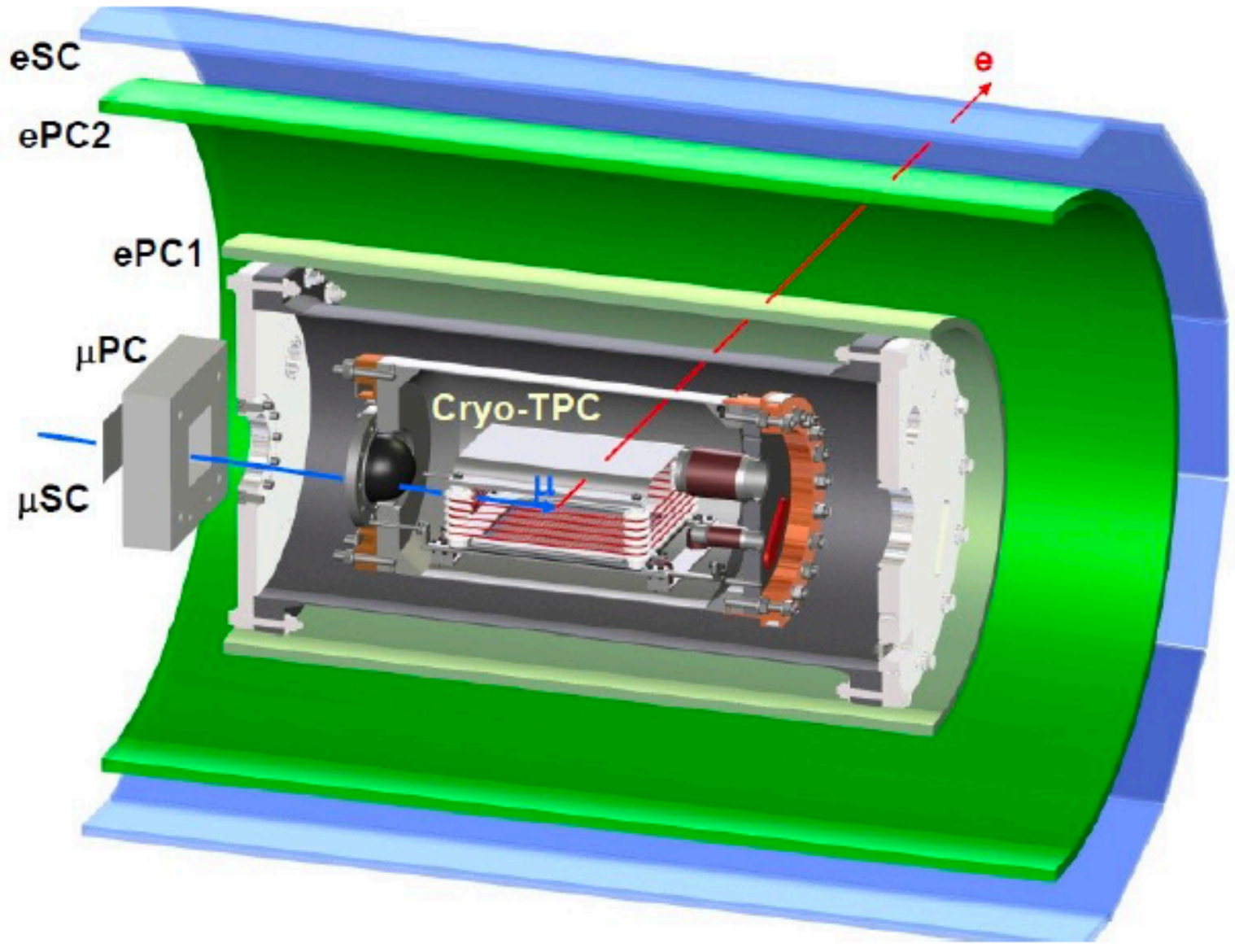
<u>Экспериментальная ситуация</u>:

a) PNPI-PSI-TUM-UCLB collaboration (HD+^{3}He(5.6%):
λ_f(eff) < $6 \cdot 10^4$ s^{-1}
b) JINR-PSI-UIUC-INPT-UF collaboration (D_2+^{3}He(5%):
λ_f(eff) ~ $5 \cdot 10^5$ s^{-1}
Различие между двумя экспериментами ~ в 10 раз !!!

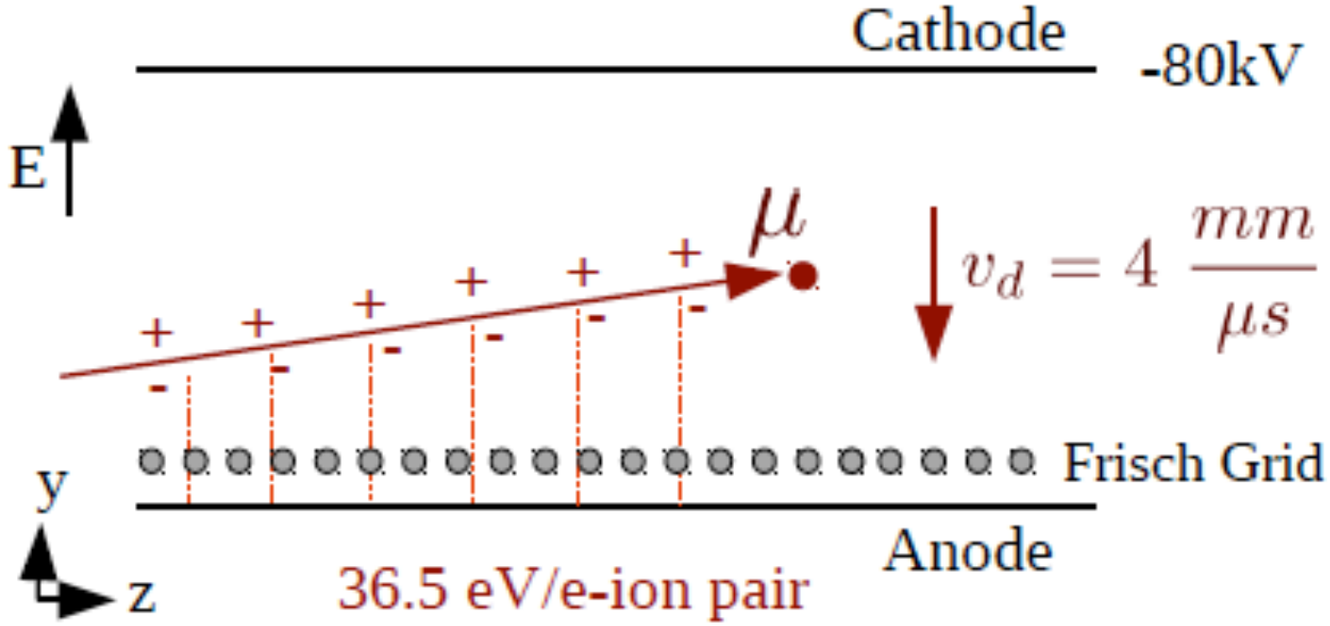
Scheme muon catalyzed fusion in D_2

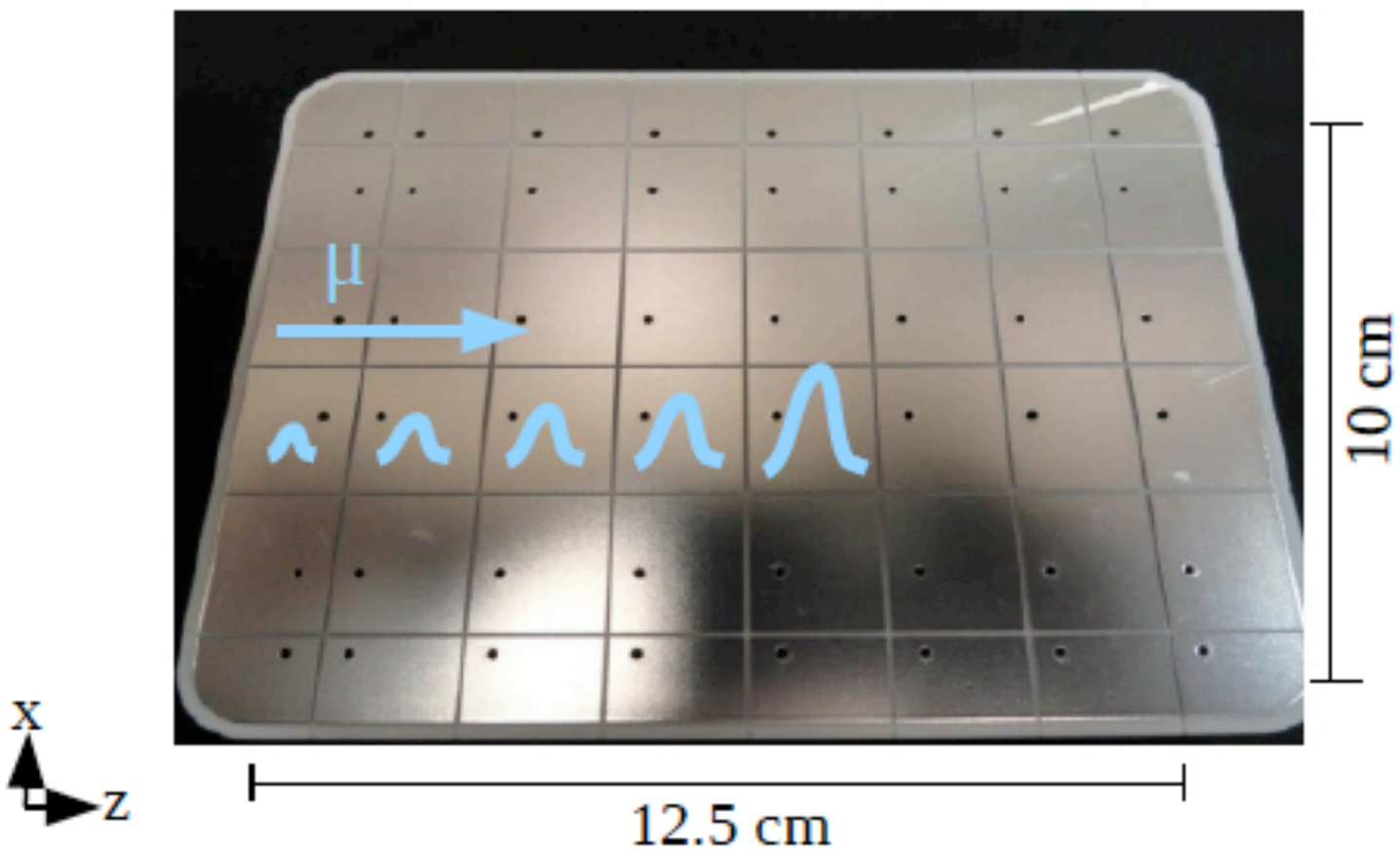


Experimental setup (MuSun)



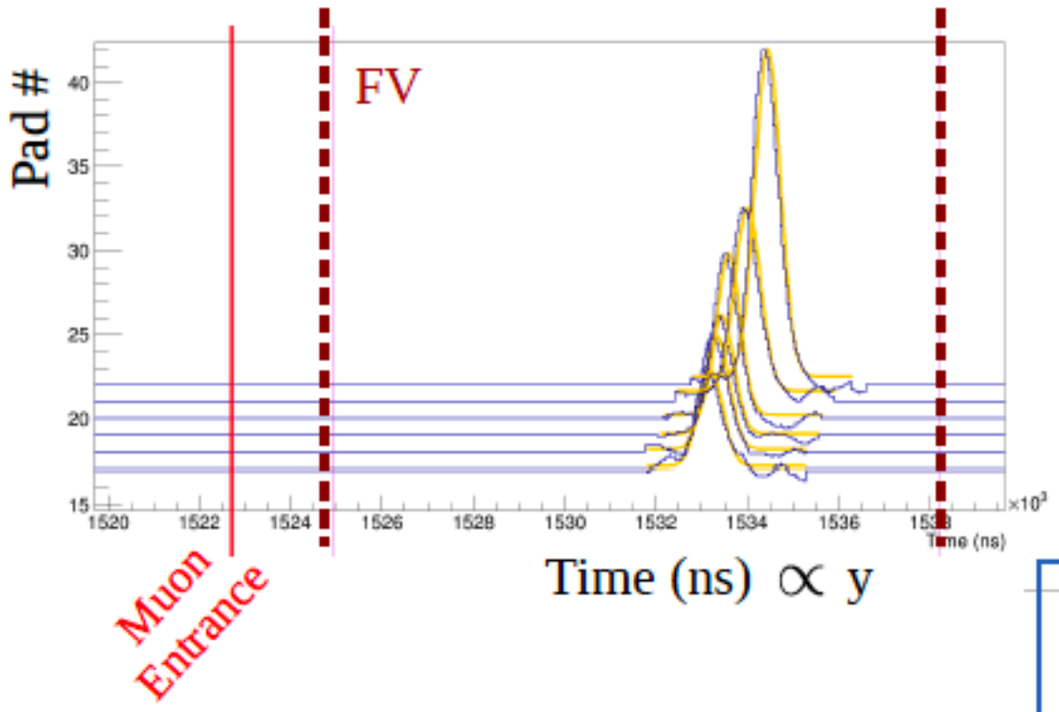
Cryogenic time projection chamber (31K, 5bar)



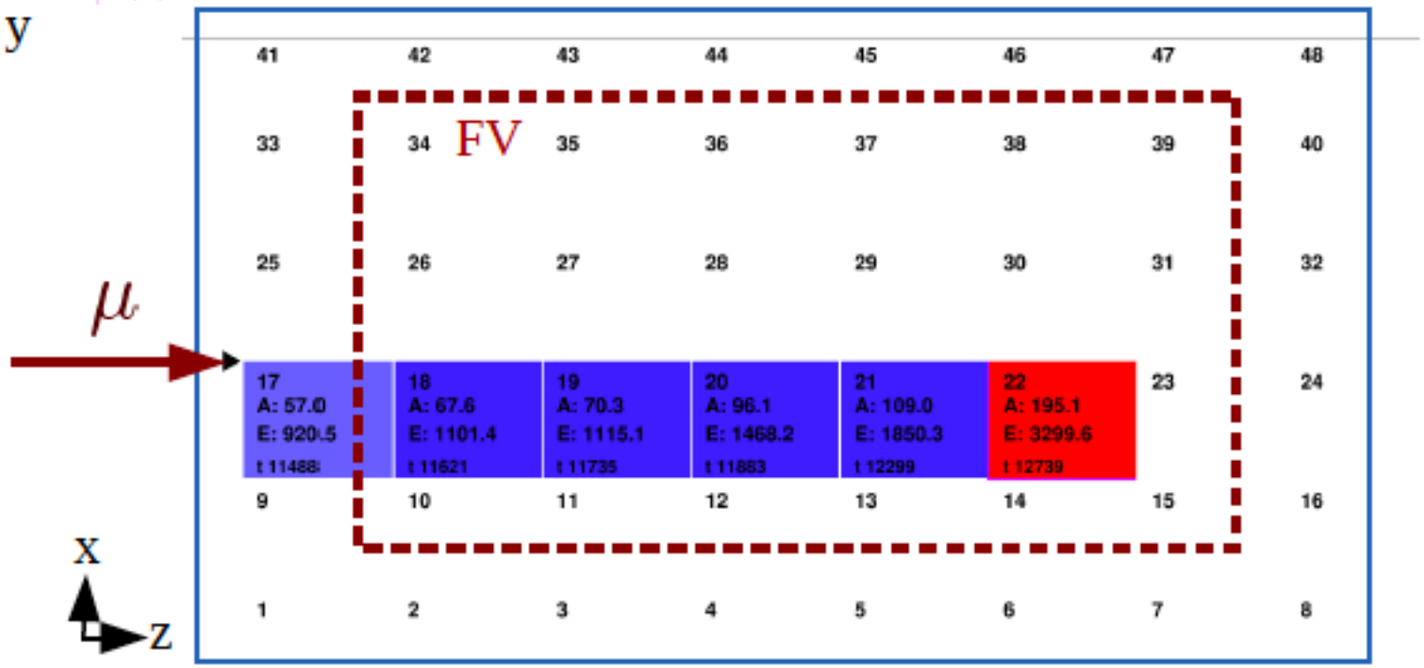


Muon stop reconstruction

Y from drift time

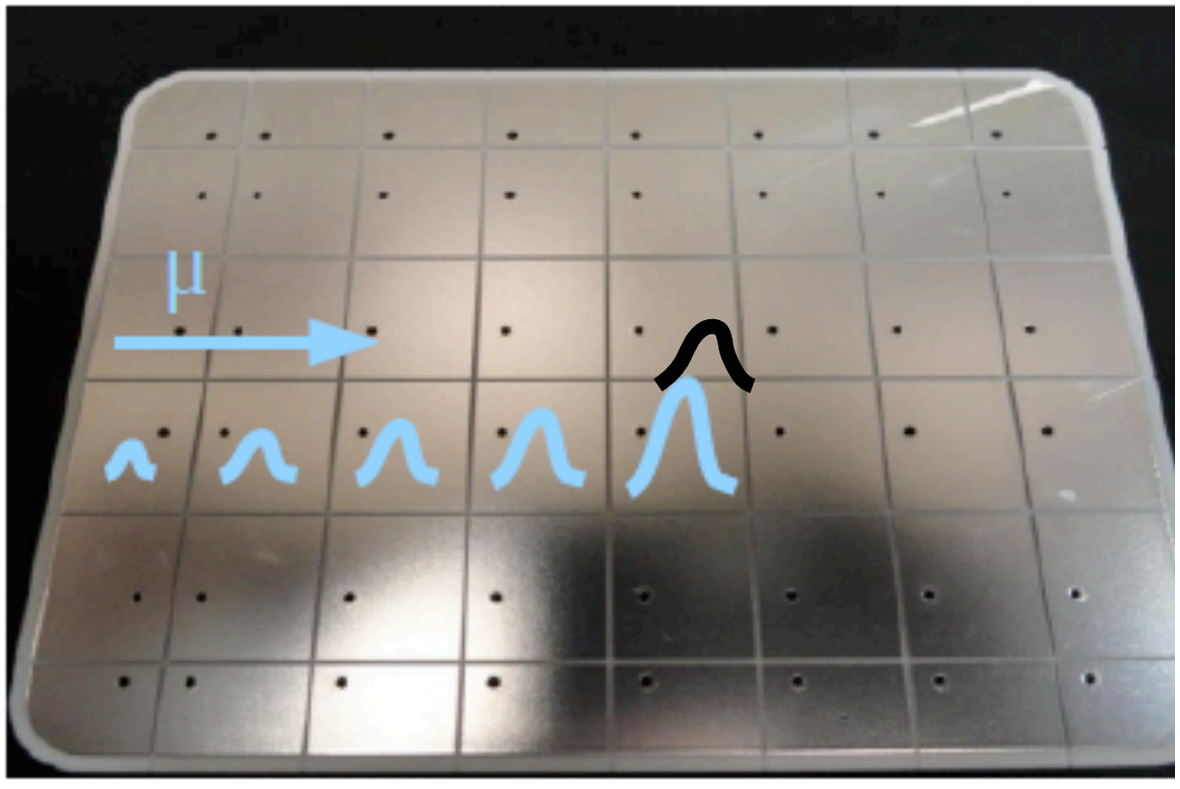


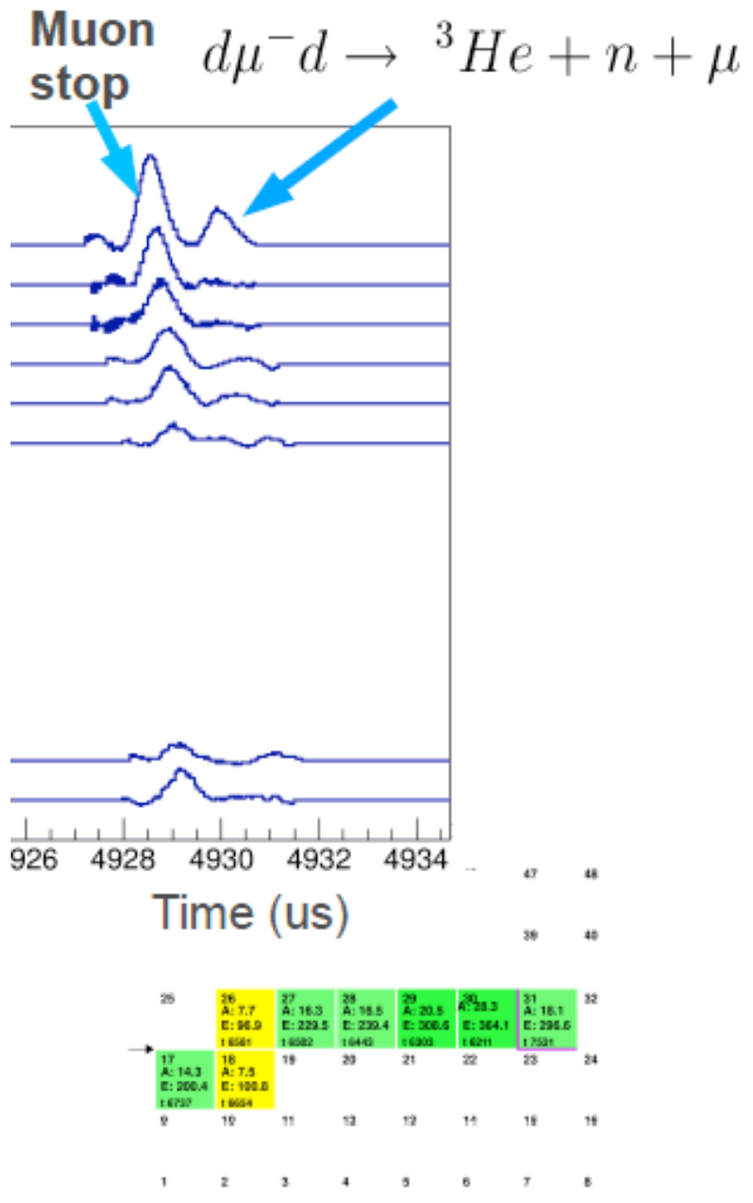
X, Z from pad plane



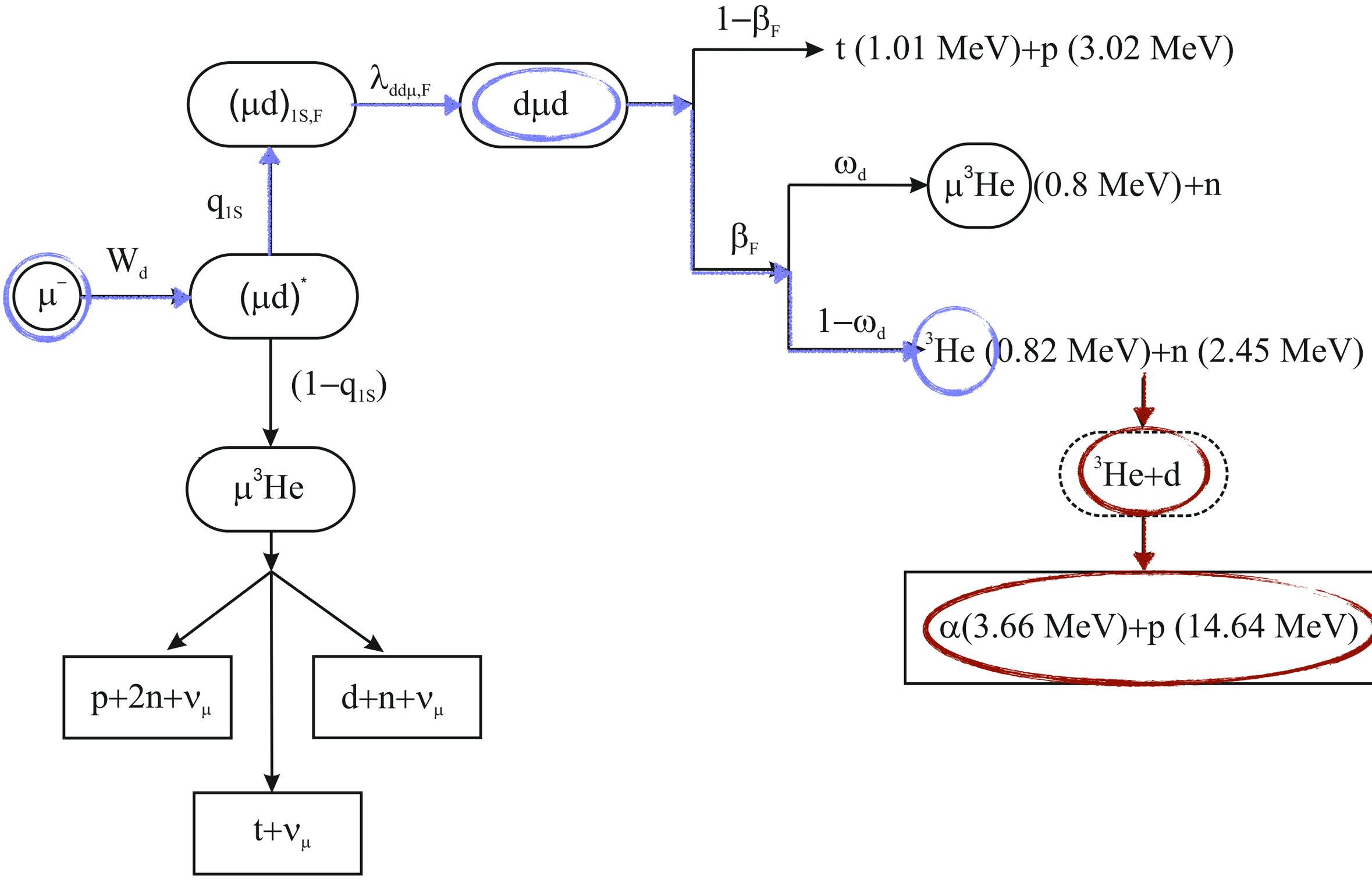
Fiducial volume cuts:
Ensure muon stops in gas

Second signal on stop pad. ^{3}He

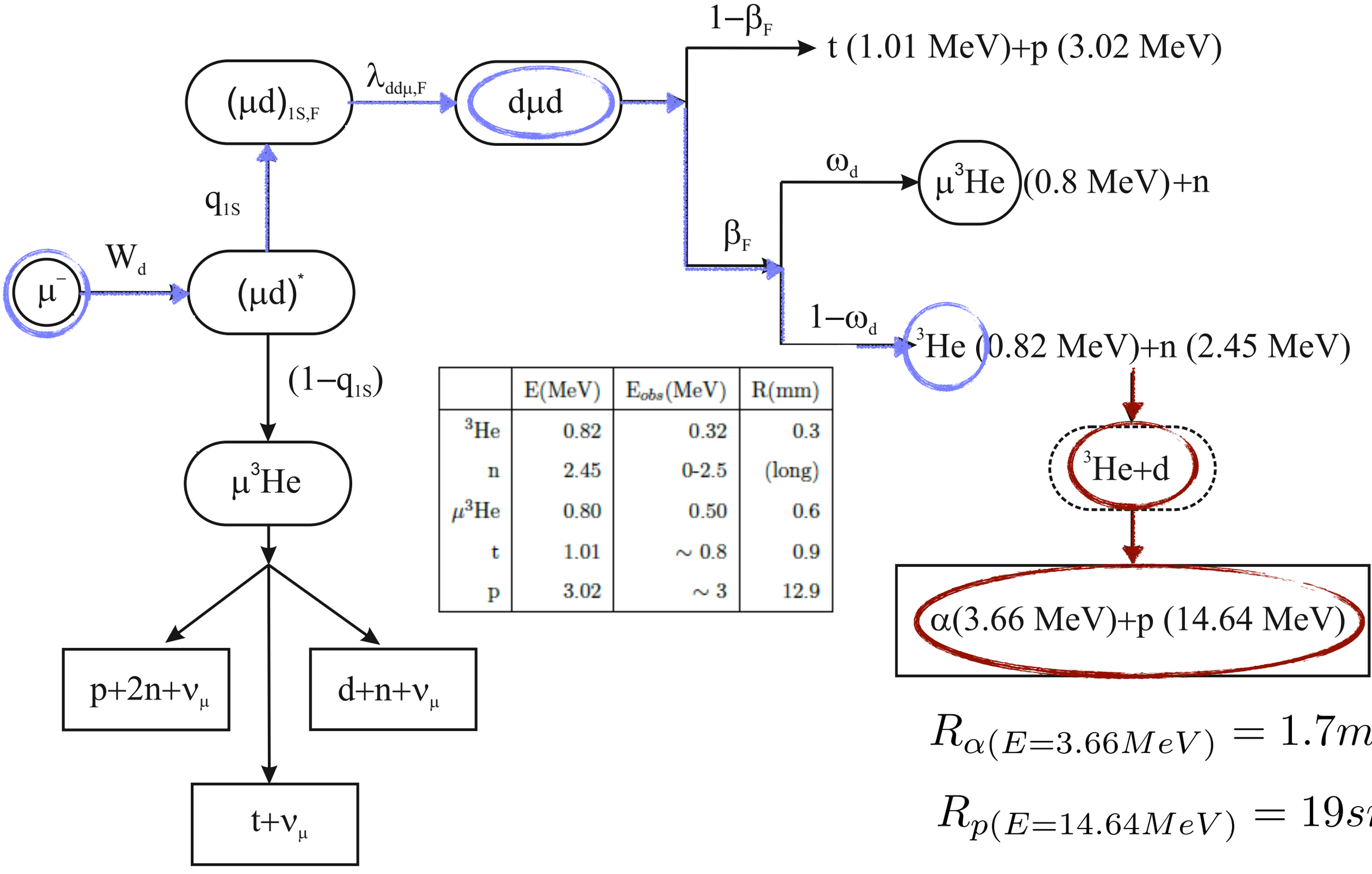




Scheme muon catalyzed fusion in D_2



Scheme muon catalyzed fusion in D_2



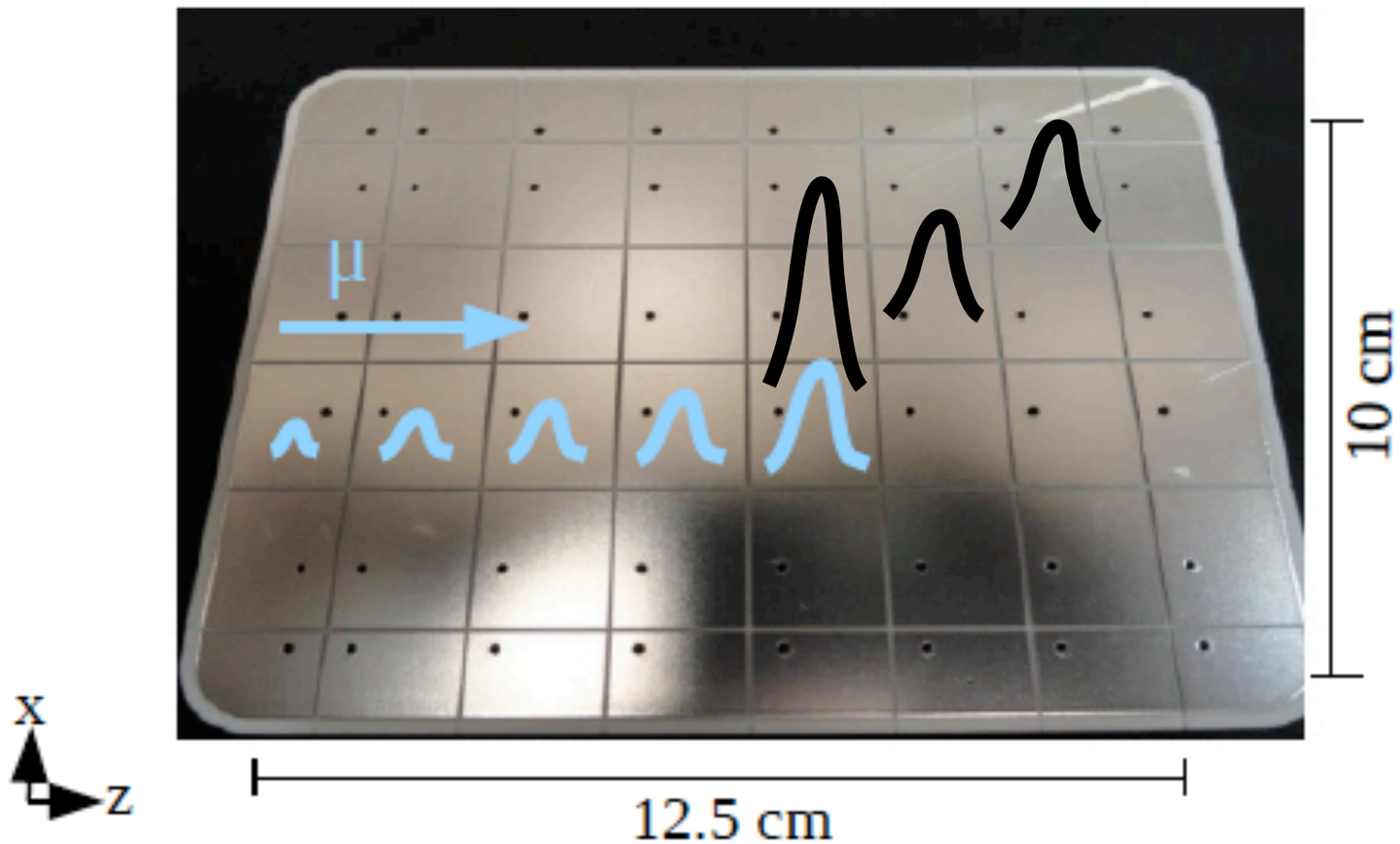
	E(MeV)	E_{obs}(MeV)	R(mm)
^{3}He	0.82	0.32	0.3
n	2.45	0-2.5	(long)
μ^3He	0.80	0.50	0.6
t	1.01	~ 0.8	0.9
p	3.02	~ 3	12.9

$$R_{\alpha(E=3.66MeV)} = 1.7mm$$

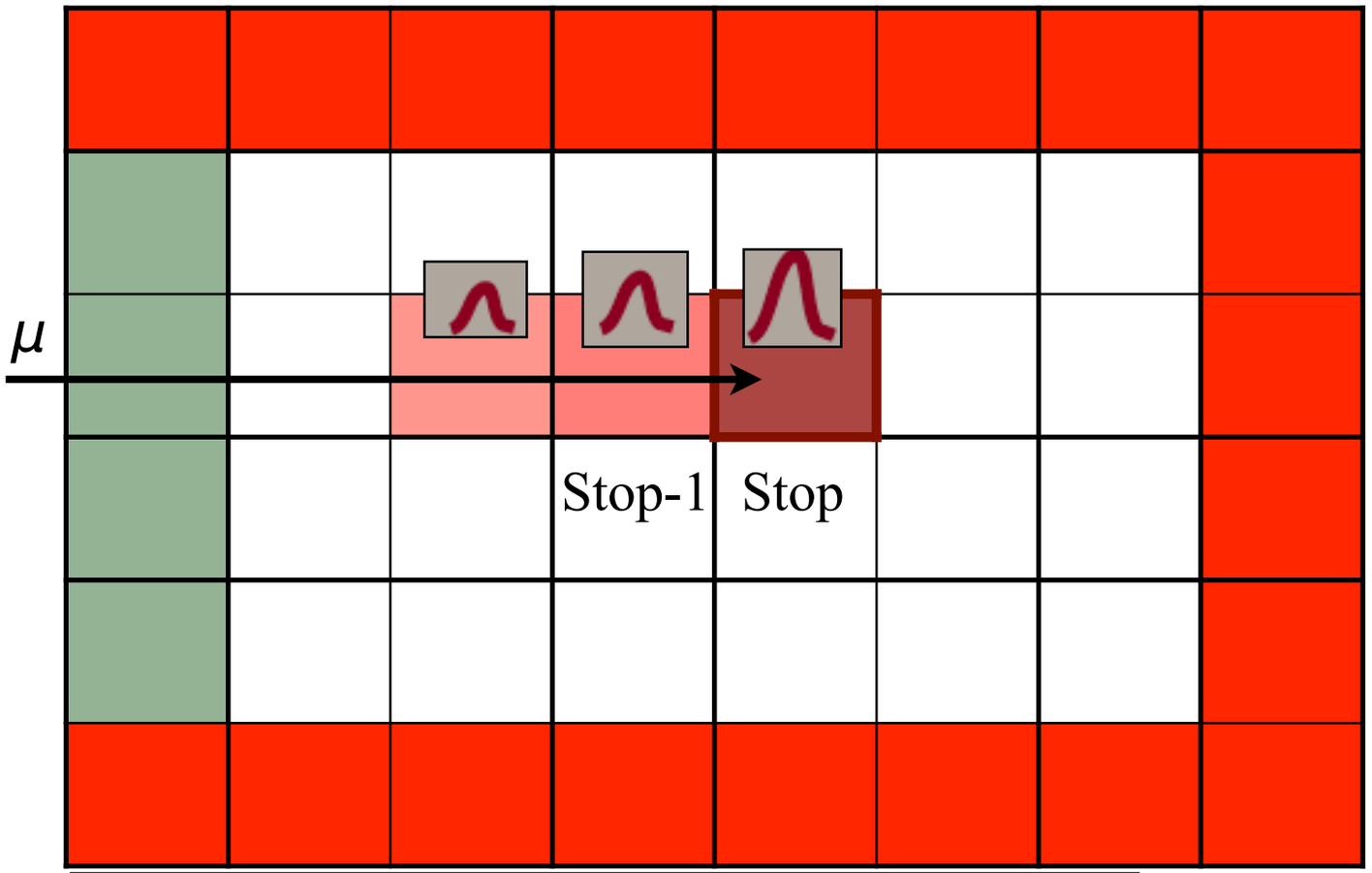
$$R_{p(E=14.64MeV)} = 19sm$$

Scheme muon catalyzed fusion in D_2

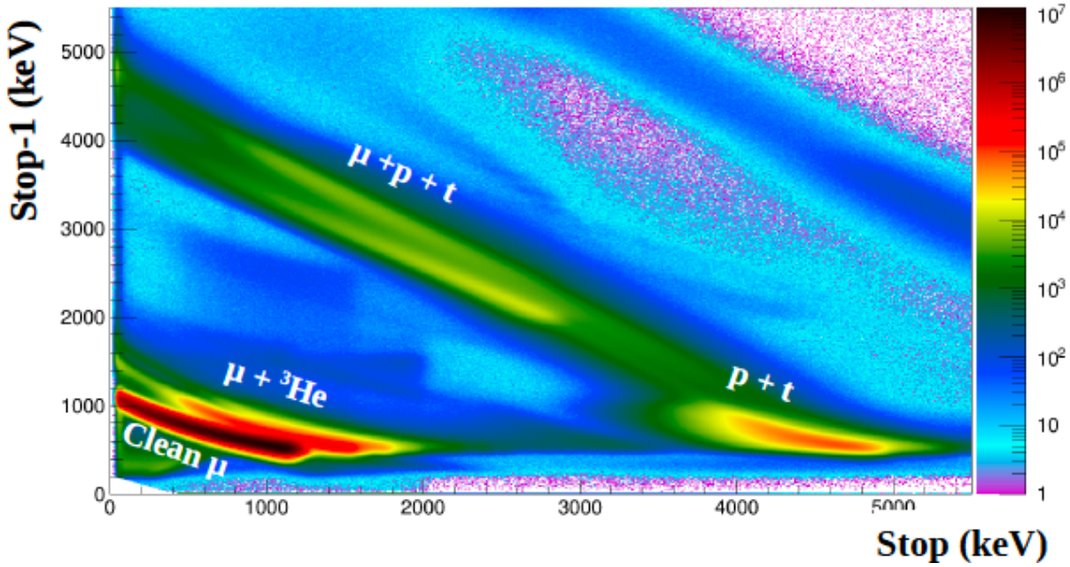
$$dd\mu \rightarrow d + {}^3He(0.82MeV) \rightarrow {}^4He(3.66MeV) + p(14.64MeV)$$

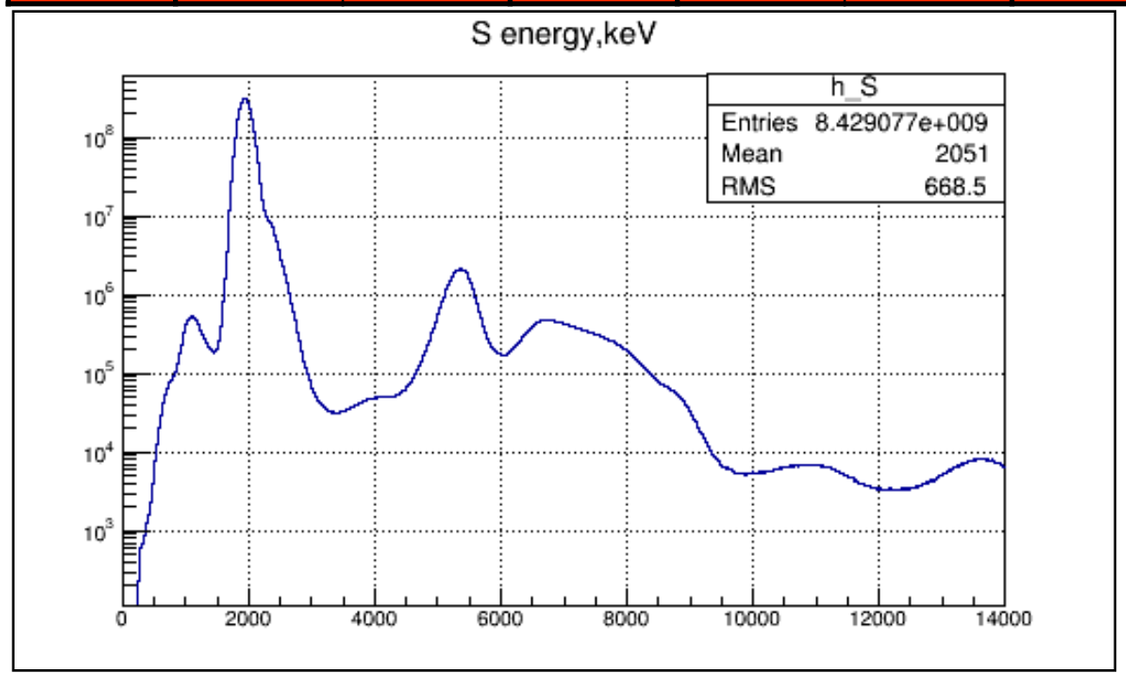


Event selection. Muon



Fiducial volume cut
Stop-1: E_1
Stop: E_0 first signal

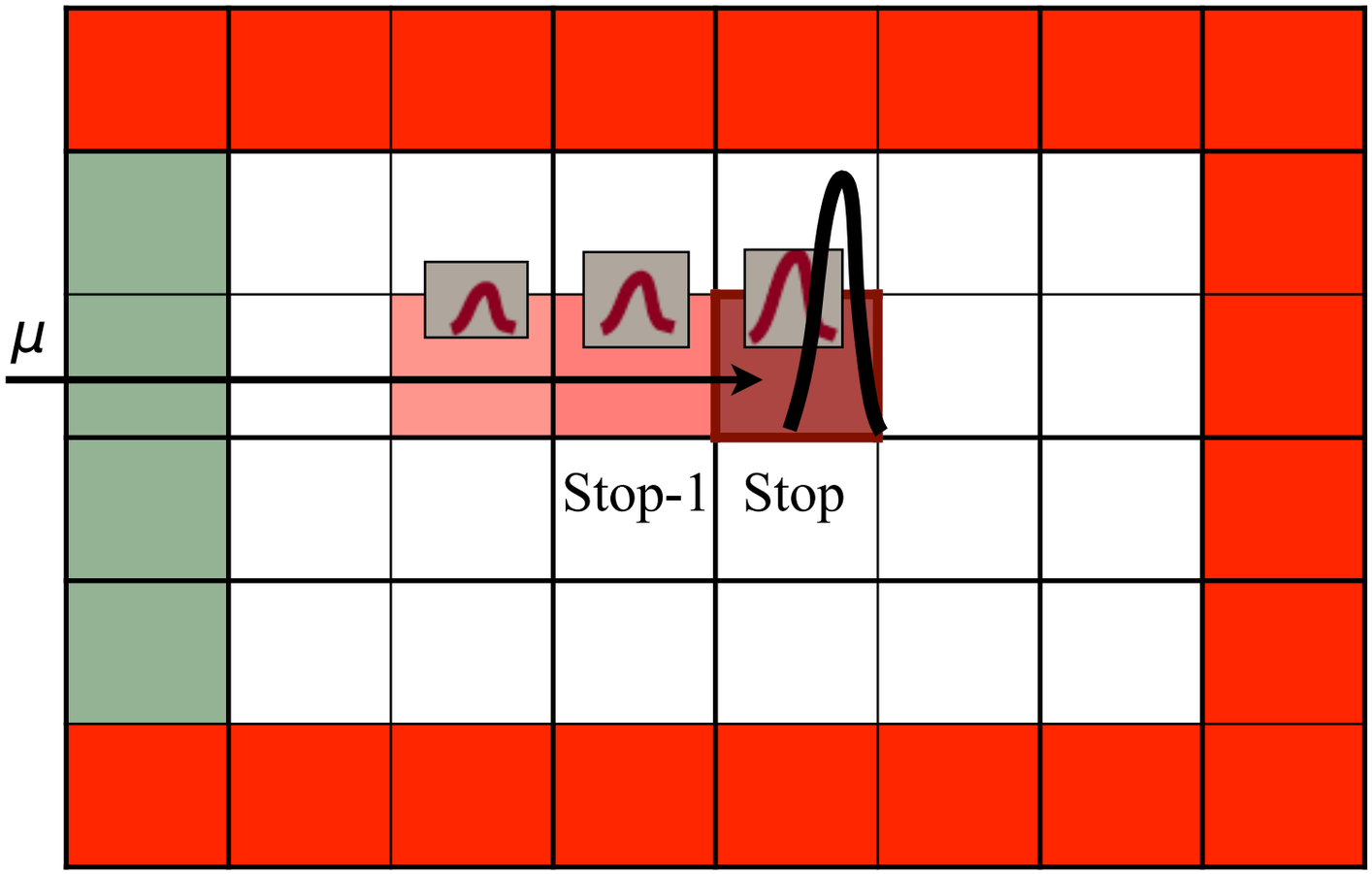




$$SE = E_0 + 2E_1$$

$$1.6MeV < SE < 2.2MeV$$

Event selection. Second signal on stop pad



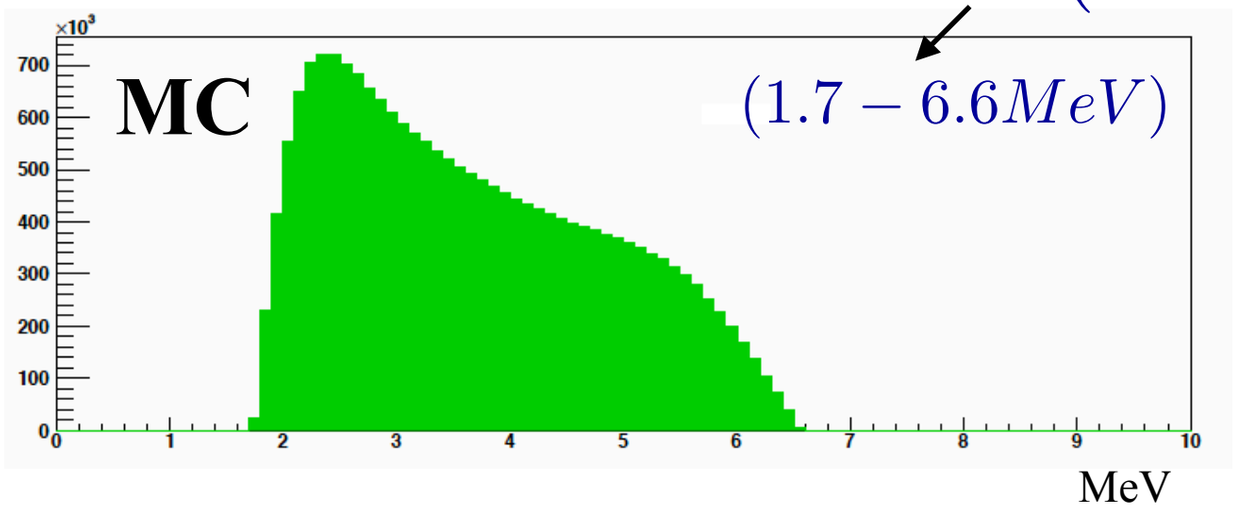
Fiducial volume cut
Stop-1: E_1
Stop: E_0 first signal
E_s second signal

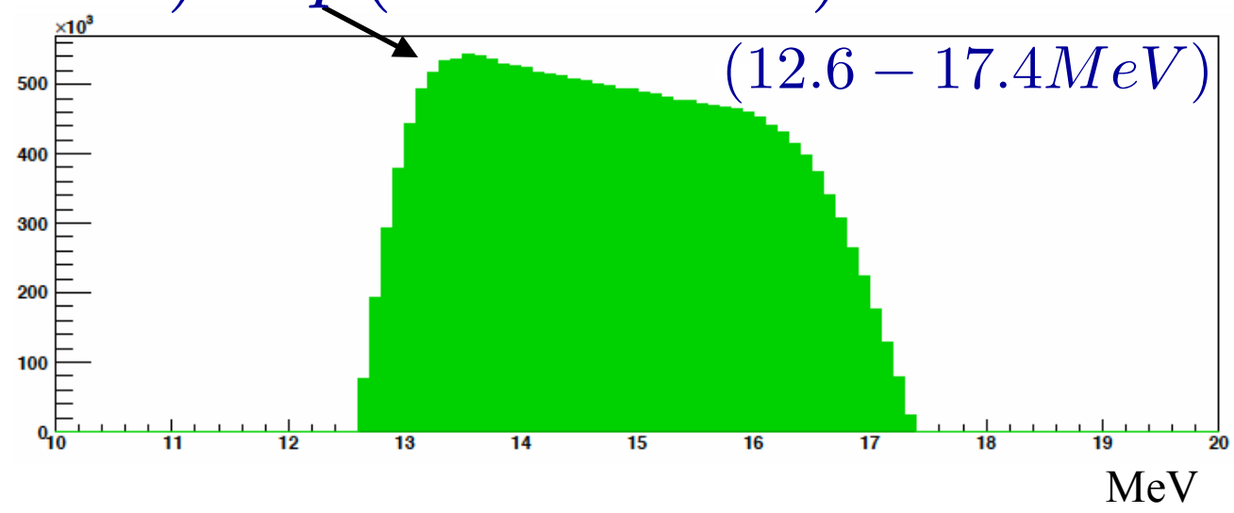
$$d + {}^3He \rightarrow {}^4He(3.66MeV) + p(14.64MeV)$$

Event selection. Second signal on stop pad

$(0 - 0.82MeV)$

$$d + {}^3He \rightarrow {}^4He(3.66MeV) + p(14.64MeV)$$

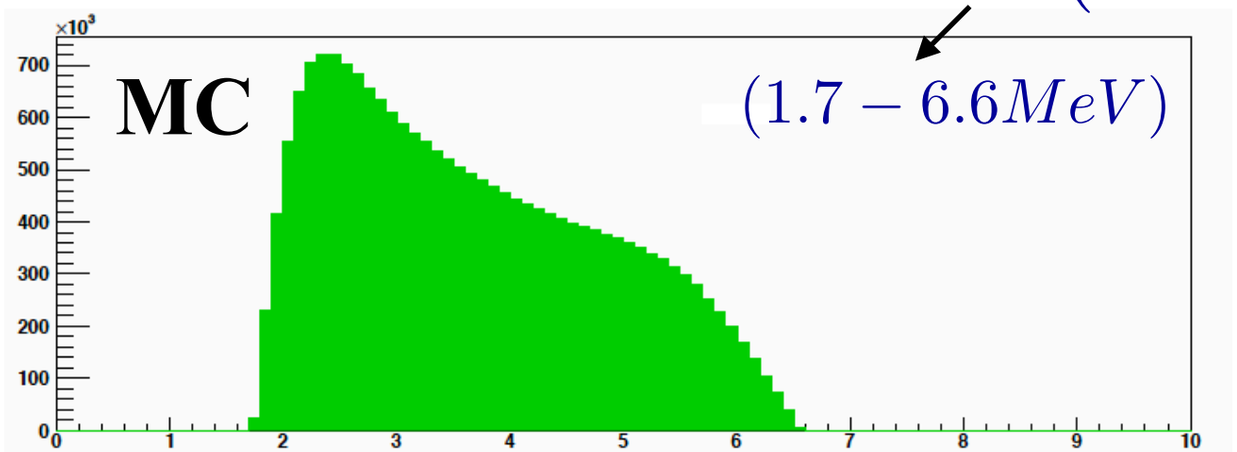


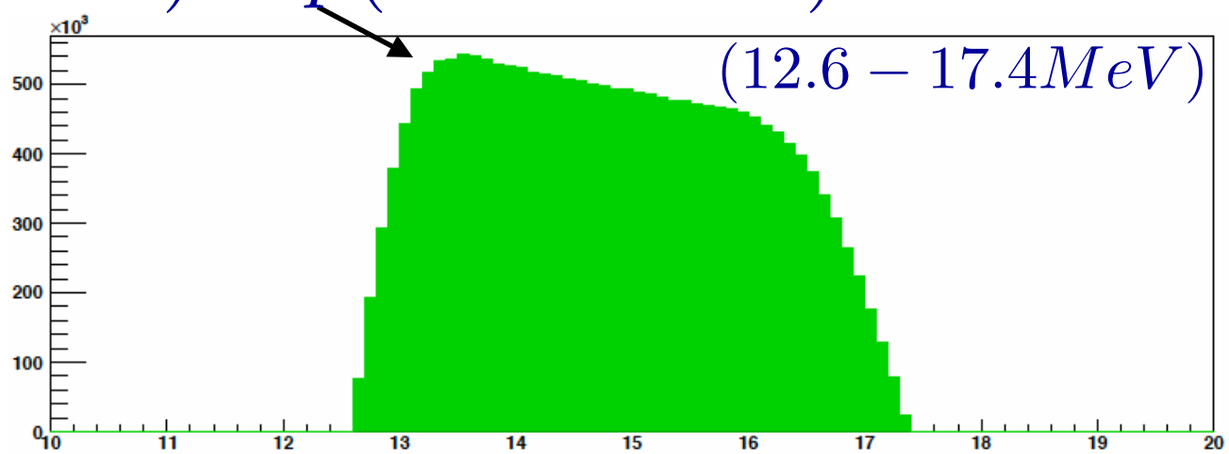


Event selection. Second signal on stop pad

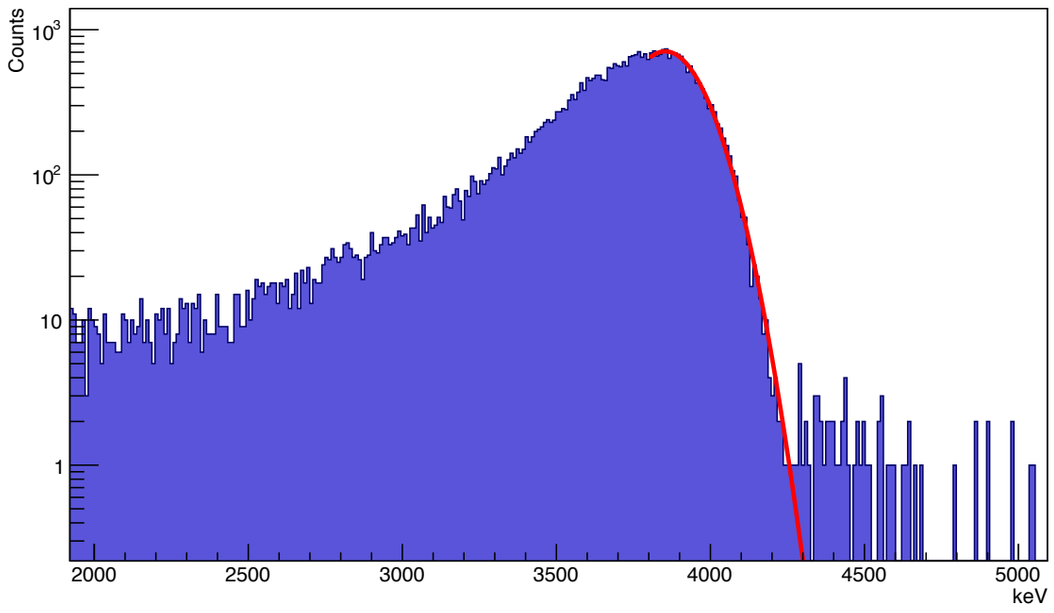
$(0 - 0.82MeV)$

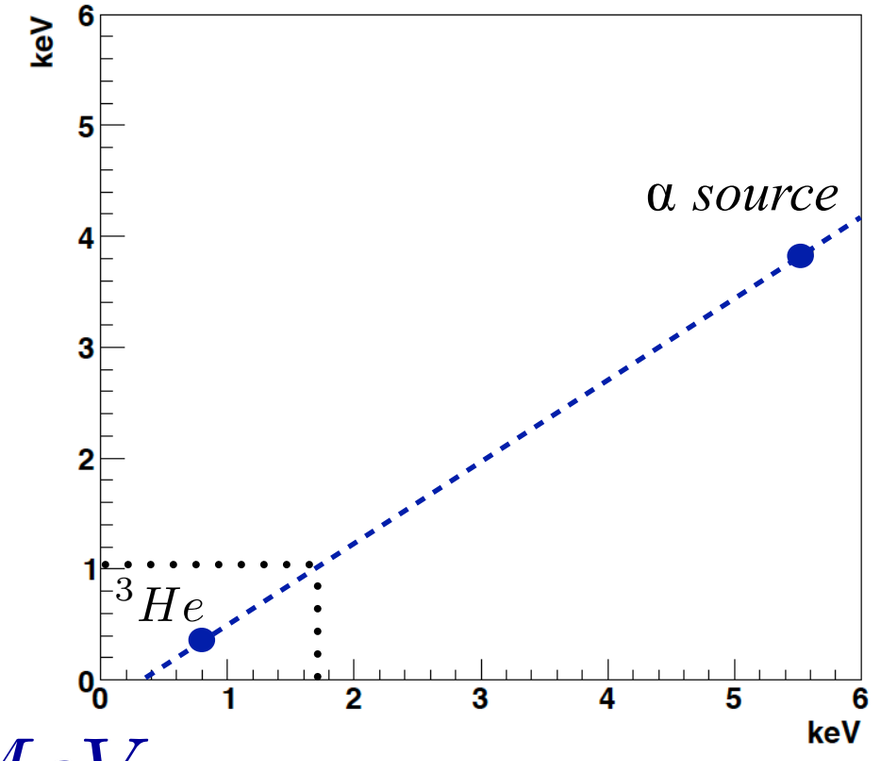
$$d + {}^3He \rightarrow {}^4He(3.66MeV) + p(14.64MeV)$$





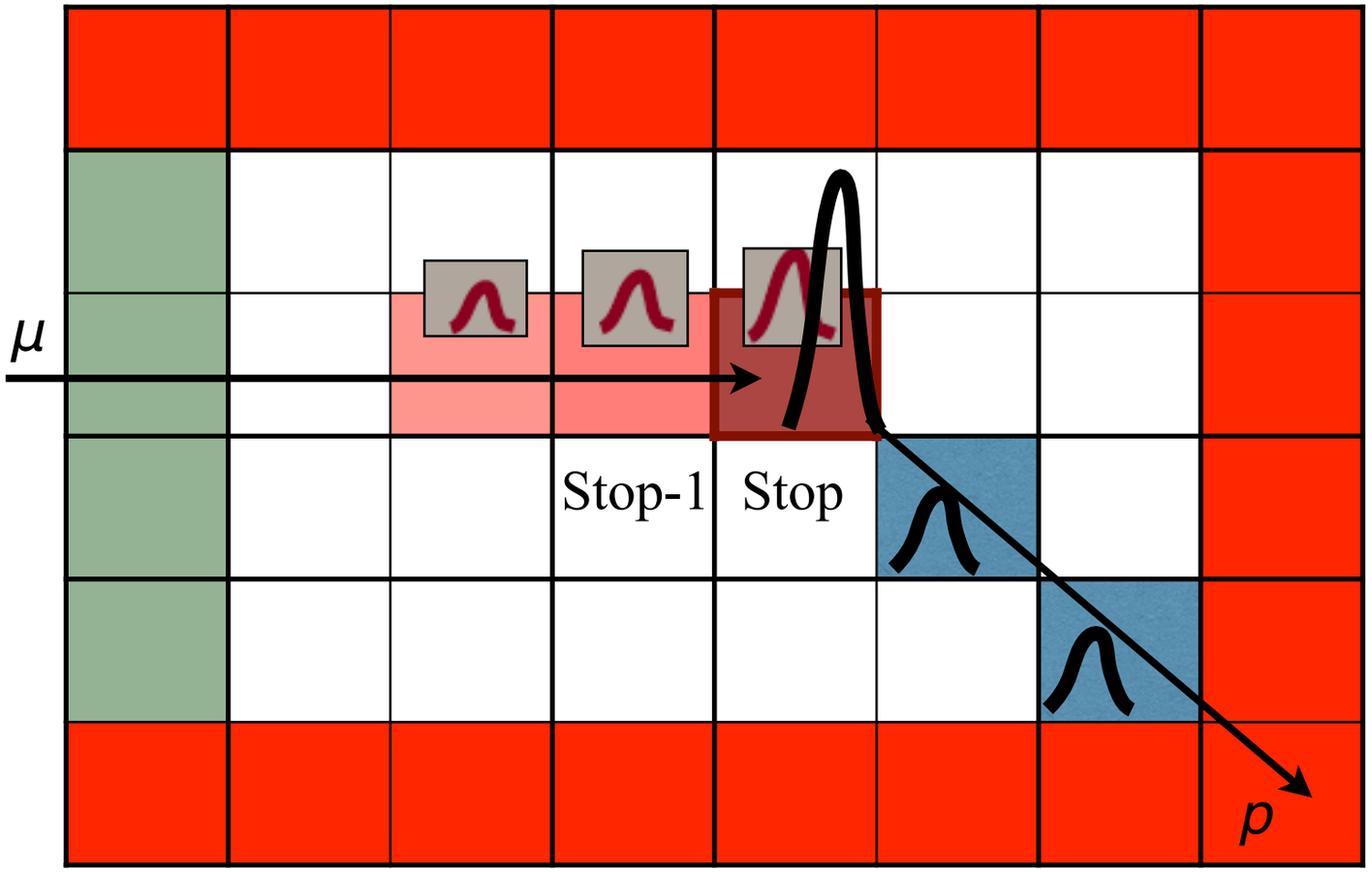
α source (E=5.5MeV)





$E_s > 1.2MeV$

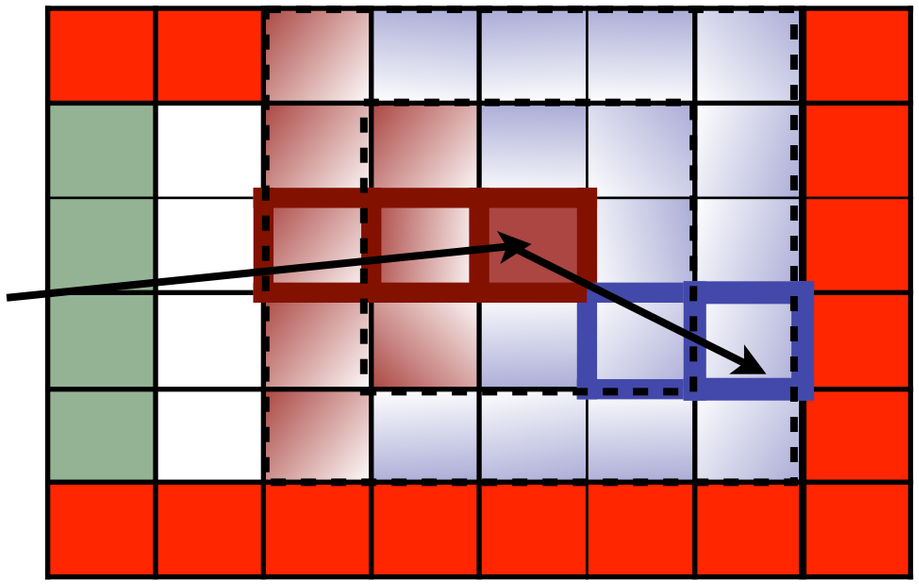
Event selection. Proton



Fiducial volume cut
Stop-1: E_1
Stop: E_0 first signal
E_s second signal

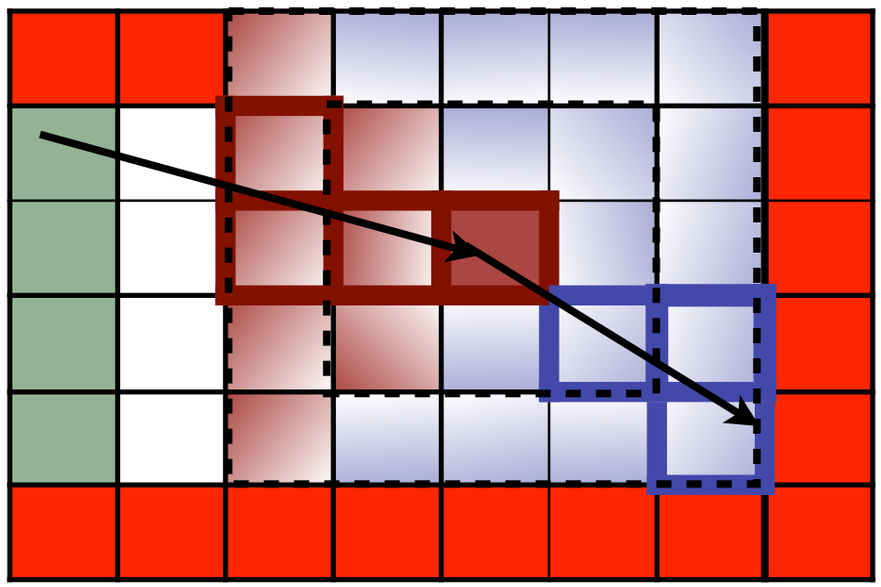
1 pad after Stop: E_{p1}
2 pad after Stop: E_{p2}

Event selection.

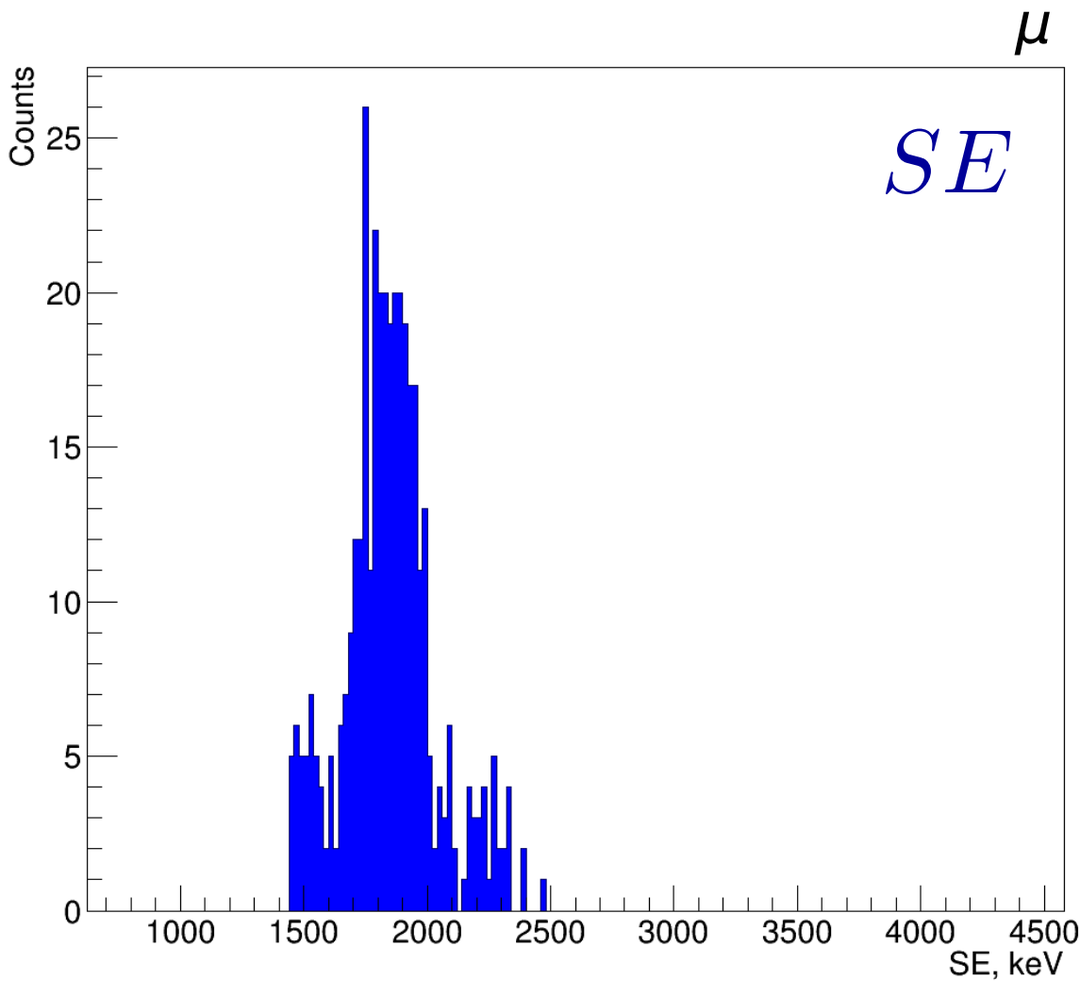


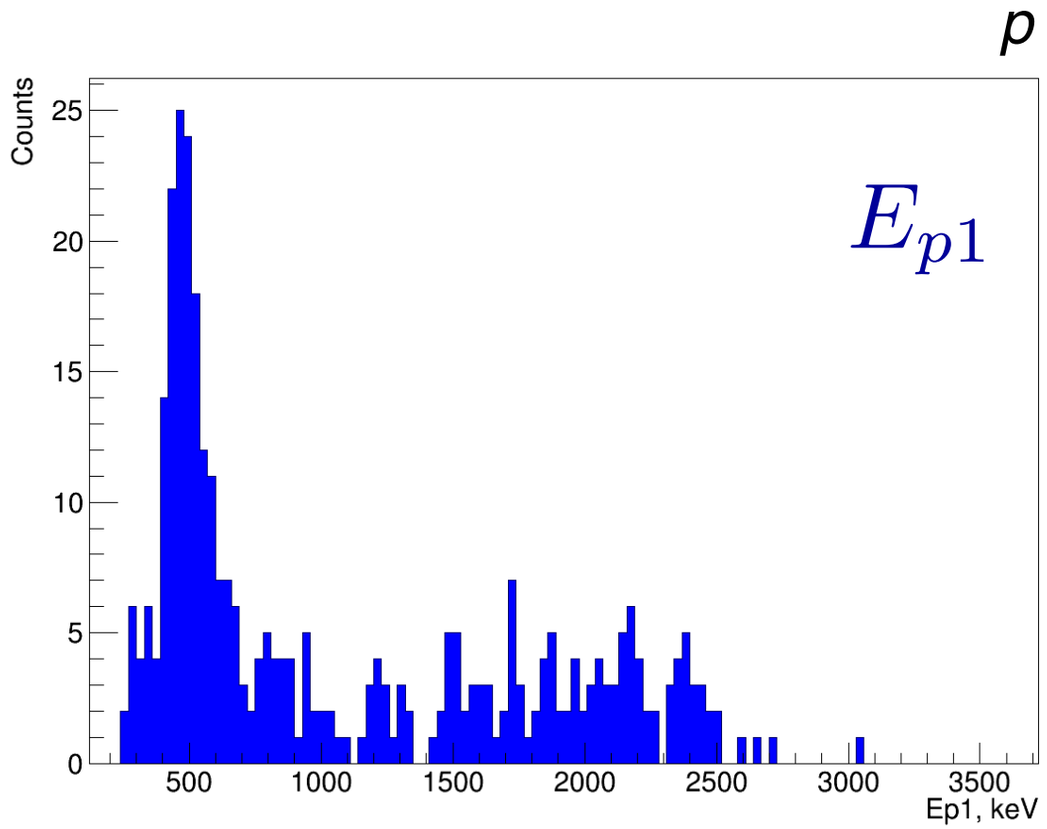
(85%)

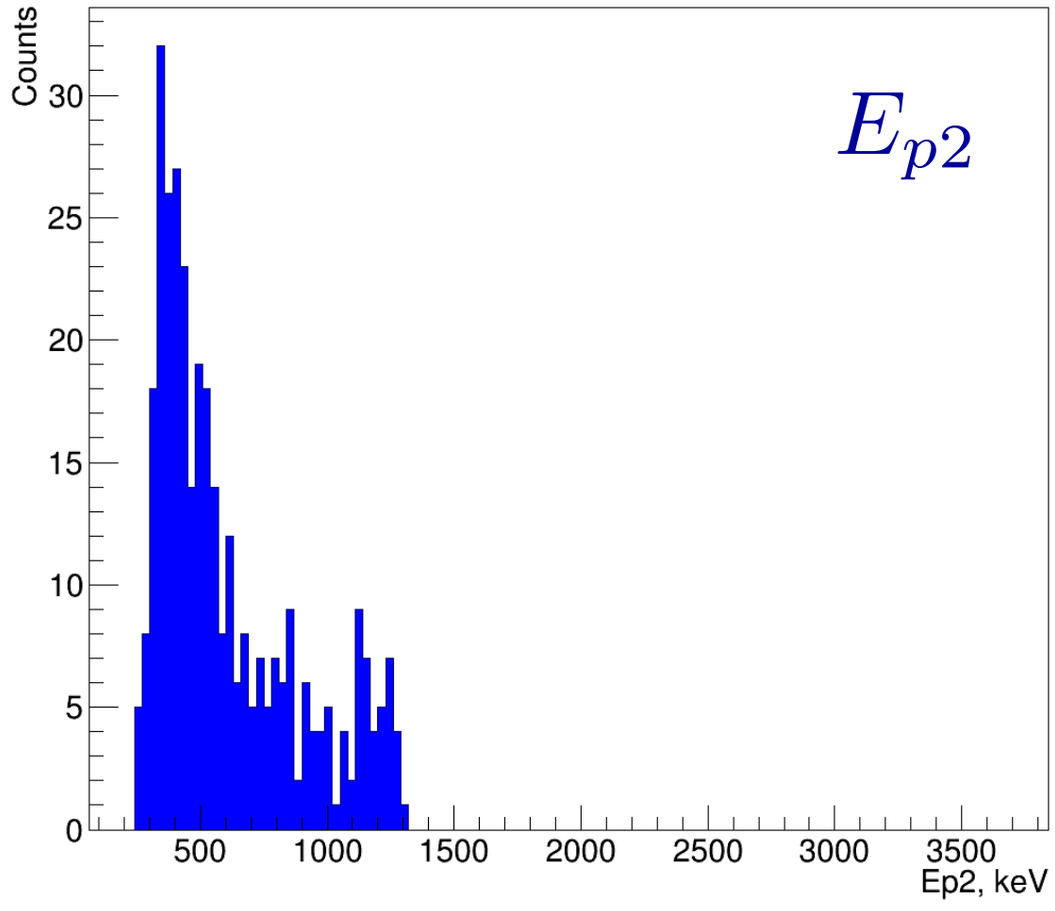
(15%)



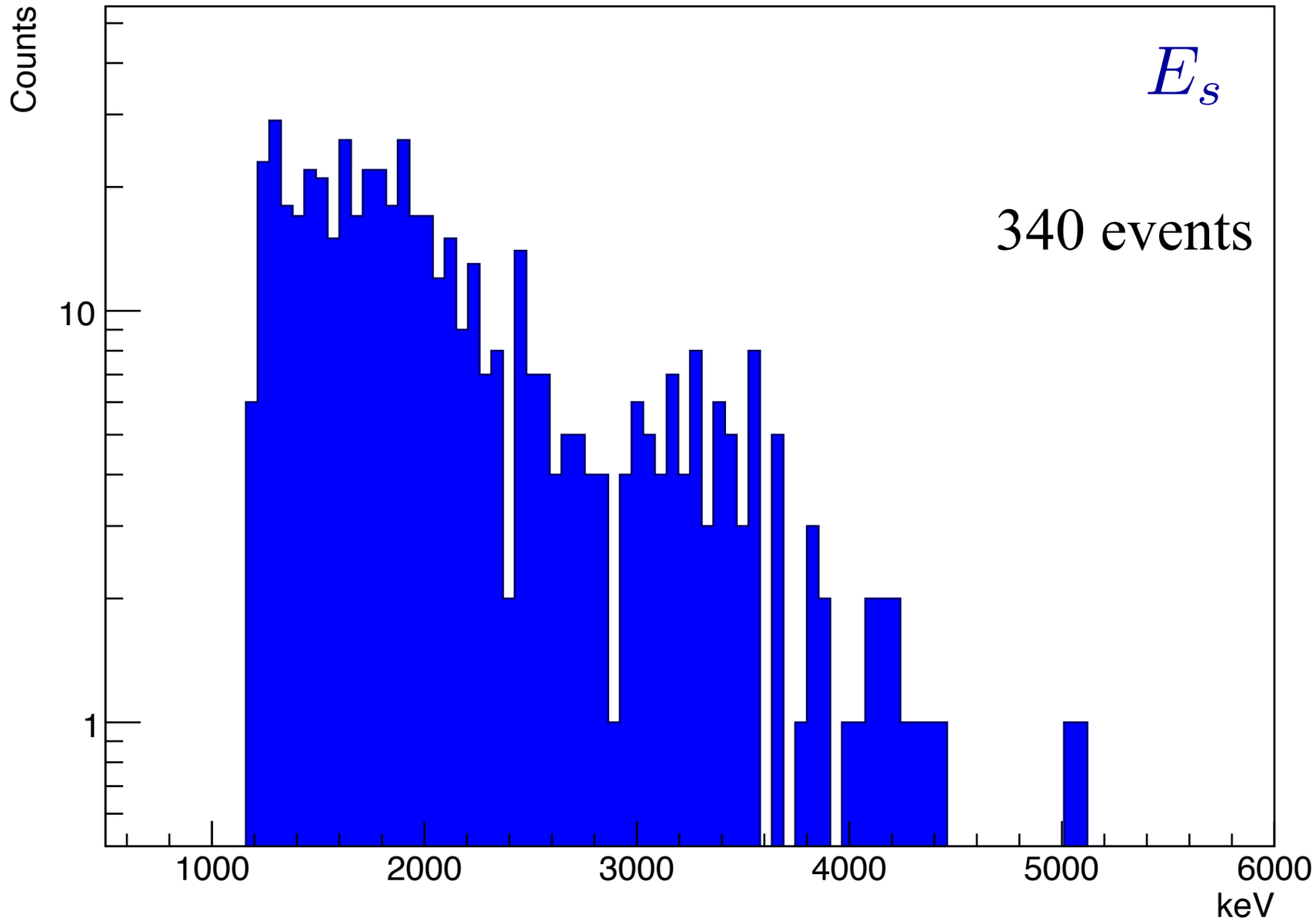
Run8



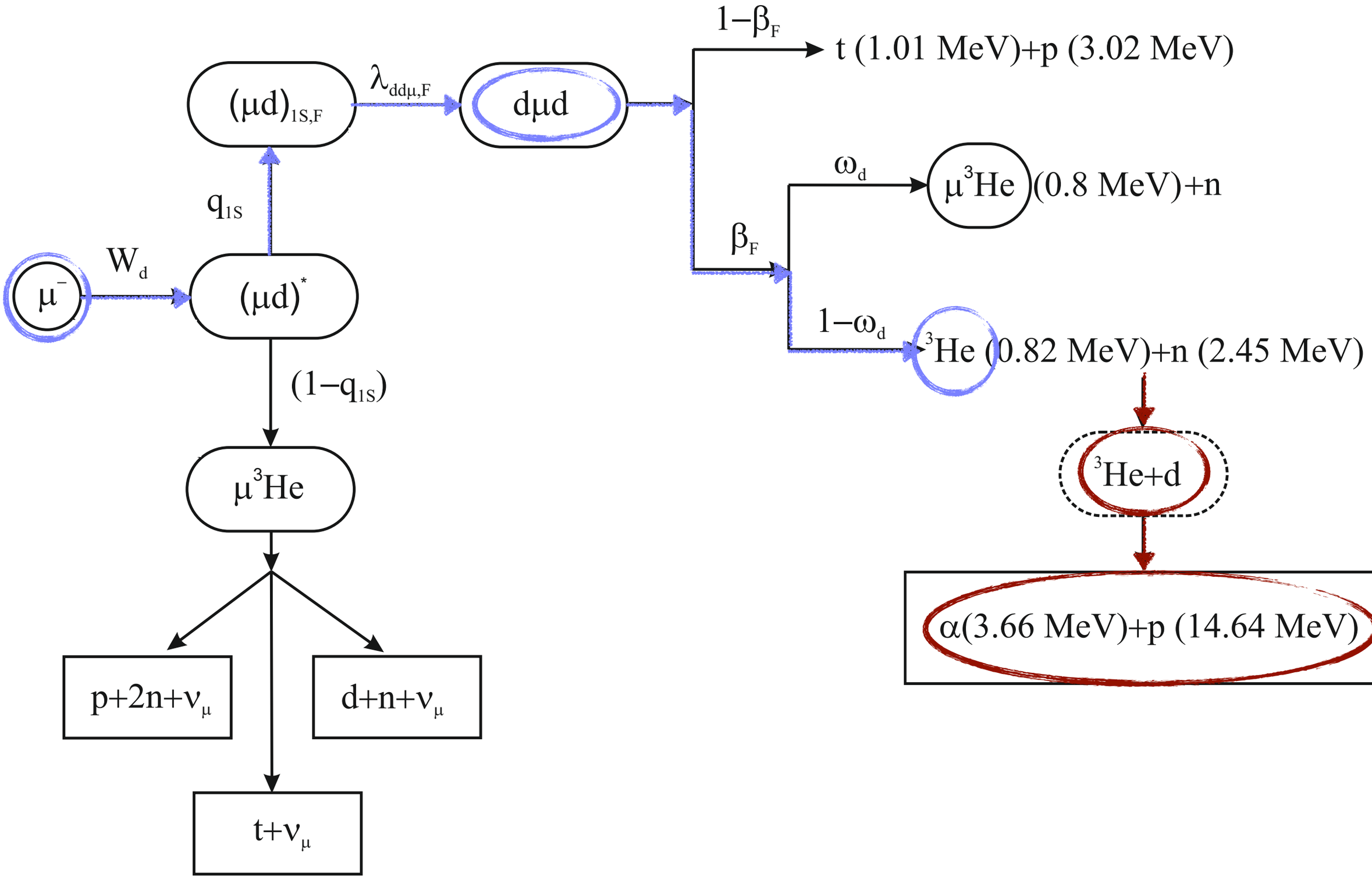




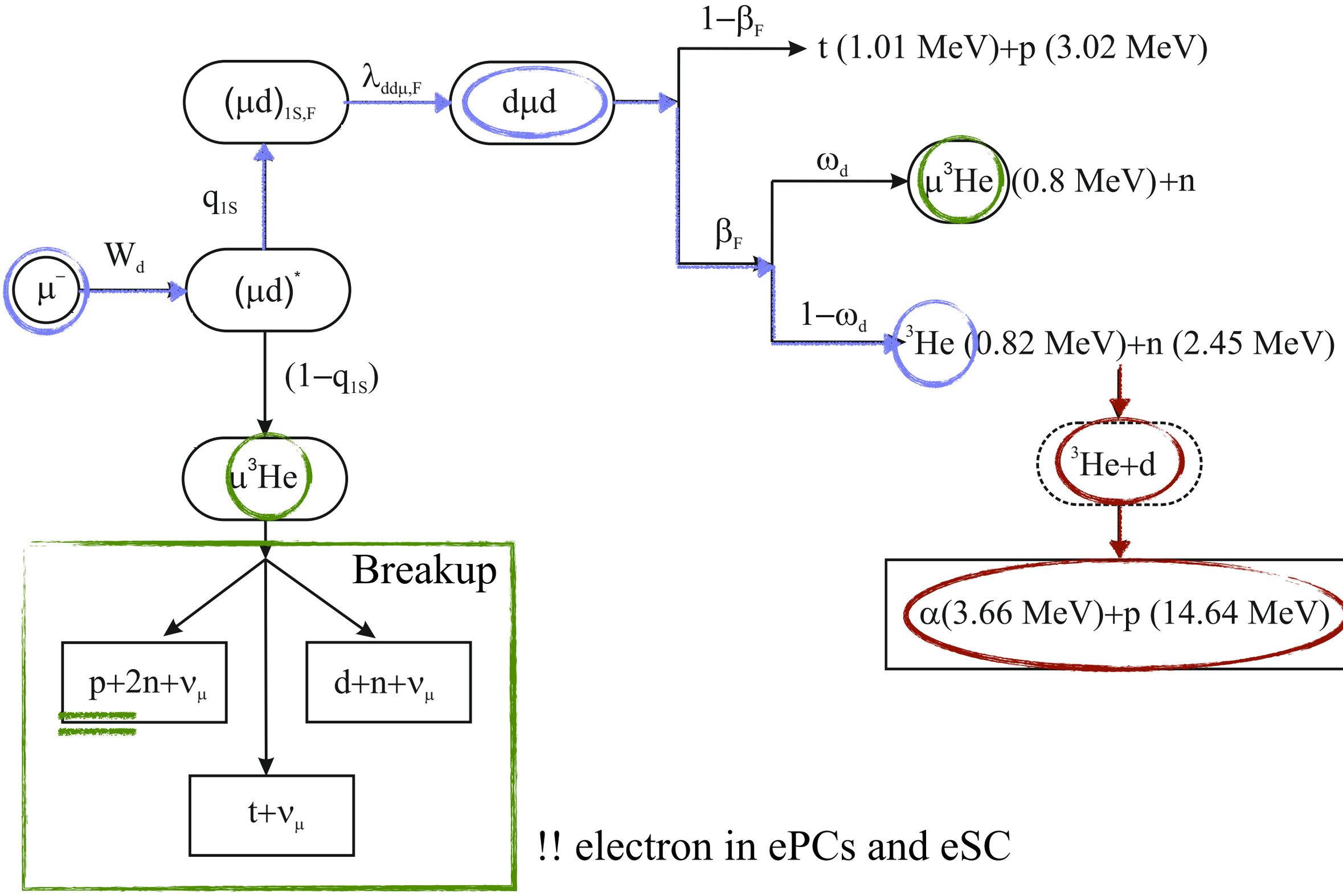
Run 8. Fusion in the fly



Sources of background

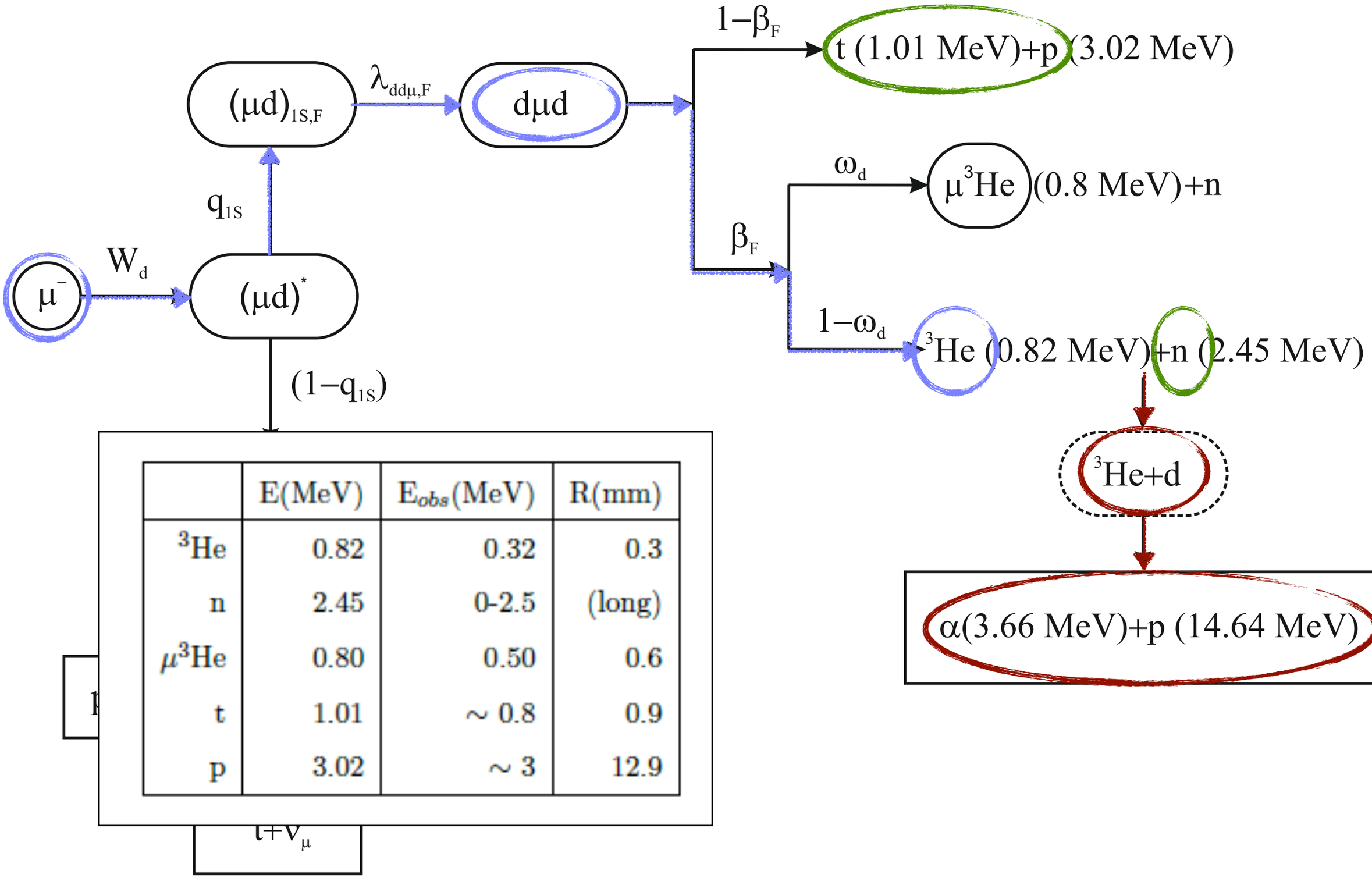


Sources of background



!! electron in ePCs and eSC

Sources of background



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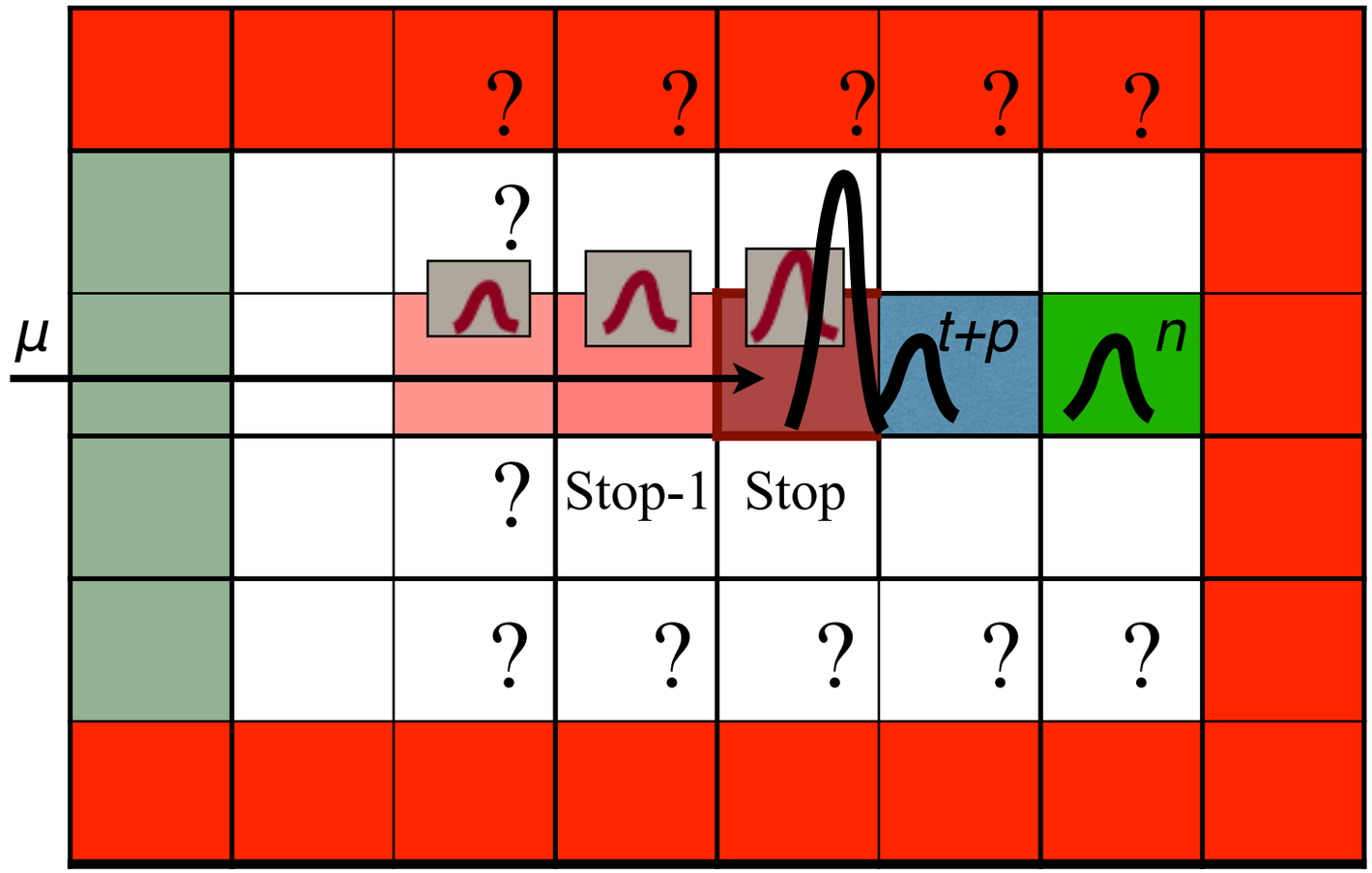
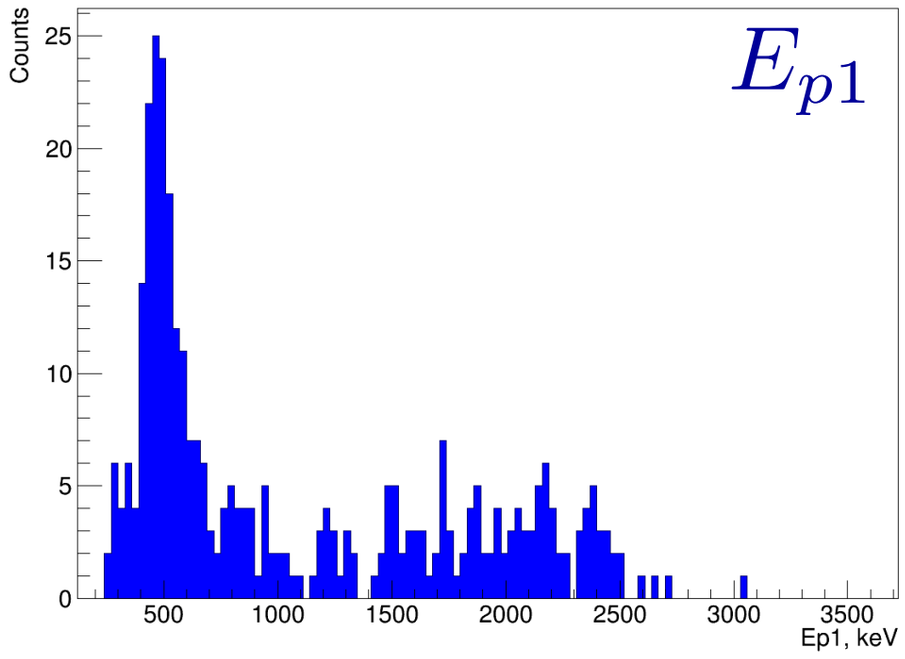
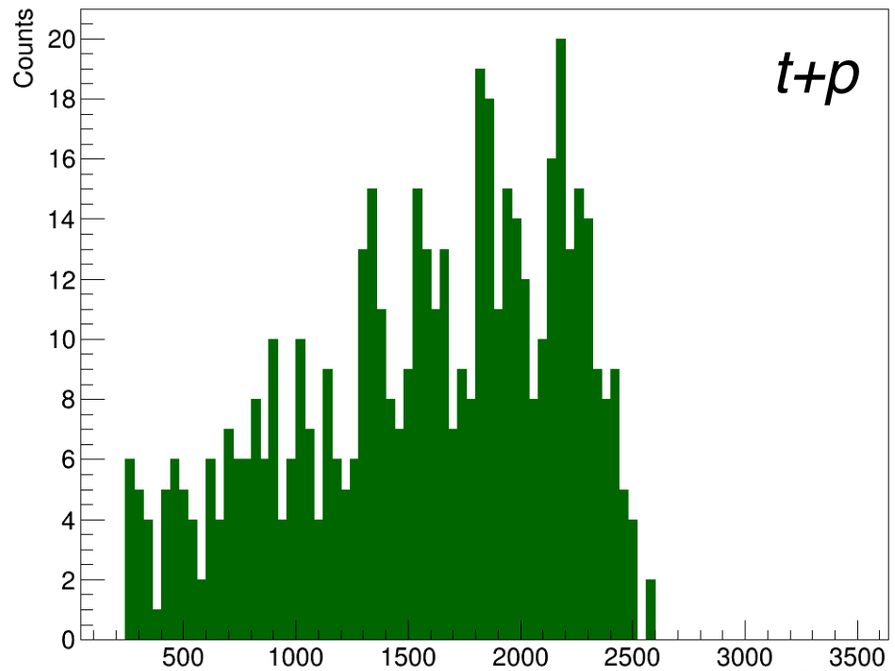
n	2.45	0-2.5	(long)
μ^3He	0.80	0.50	0.6
t	1.01	$\sim$ 0.8	0.9
p	3.02	$\sim$ 3	12.9

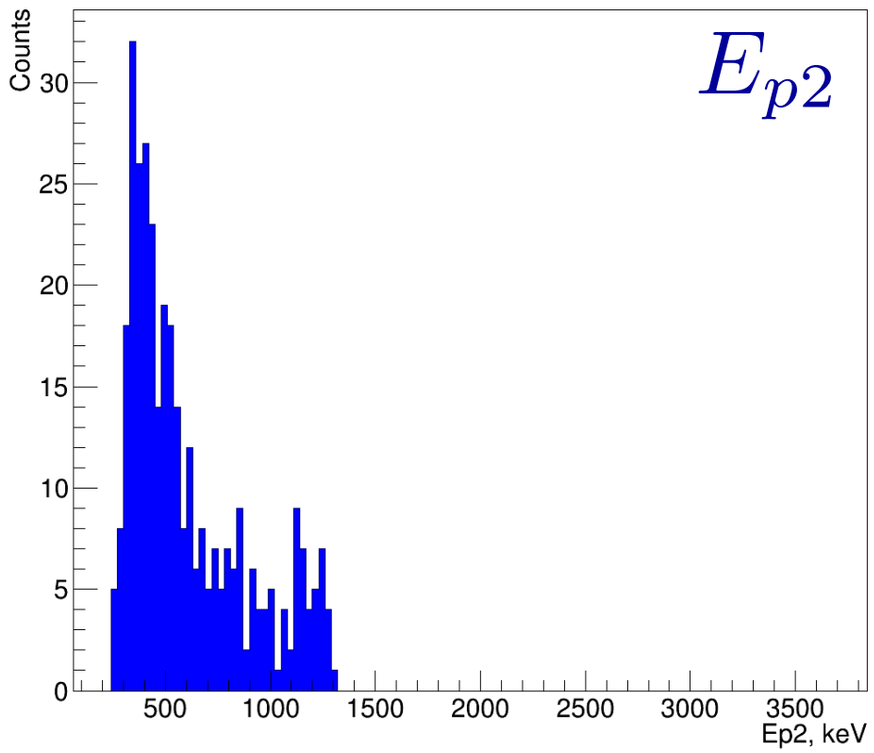
Sources of background

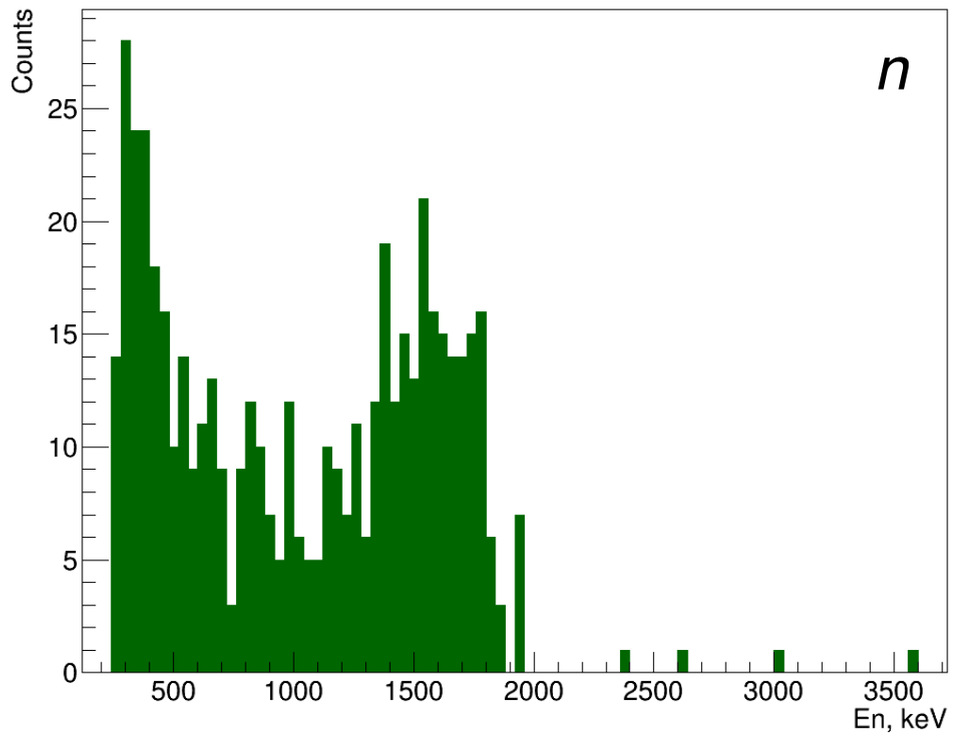


Sources of background. Neutrons.



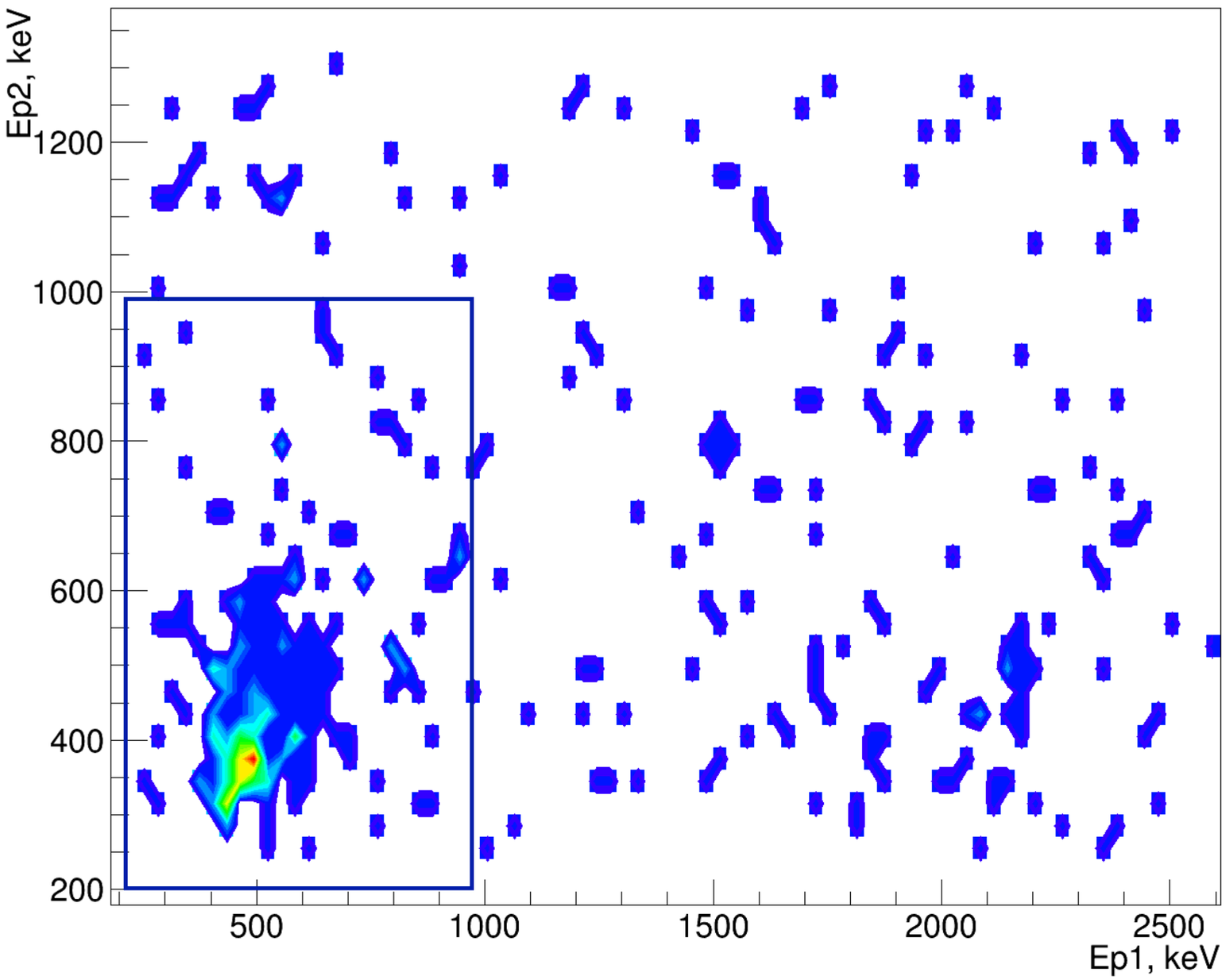






20% of events are from n

Proton track.



1 pad after Stop: E_{p1}

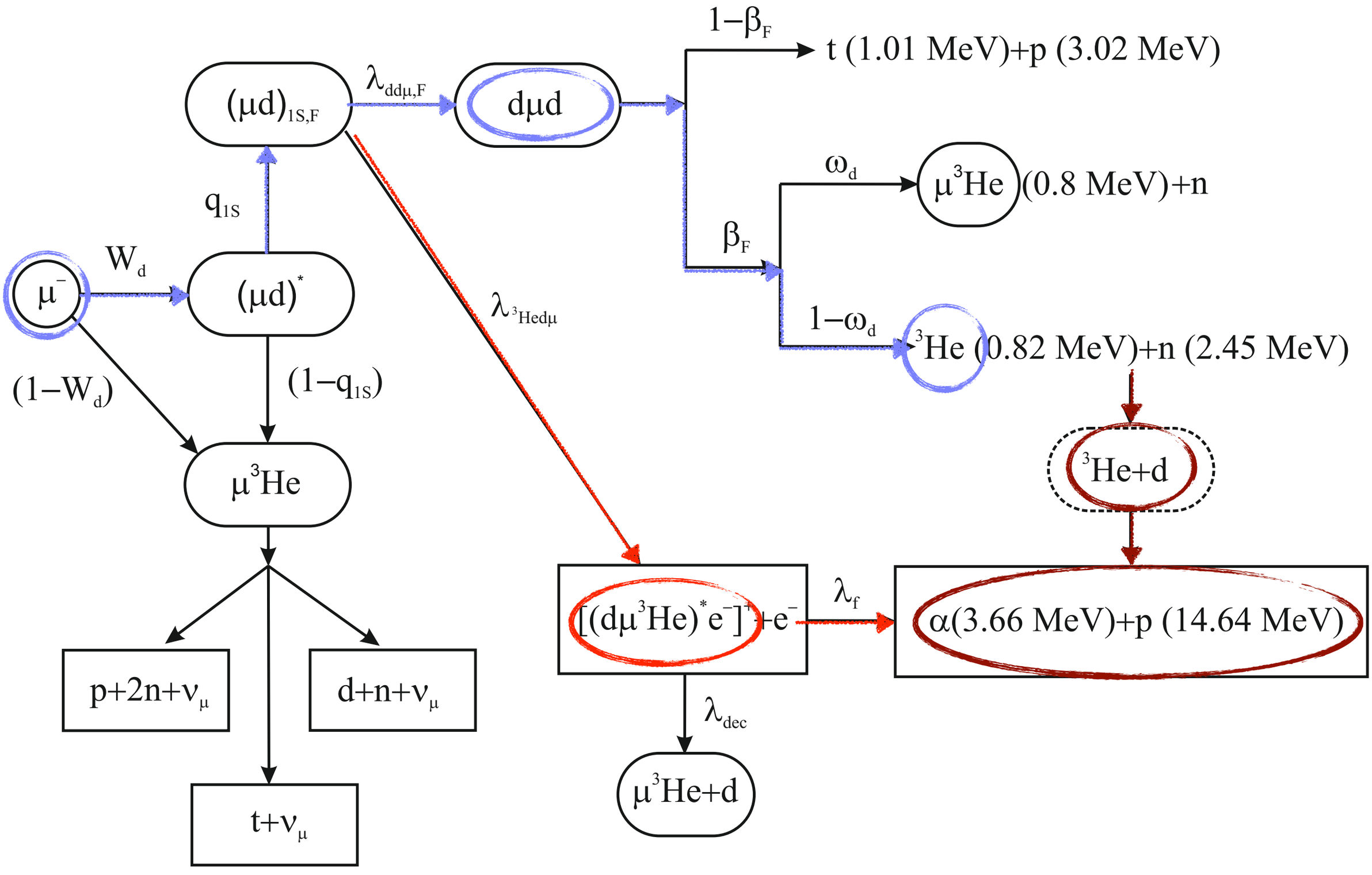
2 pad after Stop: E_{p2}

$E_{p1}, E_{p2} < 1MeV$

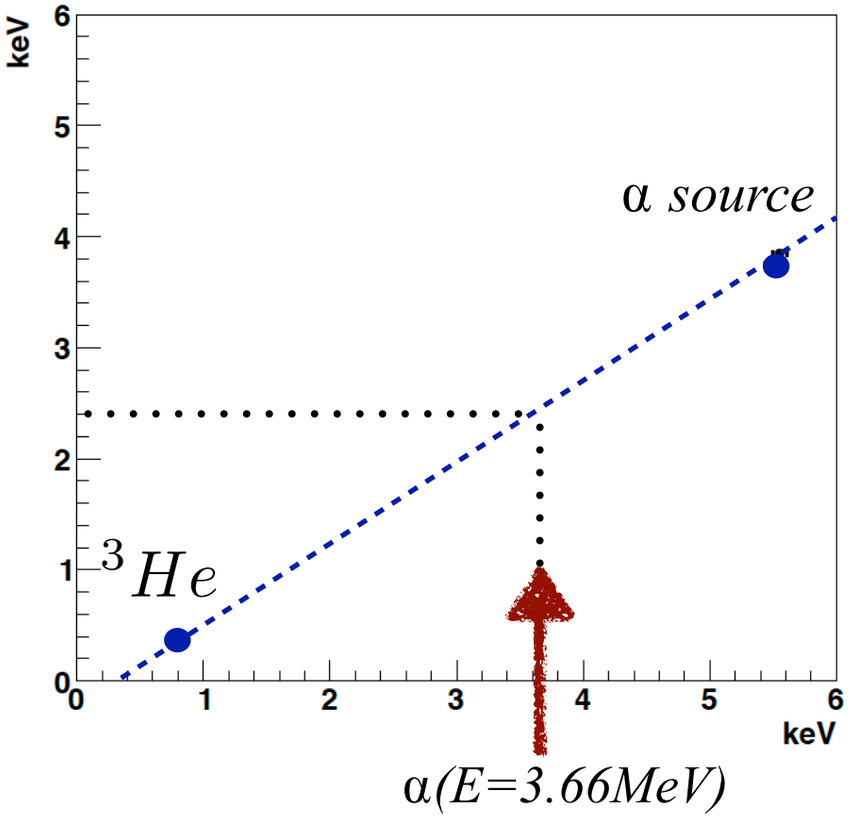
5% of events are from n

340 events ⟶ 180 fusion in the fly

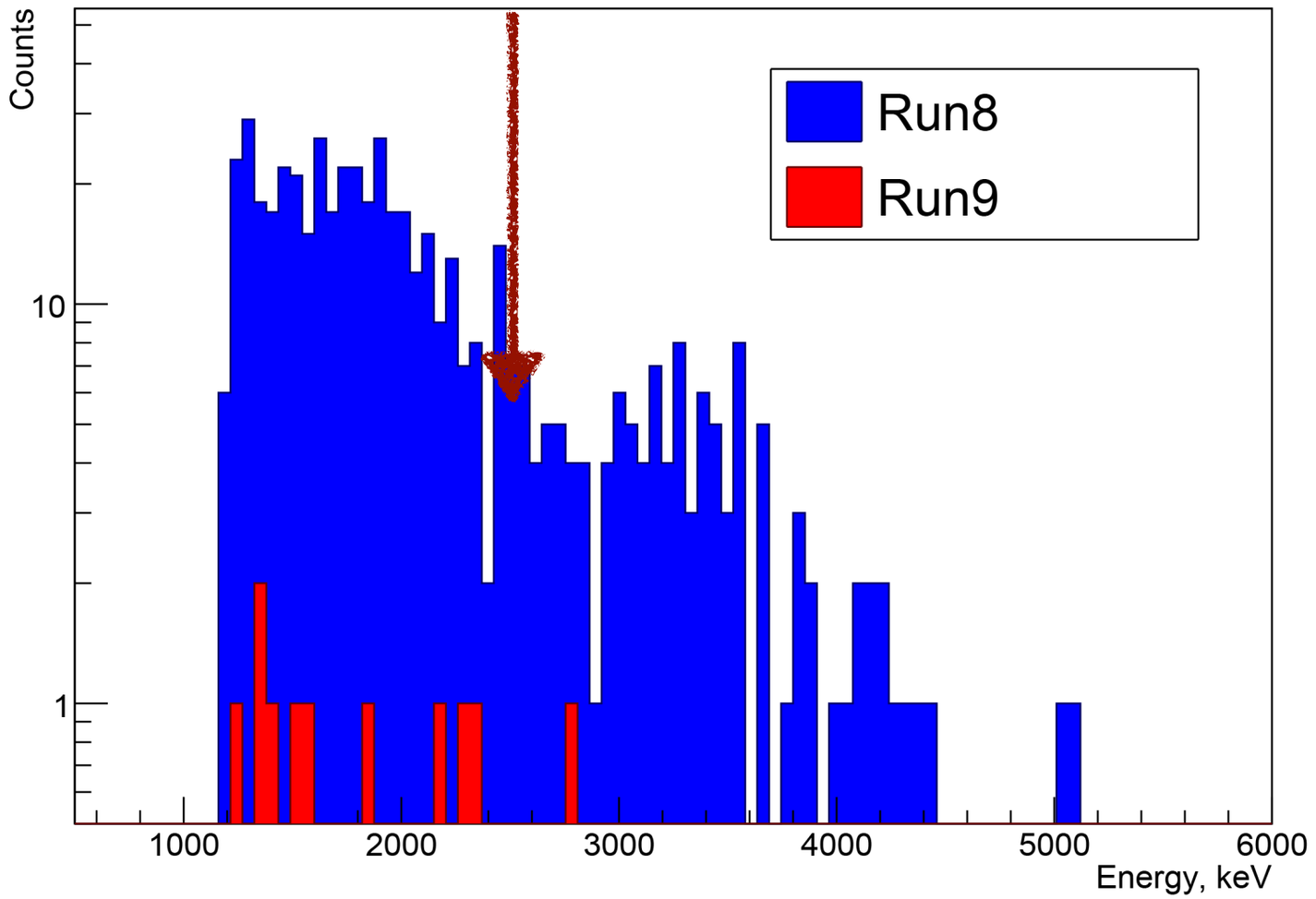
Scheme muon catalyzed fusion in $D_2 + {}^3He$. Run9



Search for muon catalyzed d^3He fusion



$E_s \sim 2.5 MeV$



PNPI-PSI-TUM-UCLB collaboration (HD+³He(5.6%):
λ_f(eff) < 6·10⁴ s⁻¹

run	N(3He)	N(4He)
Run8(D2)	1.28E+07	340
Run9(D2+3He)	3.34E+05	10

$\lambda_f < 7 \cdot 10^4 s^{-1}$

Conclusions

Unique opportunity to use MuSun setup and data:

to see the fusion in the fly for ^3He

to estimate as background for

$$d\mu + {}^3He \rightarrow [({}^3Hed\mu)e]^+ + e^-$$

$$^3Hed\mu \rightarrow {}^4He(3.66MeV) + p(14.64MeV) + \mu$$

Agreement with previous result of PNPI group

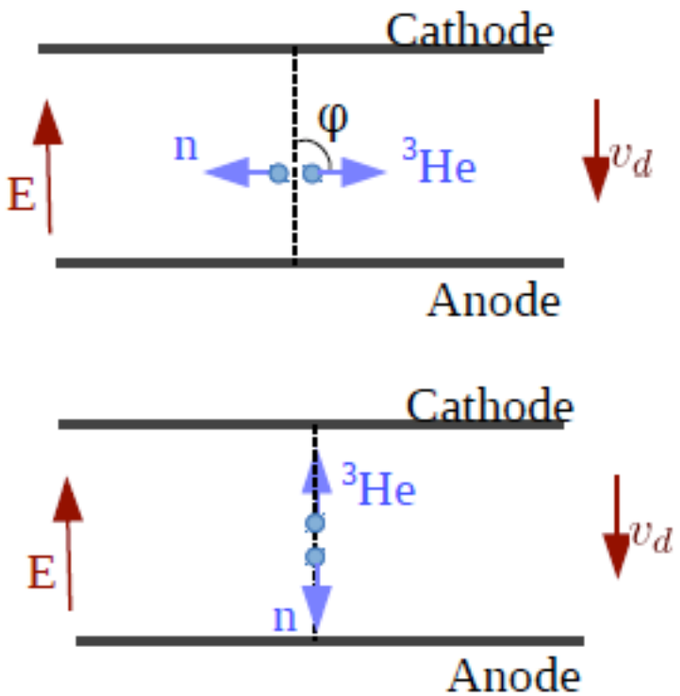
Proposal for new measurement with precision ~20%

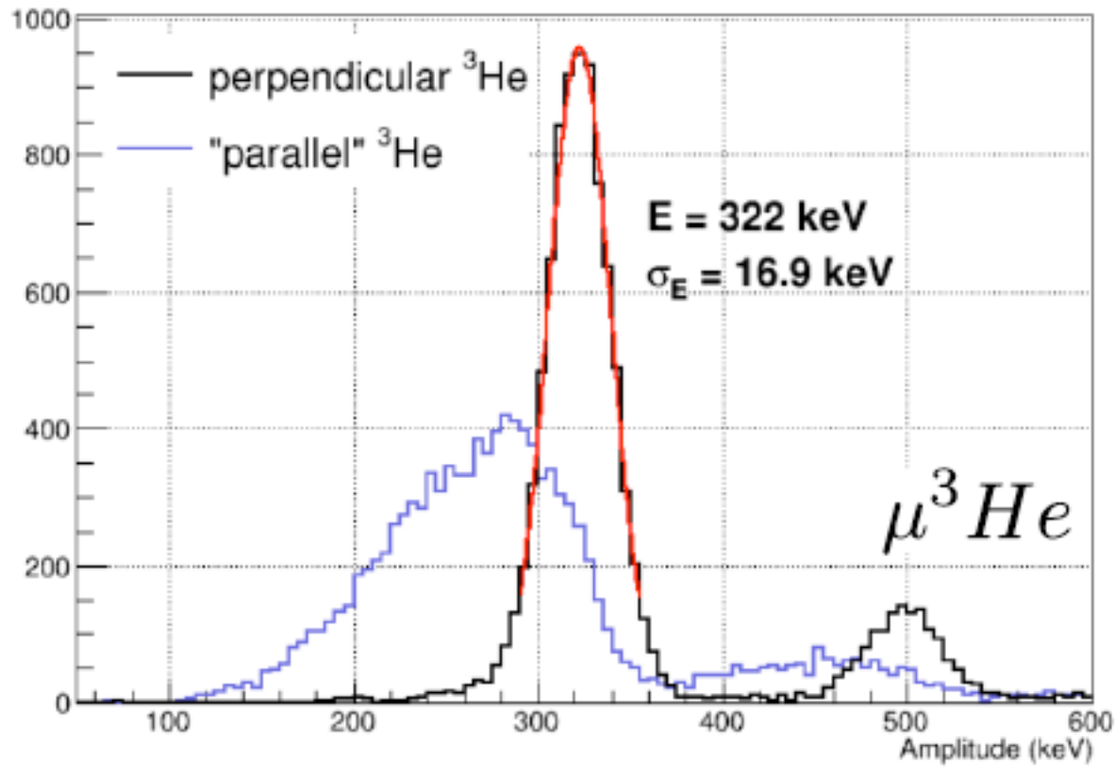
Thank you!

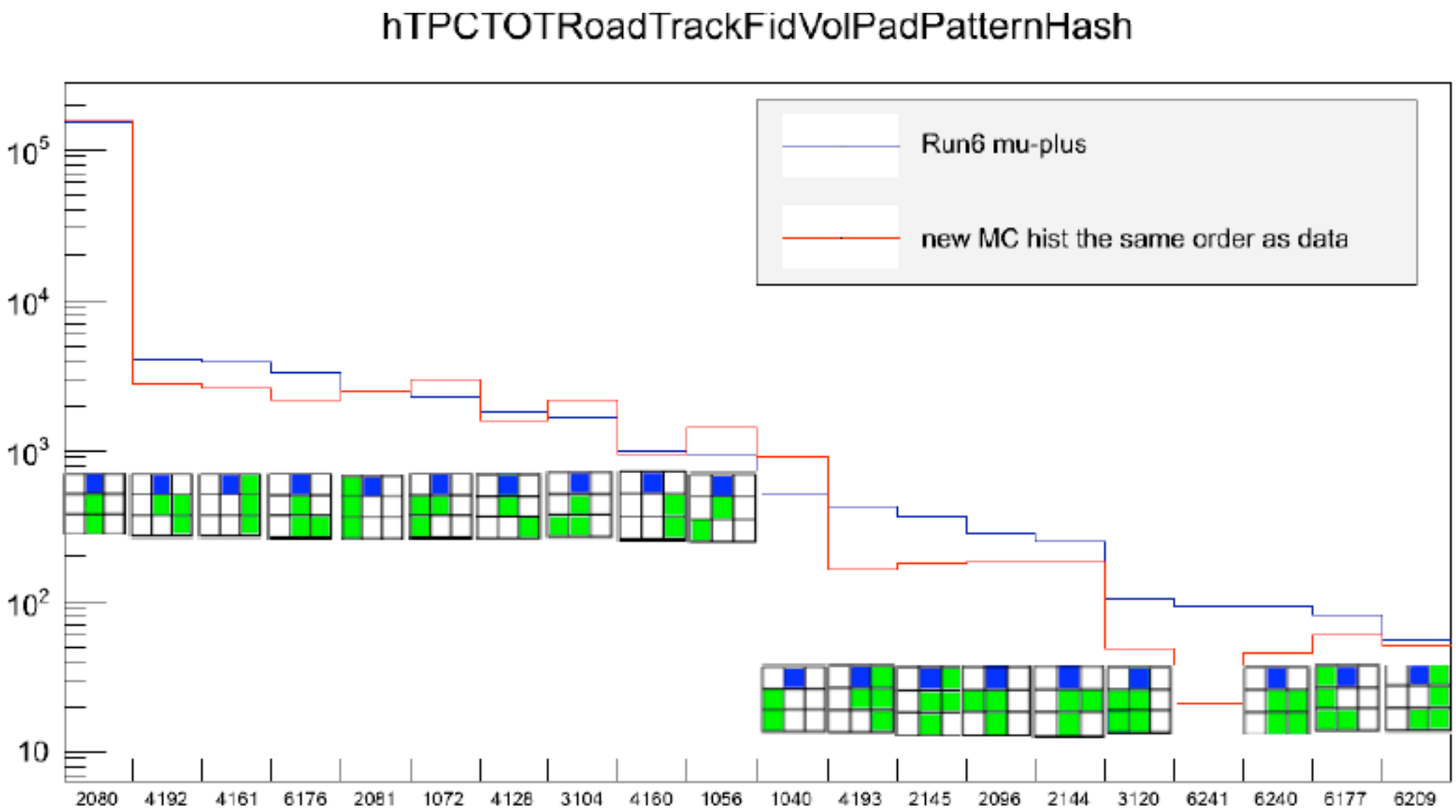
Backup

Obtain 15 keV energy resolution in the TPC

But observe long tail on the low energy side of ^{3}He



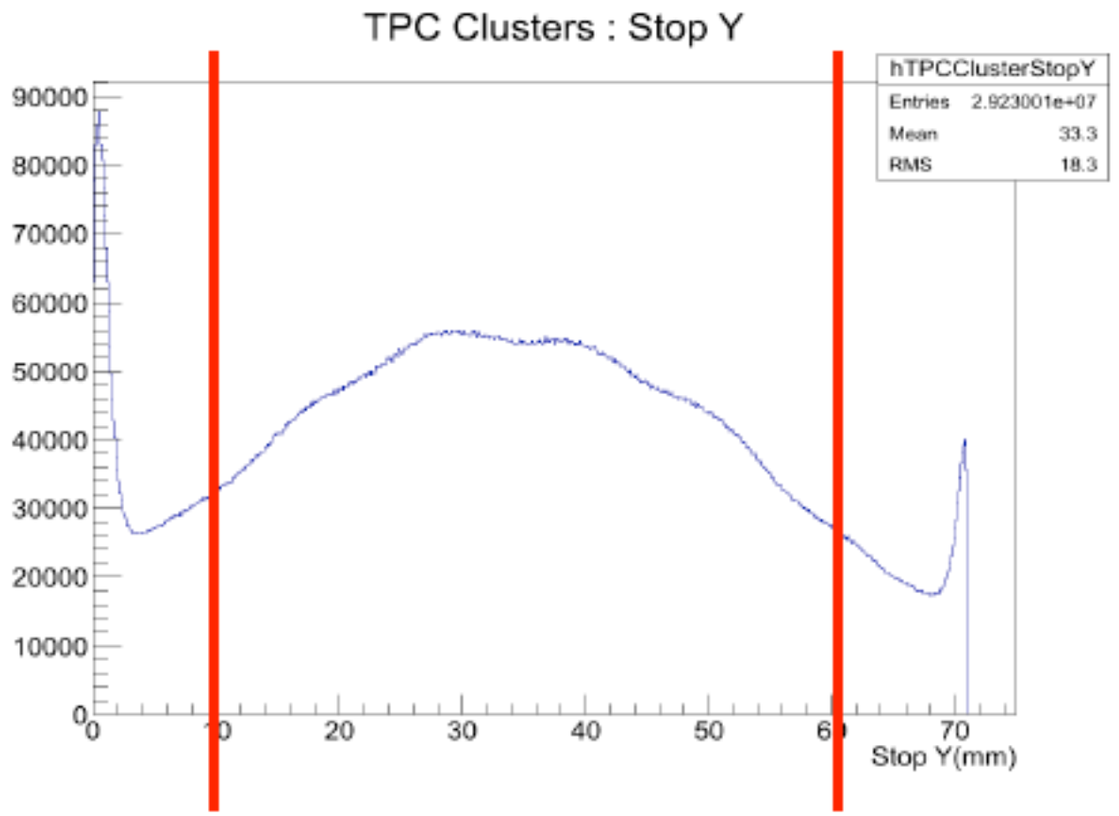


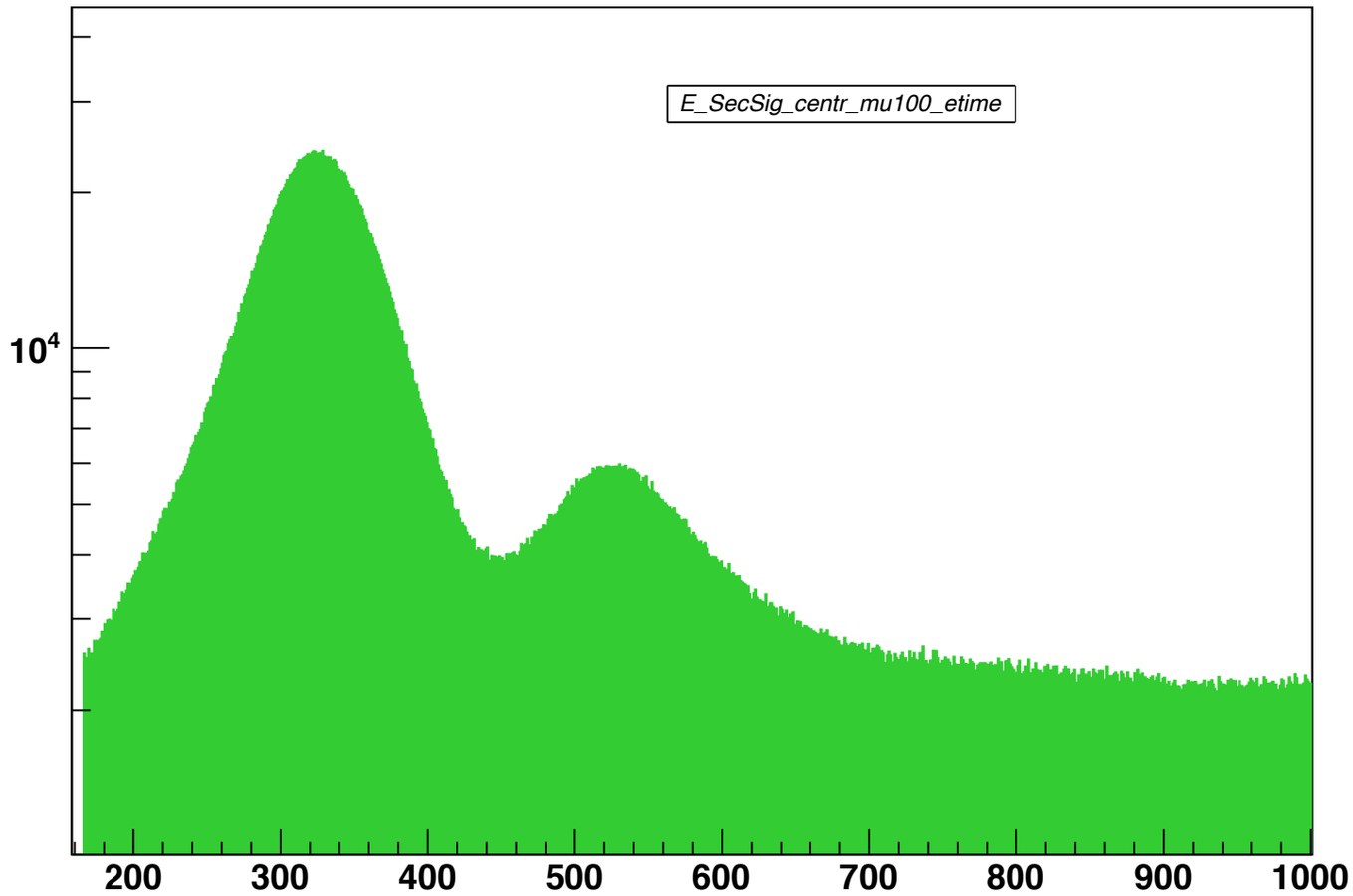

hTPCTOTRoadTrackFidVolPadPatternHash
Run6 mu-plus
new MC hist the same order as data
10^5
10^4
10^3
10^2
10
2080
4192
4161
6176
2081
1072
4128
3104
4160
1056
1040
4193
2145
2096
2144
3120
6241
6240
6177
6209

TPC Fiducial Volume

- Drift times between 2us and 12us (10mm and 61mm) are the fiducial volume Y-cut

- This cut is much easier to scan, since our resolution is better.




E_SecSig_centr_mu100_etime
10^4
200
300
400
500
600
700
800
900
1000

CryoTPC tracking