DAMSA Neutron Background Study
- Background Mitigation Summary -

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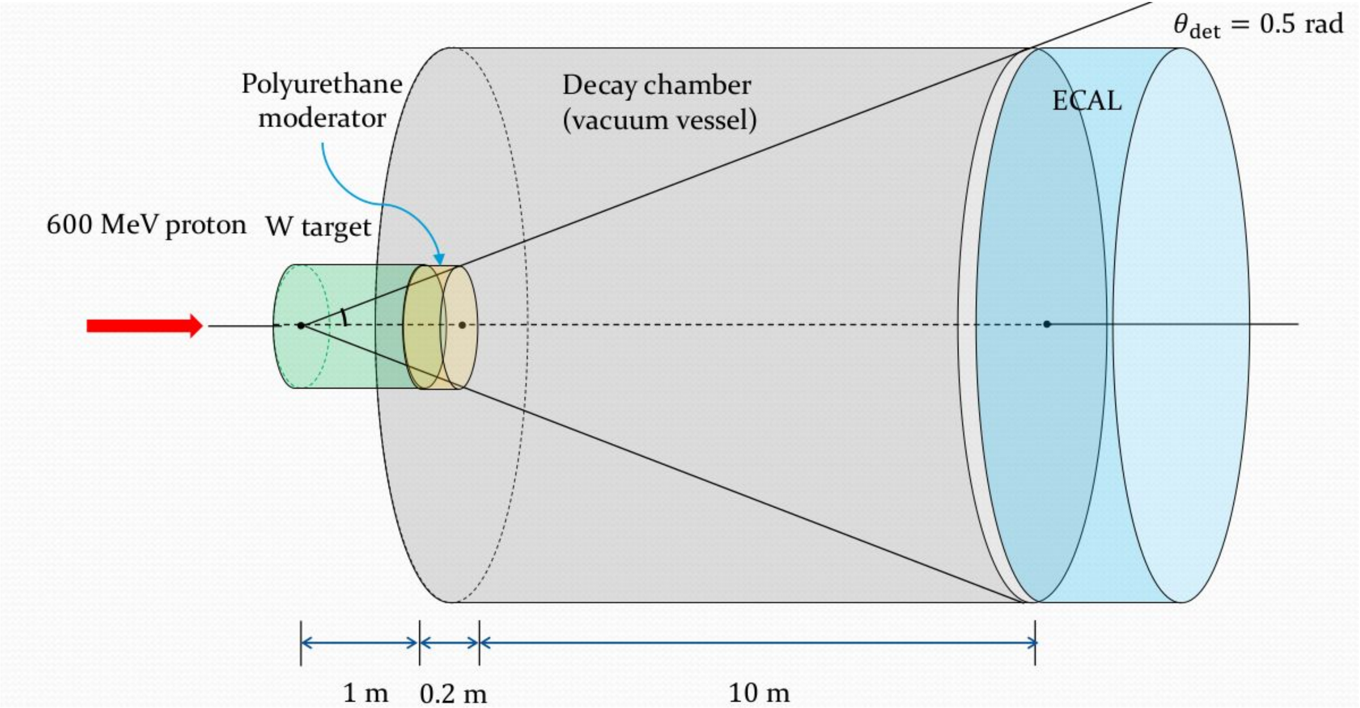
THE UNIVERSITY OF TEXAS
AT ARLINGTON

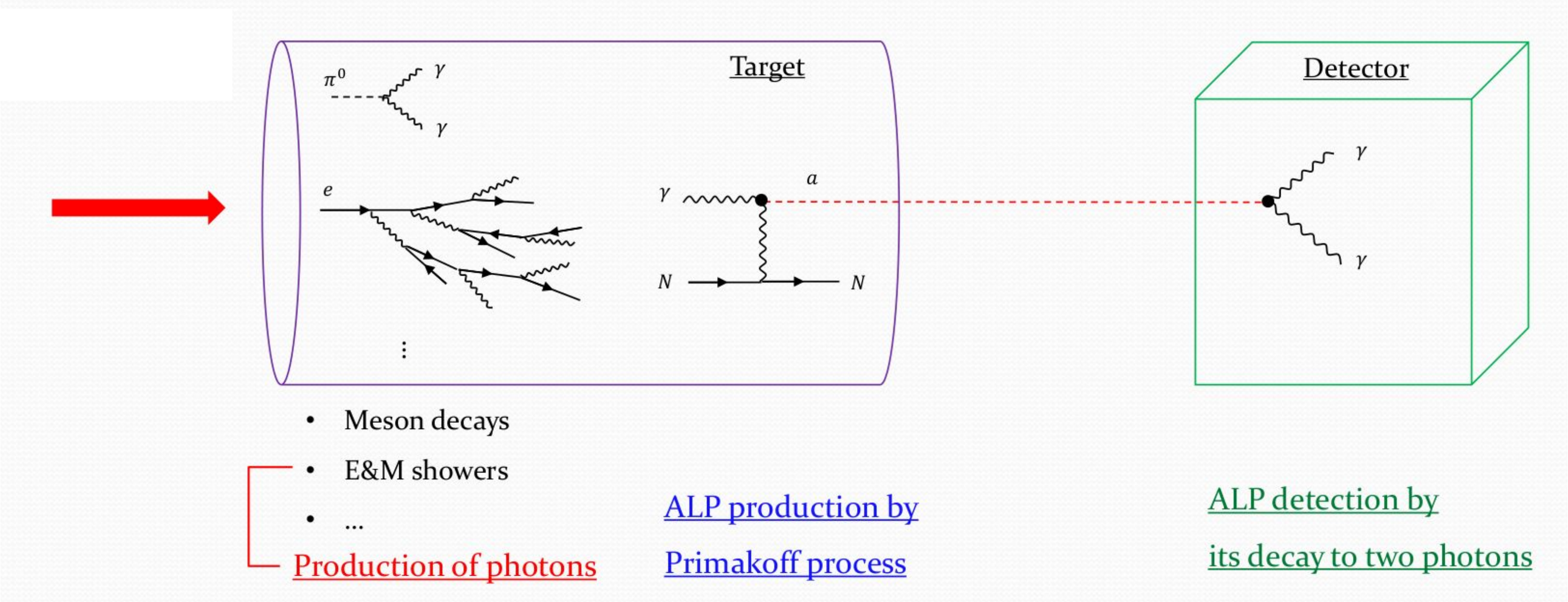
DAMSA

(Dump-Produced Aboriginal Matter Searches at an Accelerator)



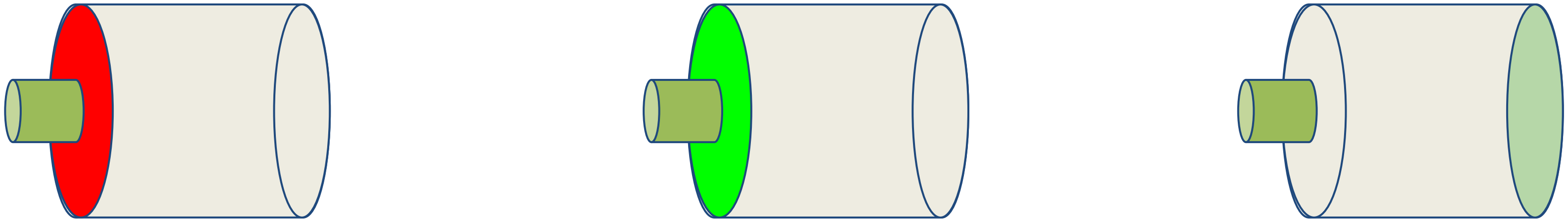
In Korean characters 담사, /da:msa/: deep thought, rumination

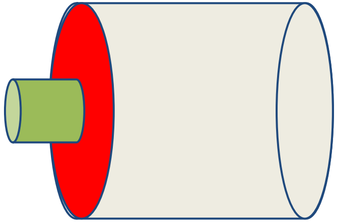
Motivation



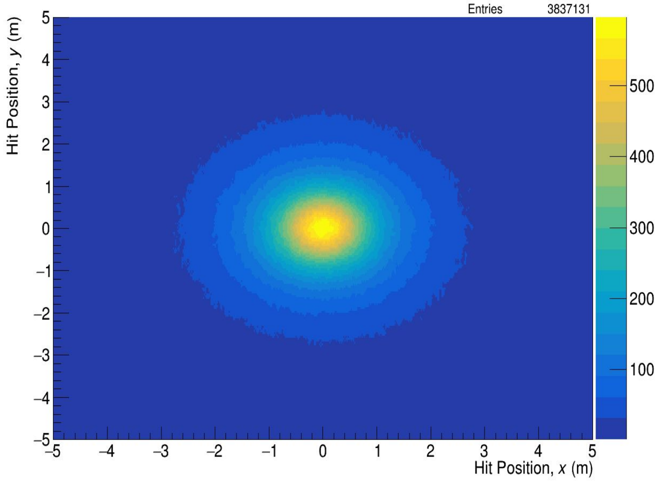
Target
π^0
γ
γ
e
γ
a
N
N
Detector
γ
γ
• Meson decays
• E&M showers
• ...
Production of photons
ALP production by
Primakoff process
ALP detection by
its decay to two photons

Content
Data Collection Positions





Beam Dump


Entries 3837131
Hit Position, y (m)
Hit Position, x (m)
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4
3
2
1
0
−1
−2
−3
−4
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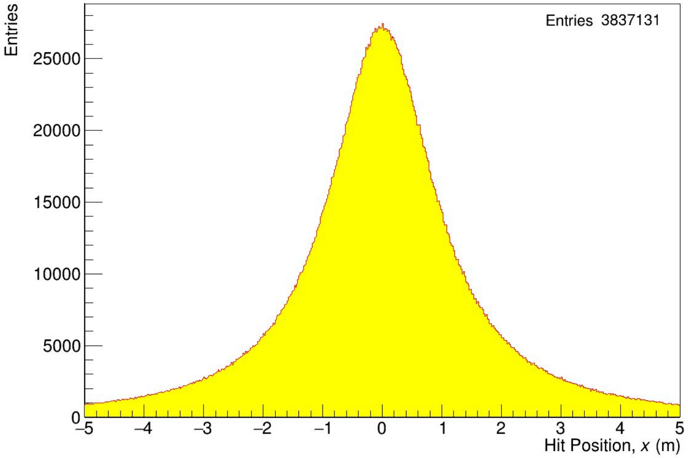
500
400
300
200
100


Entries 3837131
Entries
25000
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−3
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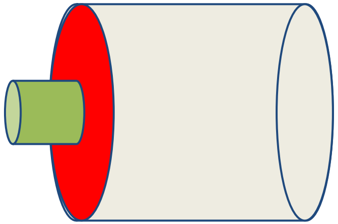
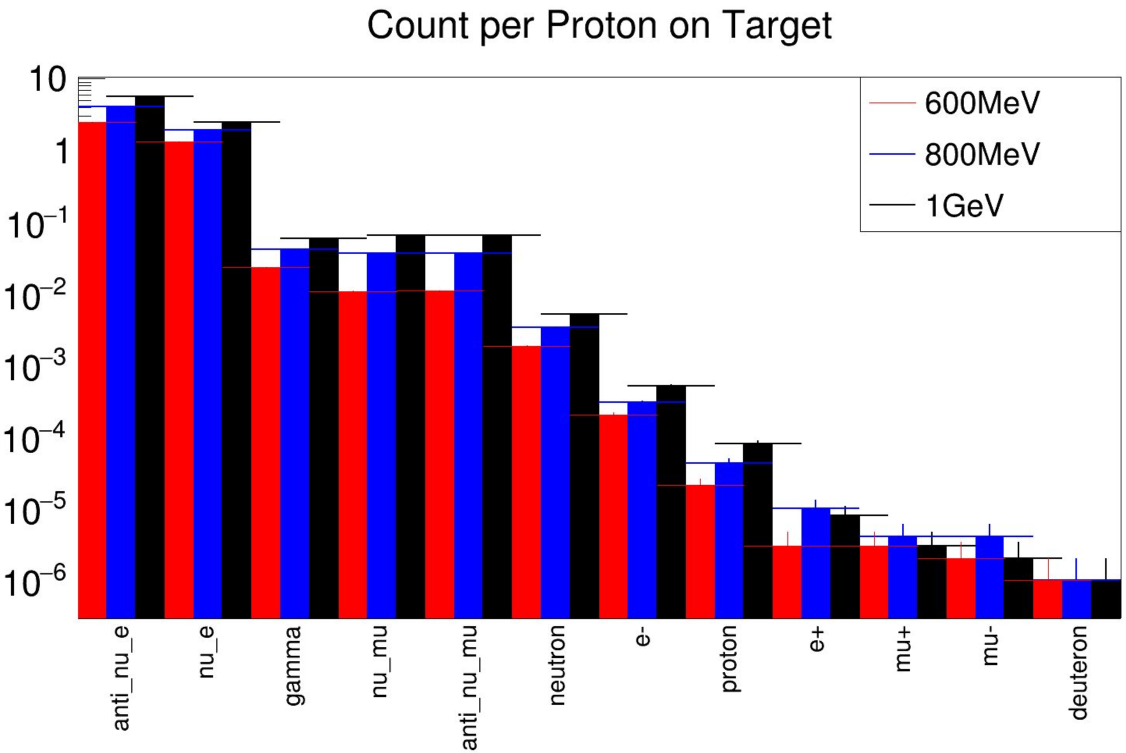
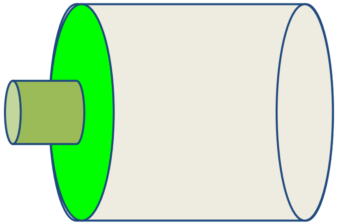
−1
0
1
2
3
4
5
Hit Position, x (m)



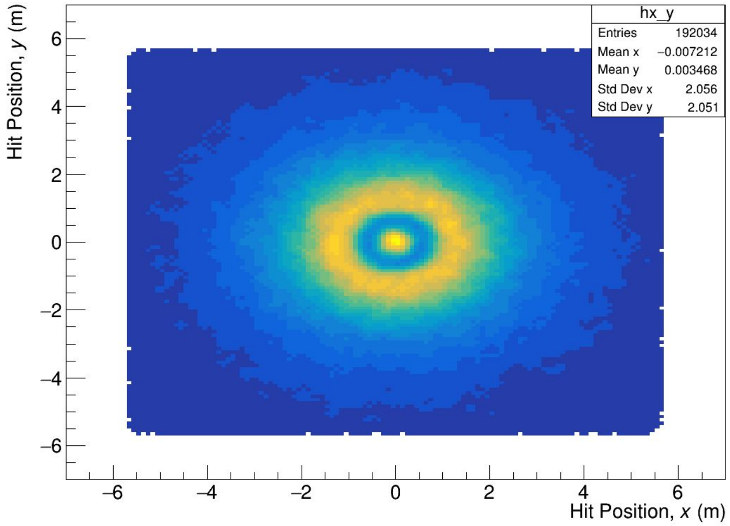
Before Decay Volume Per Proton

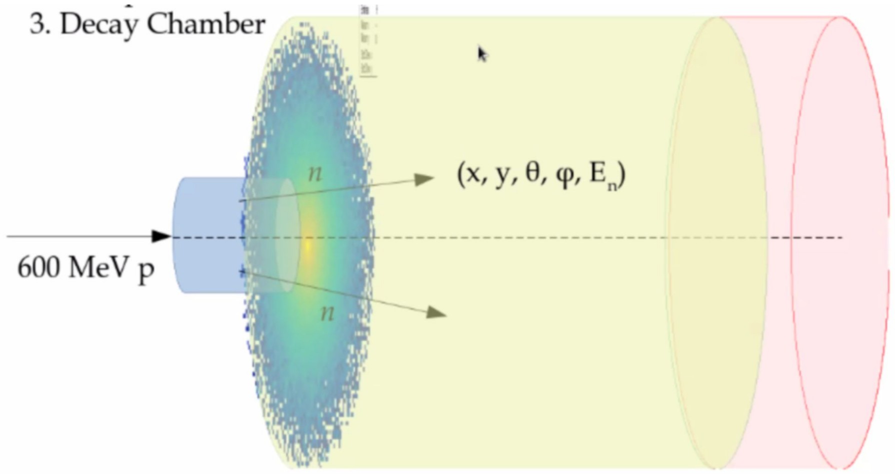


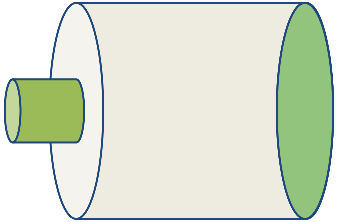
Per Proton onTarget	600MeV	800MeV	1GeV
anti_nu_e	2.46E+00	4.06E+00	5.66E+00
nu_e	1.33E+00	1.93E+00	2.50E+00
gamma	2.30E-02	4.09E-02	5.93E-02
nu_mu	1.08E-02	3.64E-02	6.47E-02
anti_nu_mu	1.09E-02	3.61E-02	6.49E-02
neutron	1.86E-03	3.35E-03	5.09E-03
e-	2.04E-04	3.03E-04	5.14E-04
proton	2.10E-05	4.30E-05	8.00E-05
e+	3.00E-06	1.00E-05	8.00E-06
mu+	3.00E-06	4.00E-06	3.00E-06
mu-	2.00E-06	4.00E-06	2.00E-06
deuteron	1.00E-06	1.00E-06	1.00E-06



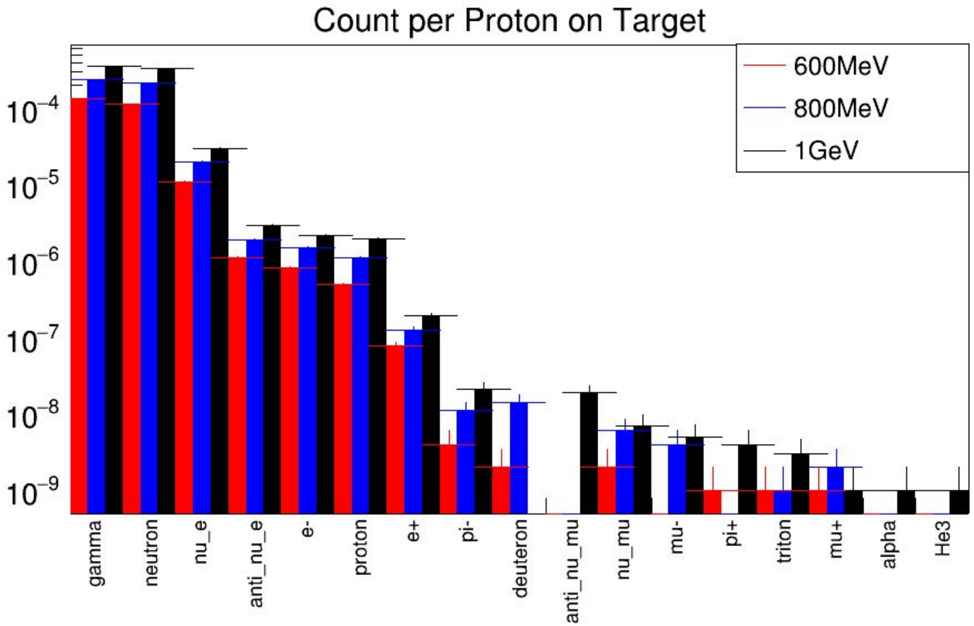
Neutron Distribution







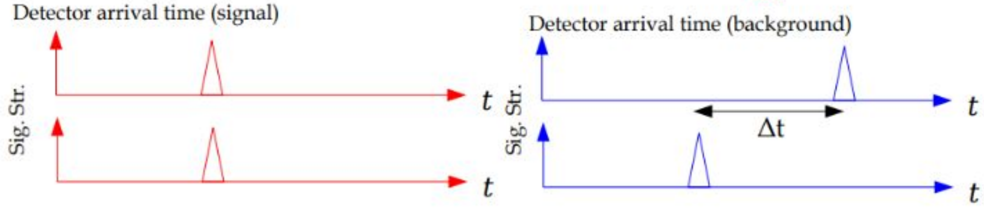
Neutron Induced After Decay Volume Per Proton

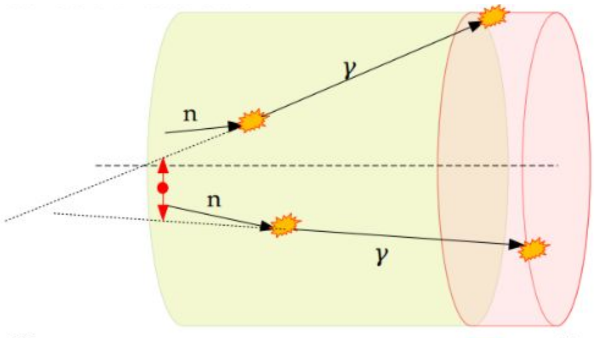


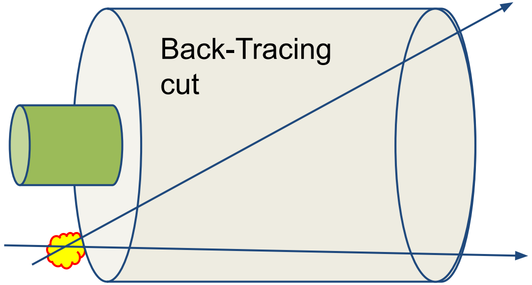
Per Proton onTarget	600MeV	800MeV	1GeV
gamma	1.34E-4	2.41E-04	3.61E-04
neutron	1.15E-04	2.14E-04	3.34E-04
nu_e	1.10E-05	2.01E-05	3.01E-05
anti_nu_e	1.10E-06	1.91E-06	2.95E-06
e-	8.25E-07	1.50E-06	2.20E-06
proton	4.87E-07	1.12E-06	1.96E-06
e+	7.90E-08	1.25E-07	1.91E-07
pi-	4.00E-09	1.10E-08	2.10E-08
deuteron	2.00E-09	1.40E-08	0.00E+00
anti_nu_mu	0.00E+00	0.00E+00	1.90E-08
nu_mu	2.00E-09	6.00E-09	7.00E-09
mu-	0.00E+00	4.00E-09	5.00E-09
pi+	1.00E-09	0.00E+00	4.00E-09
triton	1.00E-09	1.00E-09	3.00E-09
mu+	1.00E-09	2.00E-09	1.00E-09
alpha	0.00E+00	0.00E+00	1.00E-09
He3	0.00E+00	0.00E+00	1.00E-09

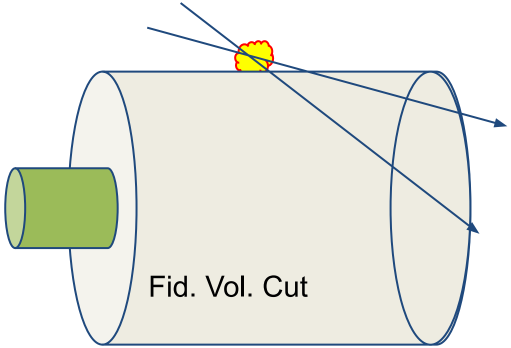
Background Considerations

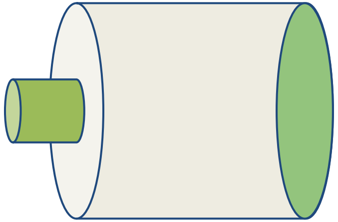
ΔTOA / DCA / Back-Tracing / Fiducial Volume



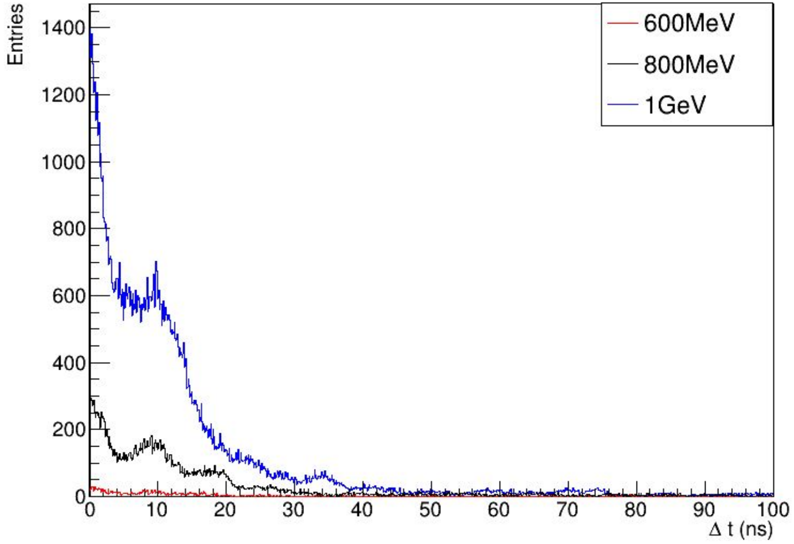


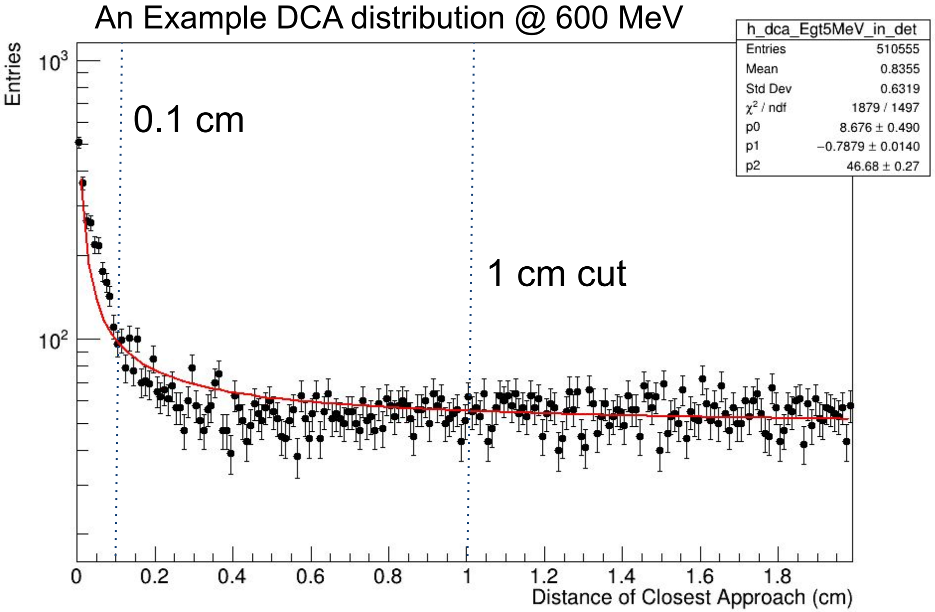


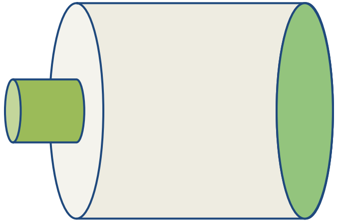




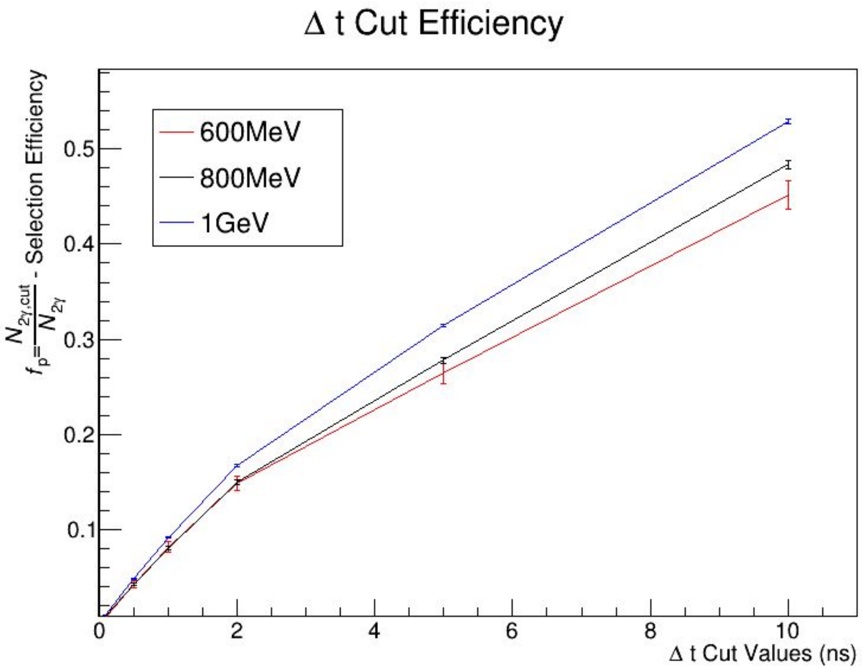
DCA / ΔTOA - 15 MeV Cut





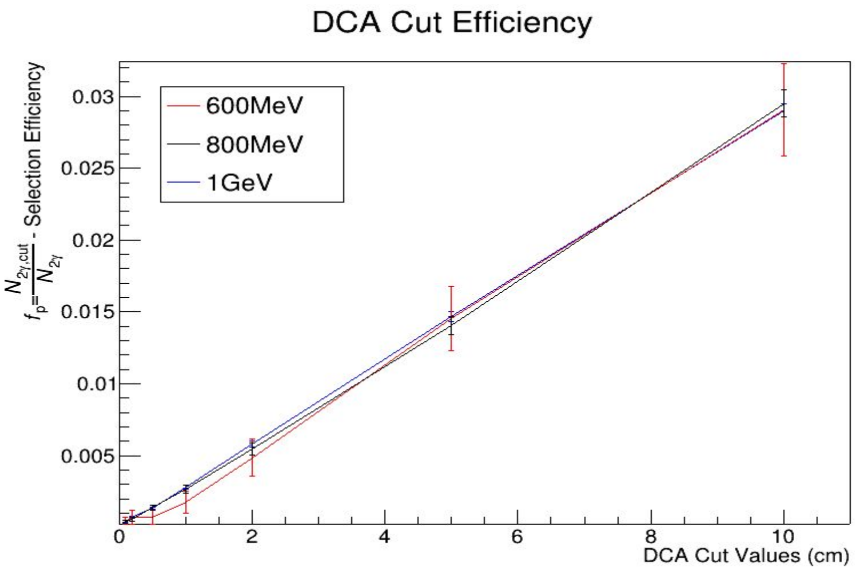


ΔTOA Selection Efficiency
15MeV cut γ



Δt cut (ns)	600MeV $N_{2\gamma,cut}/N_{2\gamma}$	σ_{600}	800MeV $N_{2\gamma,cut}/N_{2\gamma}$	σ_{800}	1GeV $N_{2\gamma,cut}/N_{2\gamma}$	σ_1
<10	4.34E-01	3.47E-02	4.73E-01	5.16E-03	5.37E-01	2.46E-03
<5	2.57E-01	1.14E-02	2.74E-01	3.64E-03	3.14E-01	1.74E-03
<2	1.45E-01	8.14E-03	1.49E-01	2.49E-03	1.55E-01	1.16E-03
<1	7.94E-02	5.84E-03	8.42E-02	1.78E-03	8.58E-02	8.25E-04
<0.5	4.21E-02	4.18E-03	4.40E-02	1.26E-03	4.47E-02	5.84E-04
<0.1	8.82E-03	1.88E-03	9.38E-03	5.74E-04	9.29E-03	2.62E-04

DCA Selection Efficiency
15 MeV cut γ



DCA (cm)	600MeV $N_{2\gamma,cut}/N_{2\gamma}$	σ_{600}	800MeV $N_{2\gamma,cut}/N_{2\gamma}$	σ_{800}	1GeV $N_{2\gamma,cut}/N_{2\gamma}$	σ_1
<10	2.79E-02	5.18E-03	2.85E-03	1.01E-03	2.83E-02	2.61E-04
<5	1.44E-02	2.82E-03	1.43E-02	7.09E-04	1.42E-02	1.24E-04
<2	5.94E-03	1.60E-03	5.79E-03	3.50E-04	5.73E-03	4.65E-05
<1	3.10E-03	1.11E-03	2.98E-03	1.22E-04	2.88E-03	2.45E-05
<0.5	1.67E-03	8.15E-04	1.54E-03	4.32E-05	1.47E-03	1.04E-05
<0.1	5.58E-04	4.72E-04	3.89E-04	1.16E-05	3.32E-04	6.12E-06

-Benchmark Beam Parameters -

Beam Energy (E_{beam}): 800 MeV

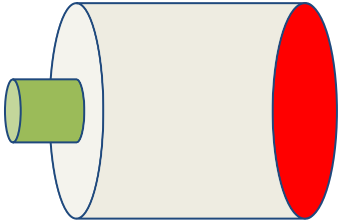
Beam Current (I_{beam}): 2 mA

Beam Power (P_{beam}): 1.6 MW

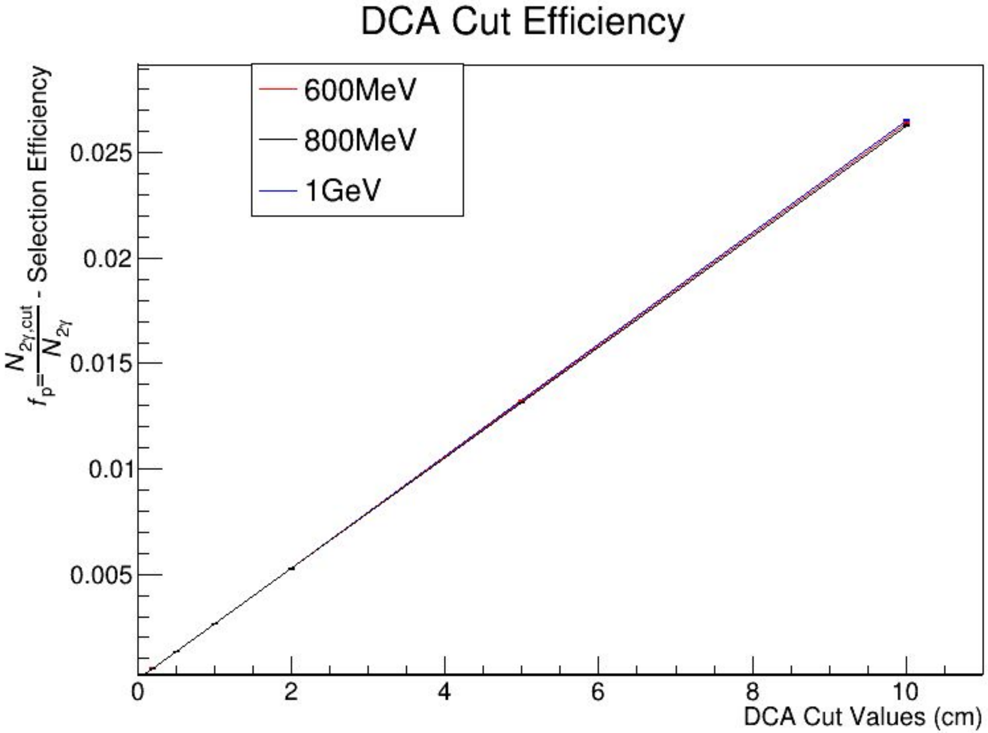
Protons-on-Target Per Year: 3.93×10^{23}

Sequential Cuts	N 600 MeV	N 800 MeV	1 GeV
Protons per pulse	$6.87X10^{12}$	$6.87X10^{12}$	$6.87X10^{12}$
Beam induced Neutrons from dump	$1.32X10^{10}$	$2.35X10^{10}$	$3.46X10^{10}$
Neutron induced photons on detector	$9.21X10^{8}$	$1.66X10^{9}$	$2.47X10^{9}$
$n\gamma$ after 15 MeV threshold cut	$4.87X10^{4}$	$3.30X10^{5}$	$7.19X10^{5}$
TOA < 40 ns	$2.44X10^{4}$	$1.65X10^{4}$	$3.60X10^{5}$
Photon Pairs	$2.98x10^{8}$	$1.36x10^{8}$	$6.48x10^{10}$
Independent Cuts	**Efficiency 600 MeV**	**Efficiency 800 MeV**	**Efficiency 1 GeV**
DCA < 1cm	$3.10x10^{-3}$	$2.98x10^{-3}$	$2.88X10^{-3}$
ΔTOA < 0.1 ns	$8.82X10^{-3}$	$9.38X10^{-3}$	$9.29X10^{-3}$
Fiducial Volume Cut	$6.13x10^{-1}$	$6.13x10^{-1}$	$6.13x10^{-1}$
Back Tracing Cut	$4.16x10^{-2}$	$4.18x10^{-2}$	$4.16x10^{-2}$
Invariant mass (9 MeV < m_{inv} < 11 MeV)	$1.88X10^{-4}$	$2.07X10^{-4}$	$2.61X10^{-4}$
Invariant mass (4 MeV < m_{inv} < 6 MeV)	$1.63X10^{-2}$	$1.62X10^{-2}$	$1.75X10^{-2}$

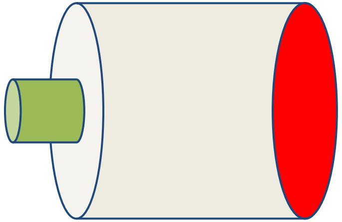
END



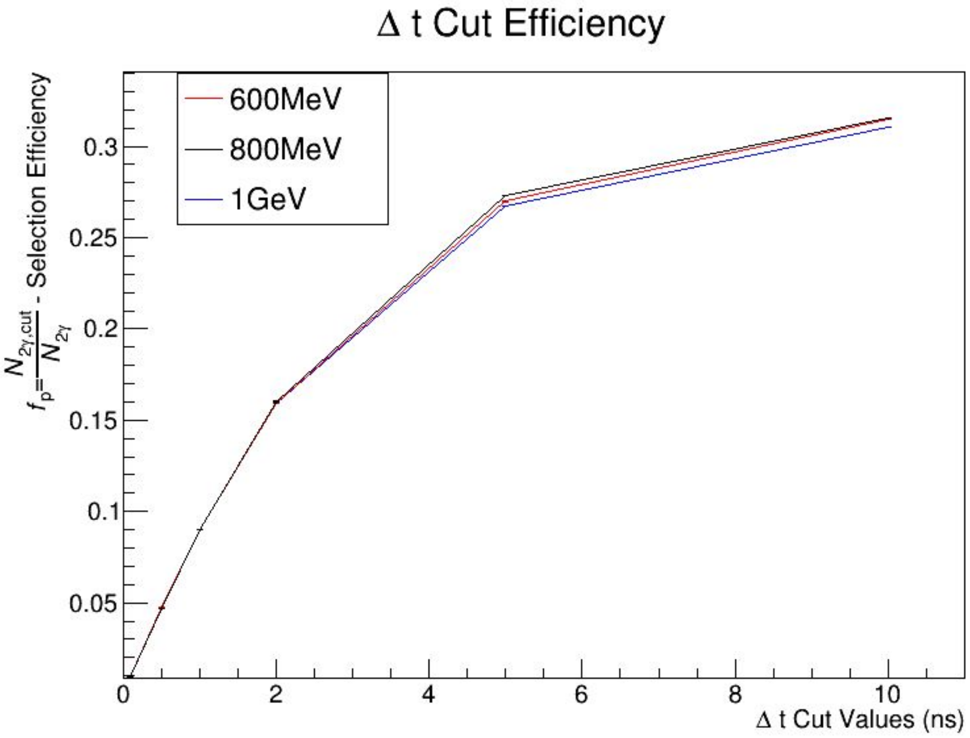
DCA Selection Efficiency
No MeV cut



DCA (cm)	600MeV $N_{2\gamma,cut}/N_{2\gamma}$	800MeV $N_{2\gamma,cut}/N_{2\gamma}$	1GeV $N_{2\gamma,cut}/N_{2\gamma}$
<10	2.64E-2	2.63E-2	2.65E-2
<5	1.32E-2	1.32E-2	1.33E-2
<2	5.29E-3	5.26E-3	5.31E-3
<1	2.66E-3	2.63E-3	2.65E-3
<0.5	1.35E-3	1.32E-3	1.33E-3
<0.1	2.84E-4	2.65E-4	2.27E-4

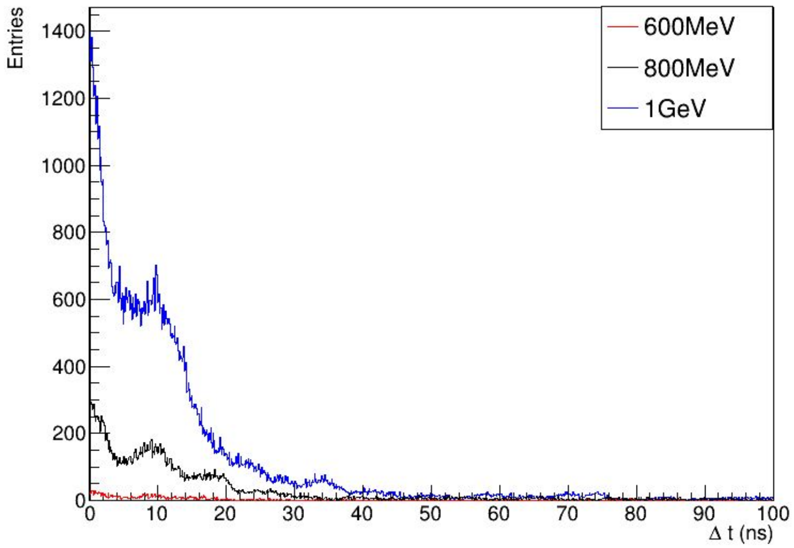


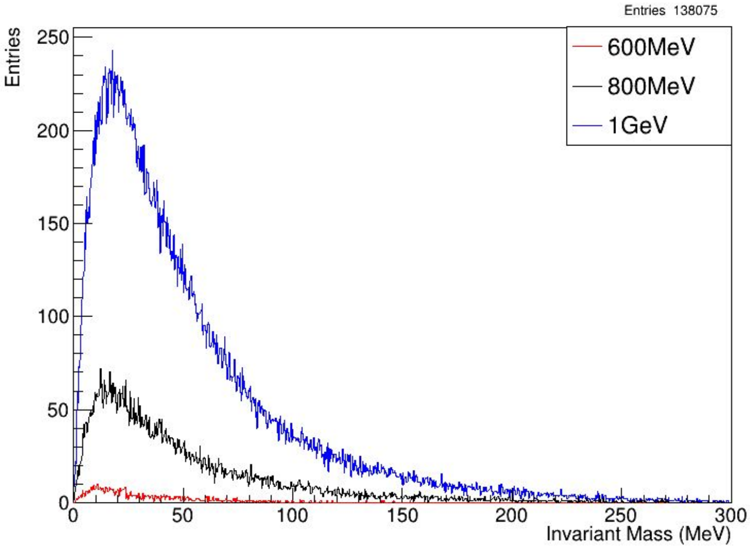
ΔTOA Selection Efficiency
No MeV cut



Δt cut (ns)	600MeV $N_{2\gamma,cut}/N_{2\gamma}$	800MeV $N_{2\gamma,cut}/N_{2\gamma}$	1GeV $N_{2\gamma,cut}/N_{2\gamma}$
<10	3.15E-1	3.15E-1	3.11E-1
<5	2.70E-1	2.73E-1	2.67E-1
<2	1.59E-1	1.60E-1	1.59E-1
<1	9.00E-2	8.99E-2	9.00E-2
<0.5	4.74E-2	4.71E-2	4.73E-2
<0.1	9.69E-3	9.67E-3	9.66E-3

ΔTOA / Invariant Mass - 15 MeV Cut





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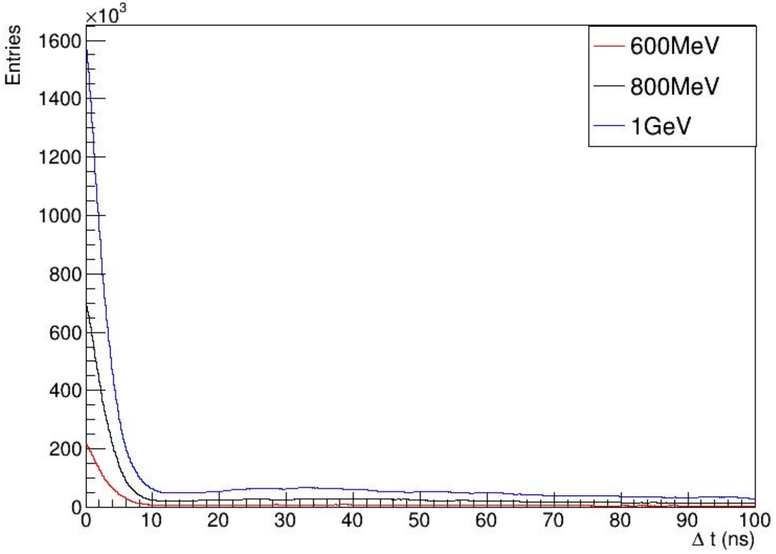
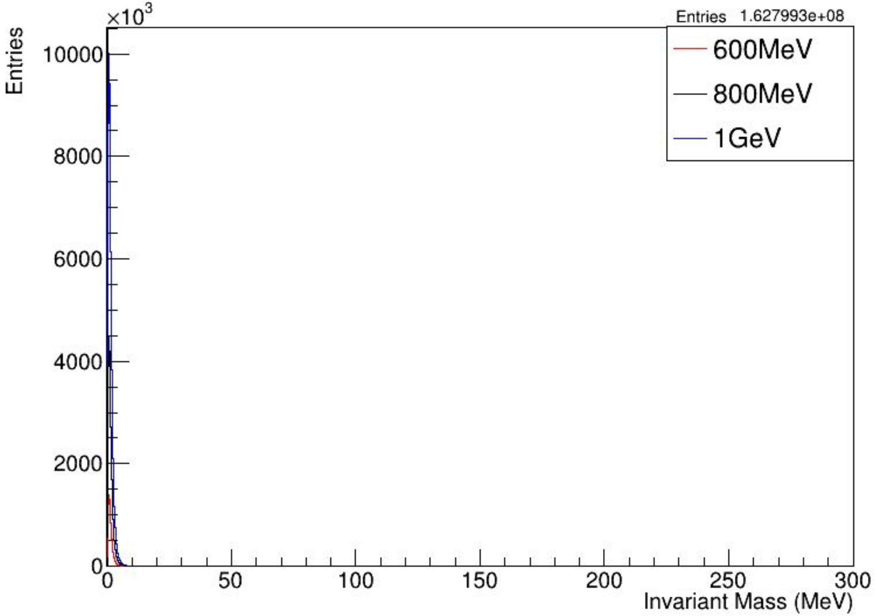
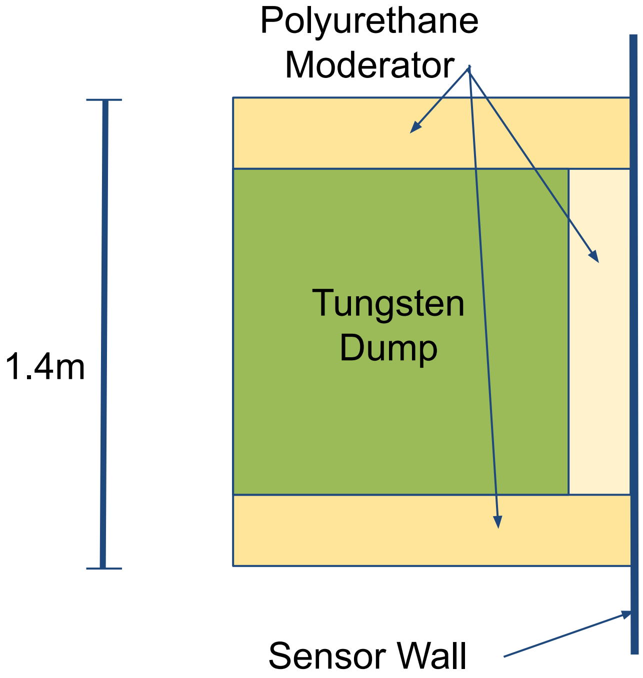
ΔTOA / Invariant Mass - No Cut





Distribution Halo



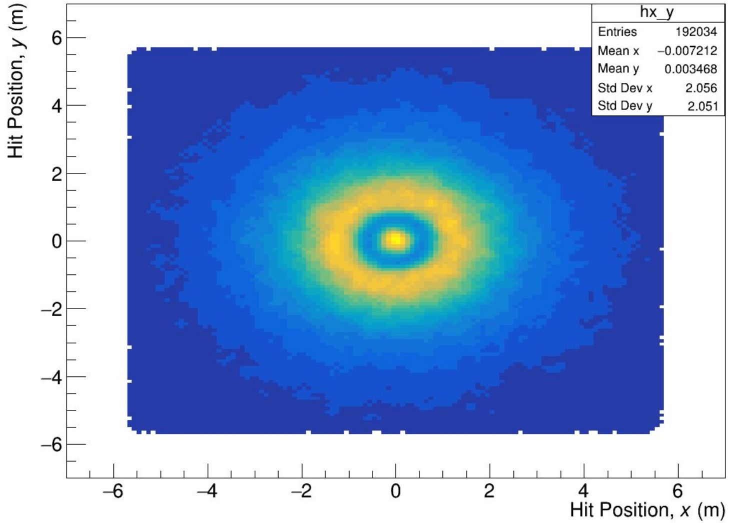


Table 1-1: PIP-II high level performance goals

Performance Parameter	PIP	PIP-II	Unit
Linac Beam Energy	400	800	MeV
Linac Beam Current	25	2	mA
Linac Pulse Length	0.03	0.55	ms
Linac Pulse Repetition Rate	15	20	Hz
Linac Upgrade Potential	N/A	CW	
Booster Protons per Pulse (extracted)	4.2	6.5	10^{12}
Booster Pulse Repetition Rate	15	20	Hz
Booster Beam Power @ 8 GeV	80	160	kW
8 GeV Beam Power to LBNF	N/A	80-120*	kW
Beam Power to 8 GeV Program	30	80-40*	kW
Main Injector Protons per Pulse (extracted)	4.9	7.6	10^{13}
Main Injector Cycle Time @ 120 GeV	1.33	1.2	sec
Main Injector Cycle Time @ 60 GeV	N/A	0.7	sec
Beam Power @ 60 GeV	N/A	1	MW
Beam Power @ 120 GeV	0.7♦	1.2♥	MW
Upgrade Potential @ 80-120 GeV	N/A	2.4	MW

* First number refers to Main Injector operations at 120 GeV; second number to 80 GeV.
♦ Applicable to 120 GeV operation only.
♥ Beam power grows approximately linear for energy change from 60 to 120 GeV.

- Benchmark Beam Parameters -

Beam energy (E_{beam}) : 600 MeV

Beam current (I_{beam}) : 660 μA

Beam power (P_{beam}) : 400 kW

Protons-on-target per year : 1.3×10^{23}

Description	Symbol	Numbers
Protons per pulse	n_p	4.8×10^7
Beam induced neutrons	n_n	1.29×10^5
Neutron-induced photons	n_γ	2.74×10^5
n_γ after 15 MeV threshold cut	$n_{\gamma,th}$	25.1
Neutron-induced photons hitting the detector	$n_{\gamma,th,det}$	2.94
< 40 ns arrival time cut	$n_{\gamma,th,det,TOA}$	1.47
Number of photon pair combinations	$n_{\gamma\gamma}$	< 1
Cut	**Symbol**	**Efficiency**
Fiducial volume cut	$\epsilon_{fid.vol.}$	6.13×10^{-1}
DCA < 1 cm	ϵ_{DCA}	4.23×10^{-3}
$\Delta TOA < 0.1$ ns	$\epsilon_{\Delta TOA}$	2.01×10^{-1}
Back-tracing	$\epsilon_{backtrace}$	4.16×10^{-2}
Invariant mass ($29MeV < m_{inv} < 31MeV$)	$\epsilon_{m_{inv}}$	2.52×10^{-2}
Invariant mass ($99MeV < m_{inv} < 101MeV$)	$\epsilon_{m_{inv}}$	1.25×10^{-3}
Invariant mass ($199MeV < m_{inv} < 201MeV$)	$\epsilon_{m_{inv}}$	2.02×10^{-5}

Proton / Pulse = 2mA x (1A/e3mA) x (C/As) x (Protons/1.602e-19 Coulomb) x 55ms/pulse x (1s/e3ms) = 6.87e14 Protons/Pulse

Unique Pairs = n(n-1) / 2

$$\Delta \mathrm{r} = \frac{\sqrt{r(1-\mathrm{r})}}{N}$$

$\Delta \mathrm{r} \equiv$ Binomial Error

$r \equiv Fraction\ o$

$1 - r \equiv$ Fractio

$\mathrm{N} \equiv$ Total numb