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Simulation and design of the low-energy LAMPS system at RAON

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Outline

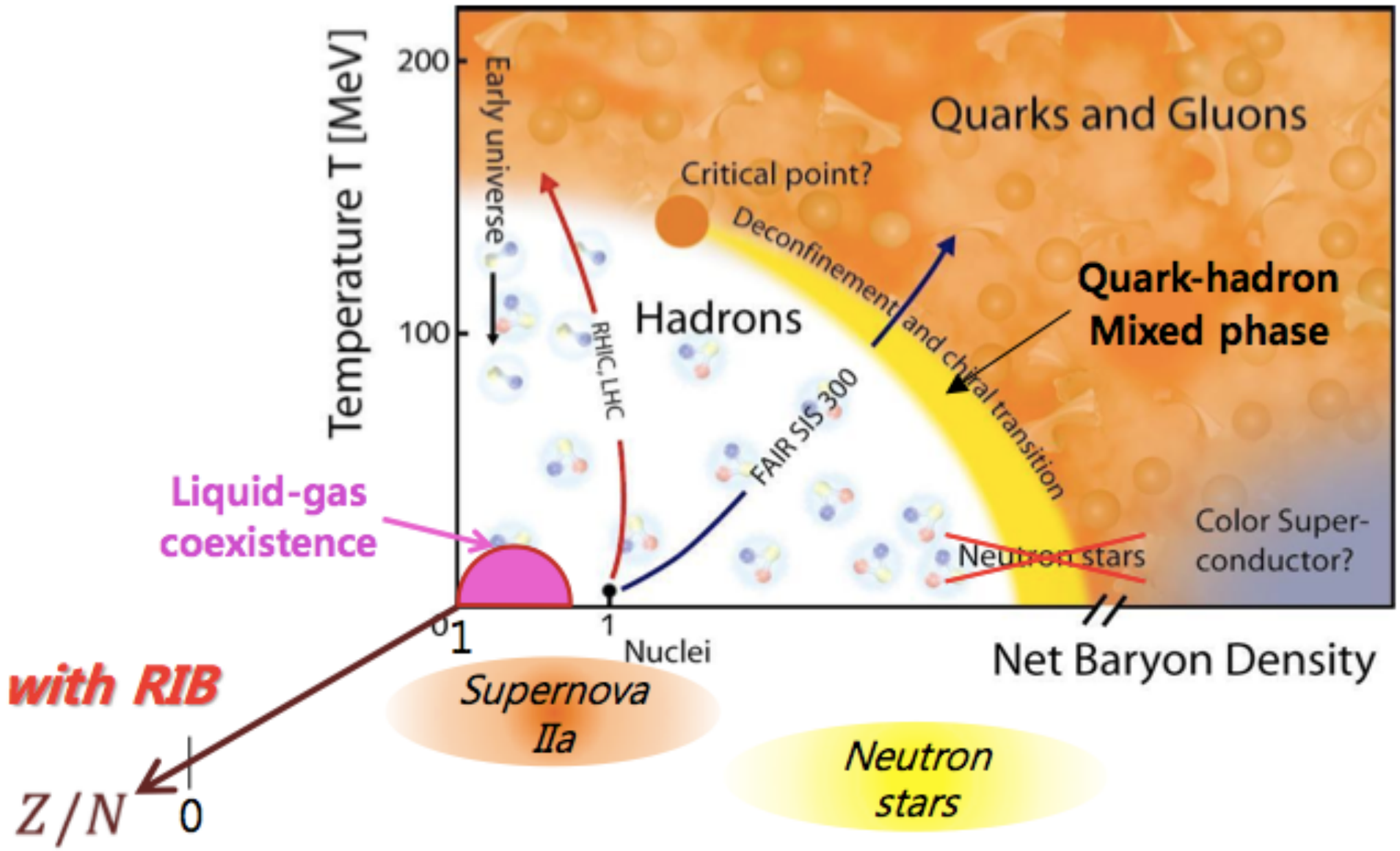
1. Introduction

2. RAON - LAMPS (low energy)

3. Design of LAMPS-L experimental setup

4. Simulation Results

Nuclear Phase Diagram



Equation of State (EoS) and Symmetry Energy

- Energy of nuclear matter

$$E(\rho,\delta)/A = E(\rho,\delta=0) + E_{sym}(\rho)\delta^2 + \mathcal{O}(\delta^4) + \cdots$$

where $\rho = \rho_n + \rho_p$ and $\delta = \frac{\rho_n - \rho_p}{\rho_n + \rho_p}$

- Useful expansion of $E_{sym}(\rho)$ around ρ_0

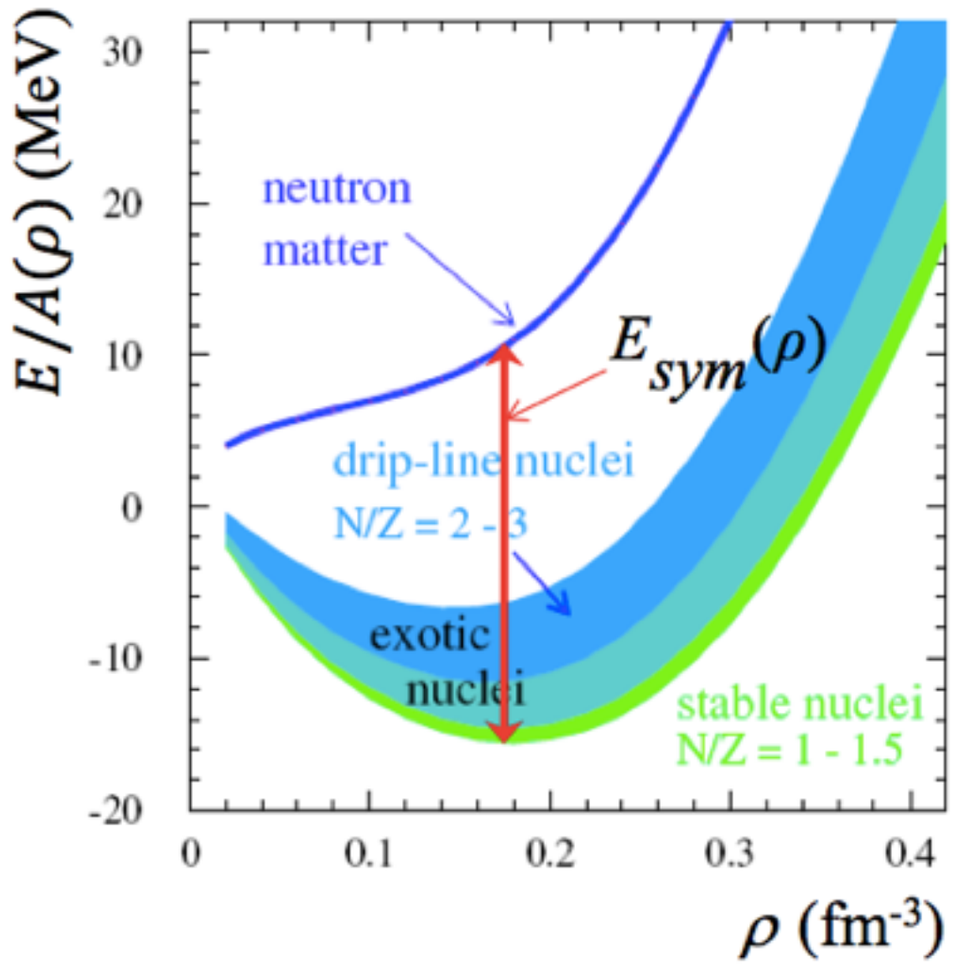
$$E_{sym}(\rho) = J + \frac{L}{3}\left(\frac{\rho-\rho_0}{\rho_0}\right) + \frac{K_{sym}}{18}\left(\frac{\rho-\rho_0}{\rho_0}\right)^2$$

where

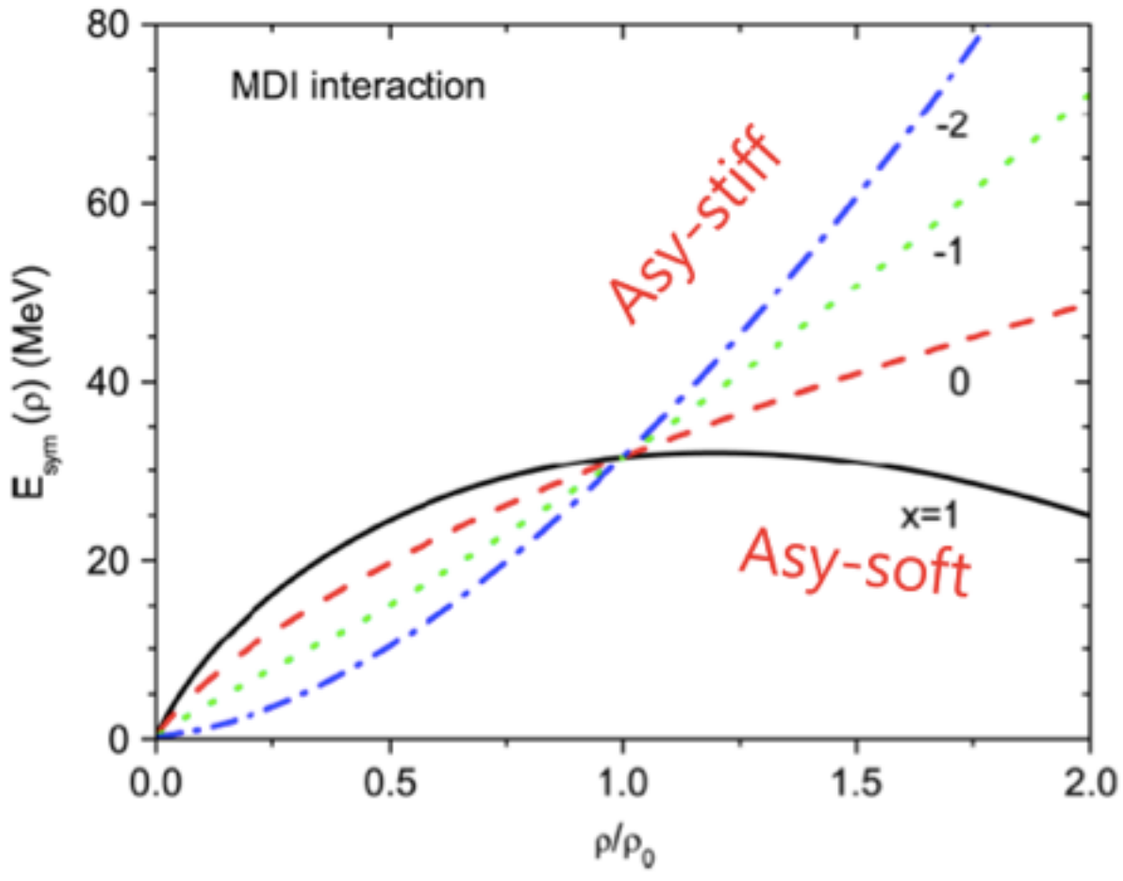
$$L = \frac{3}{\rho_0}P_{sym} = 3\rho_0 \left.\frac{\partial E_{sym}(\rho)}{\partial\rho}\right|_{\rho=\rho_0} \quad \text{(slope)}$$

$$K_{sym} = 9{\rho_0}^2 \left.\frac{\partial^2 E_{sym}(\rho)}{\partial\rho^2}\right|_{\rho=\rho_0} \quad \text{(curvature)}$$

Equation of State and Symmetry Energy

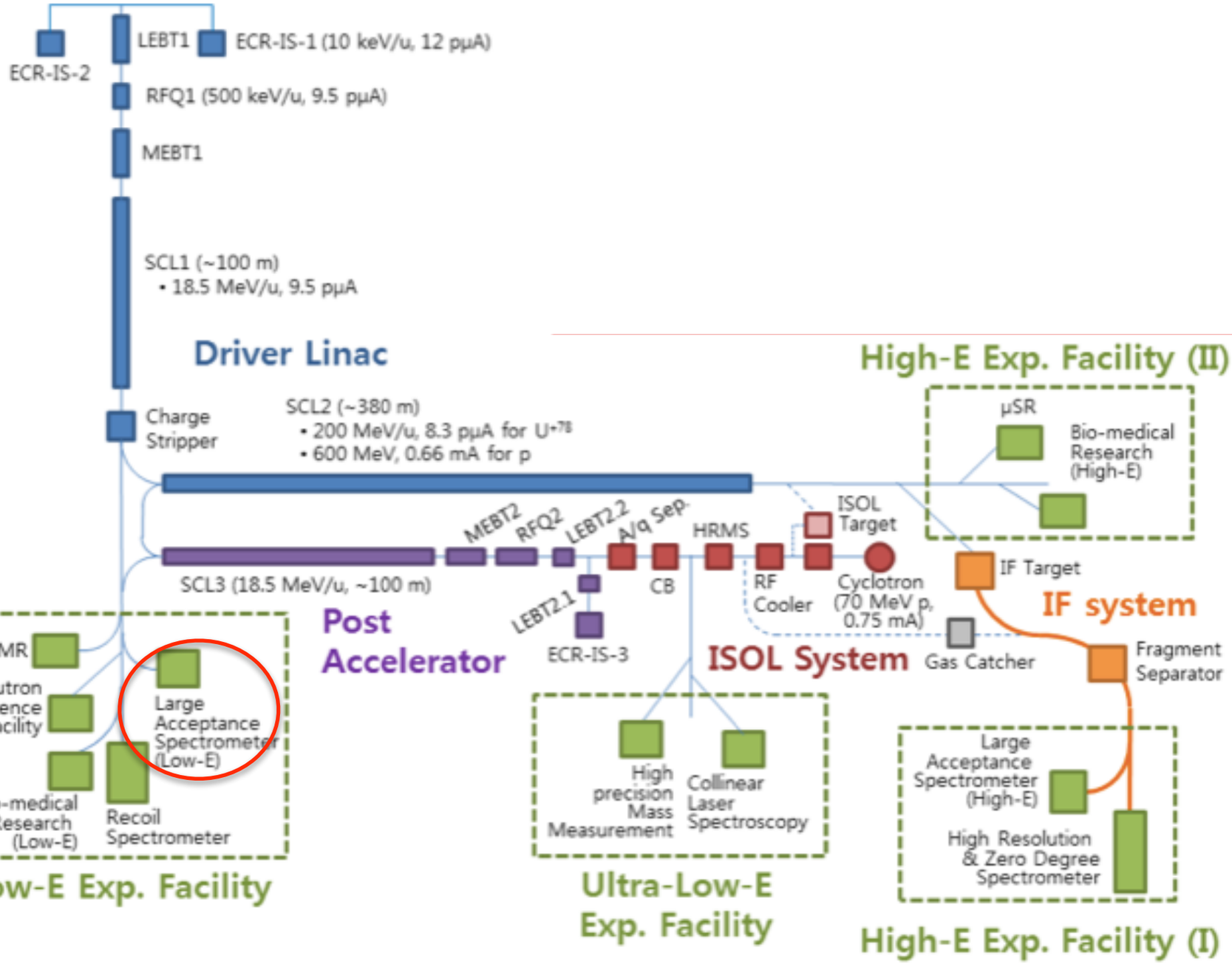


CDR, FAIR (2001)

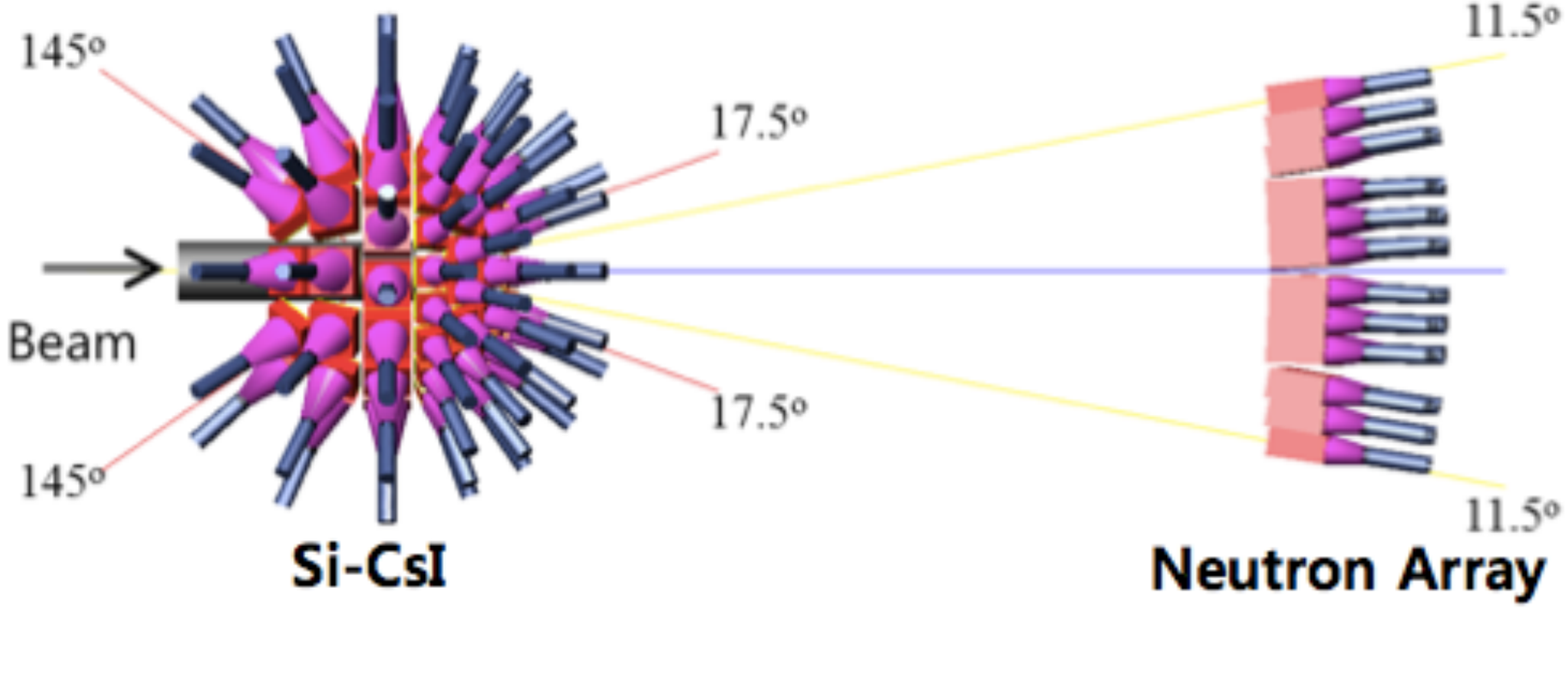


L.W. Chen, C.M. Ko, B.A. Li,
Phys. Rev. Lett. 94, 032701 (2005)

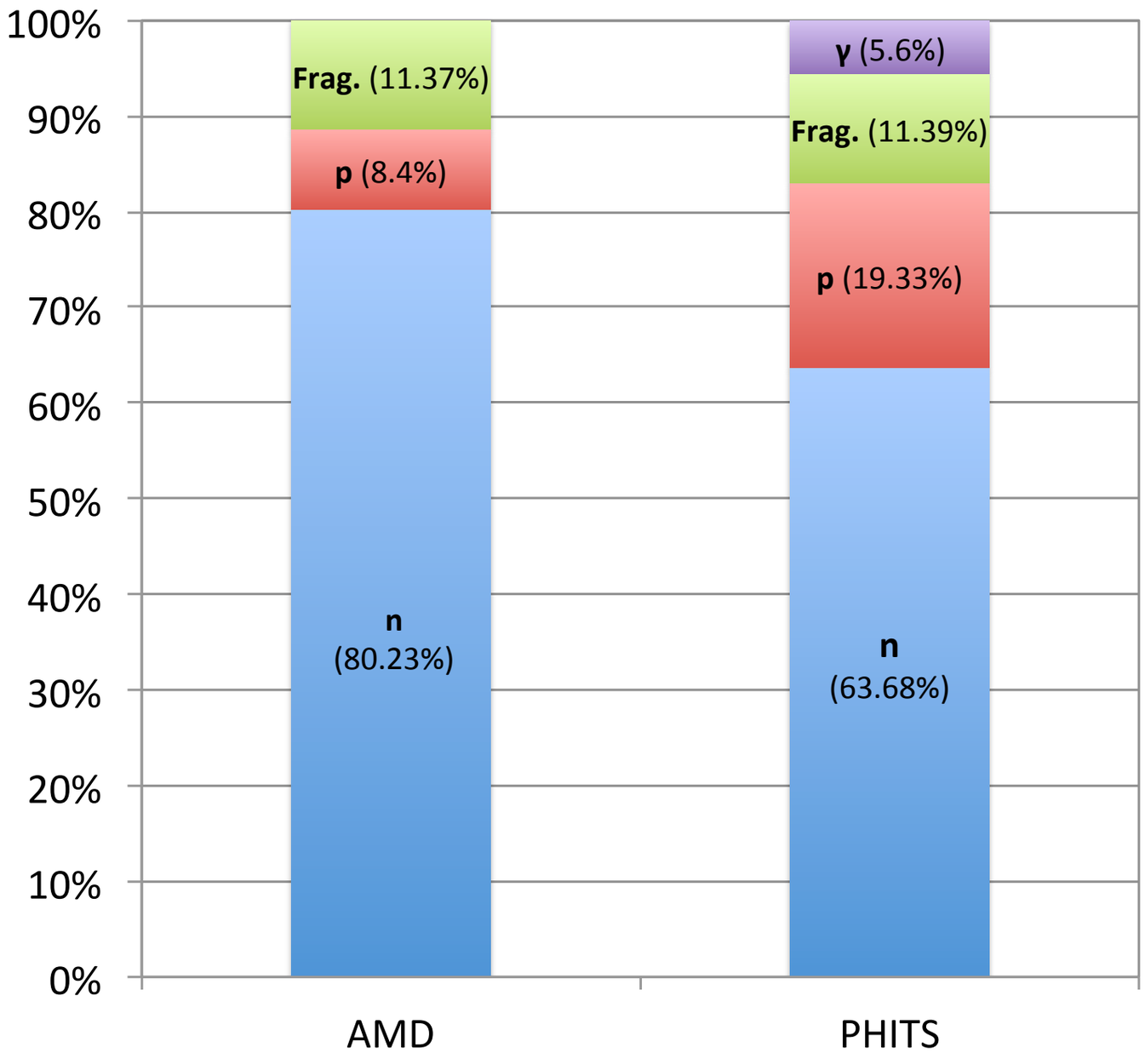
RAON : RISP Accelerator



Large Acceptance Multi-Purpose Spectrometer (LAMPS) - low energy



AMD & PHITS



AMD : $^{132}Sn + ^{124}Sn$ - (20 MeV/u)

PHITS : $^{132}Sn + ^{124}Sn$ - (18.5 MeV/u)

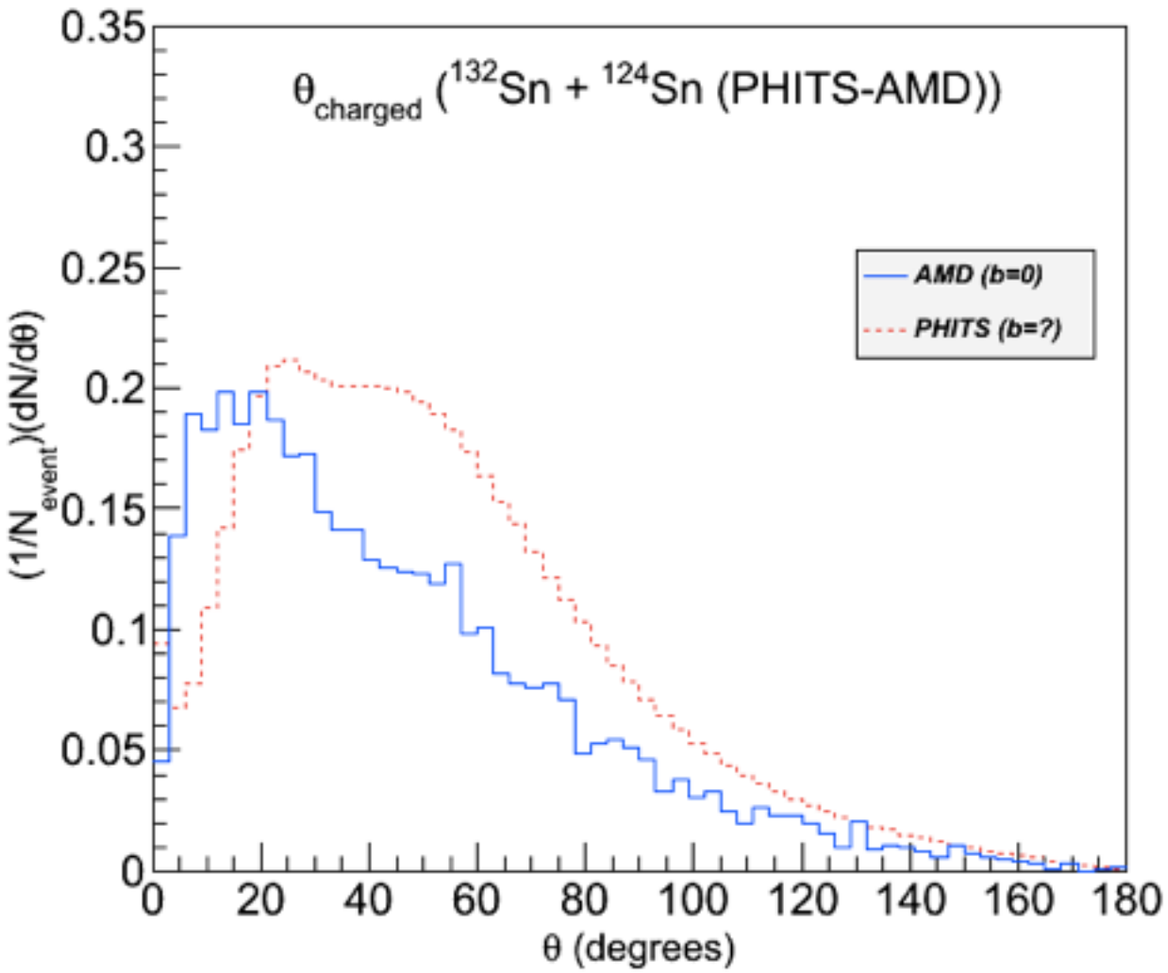
gamma

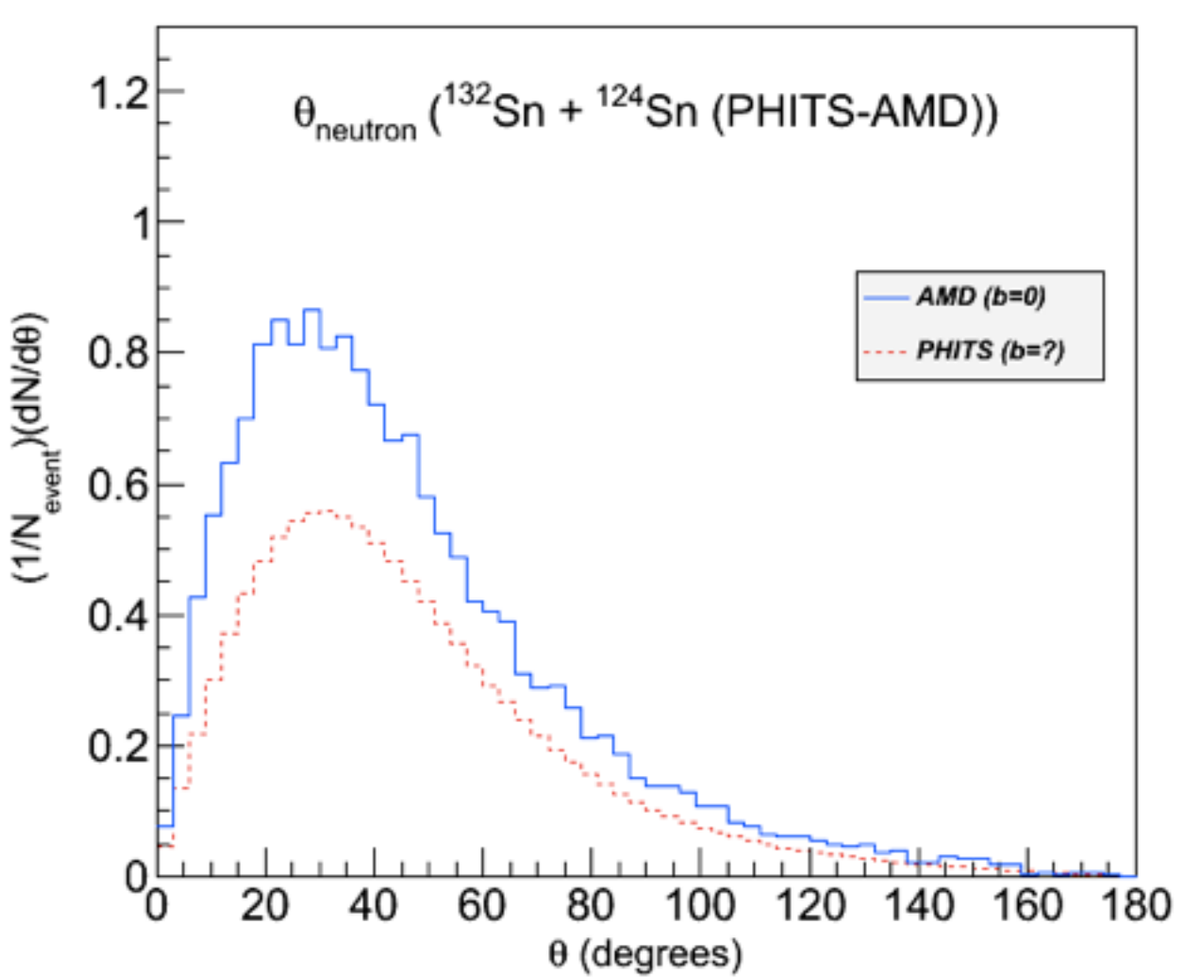
fragment

proton

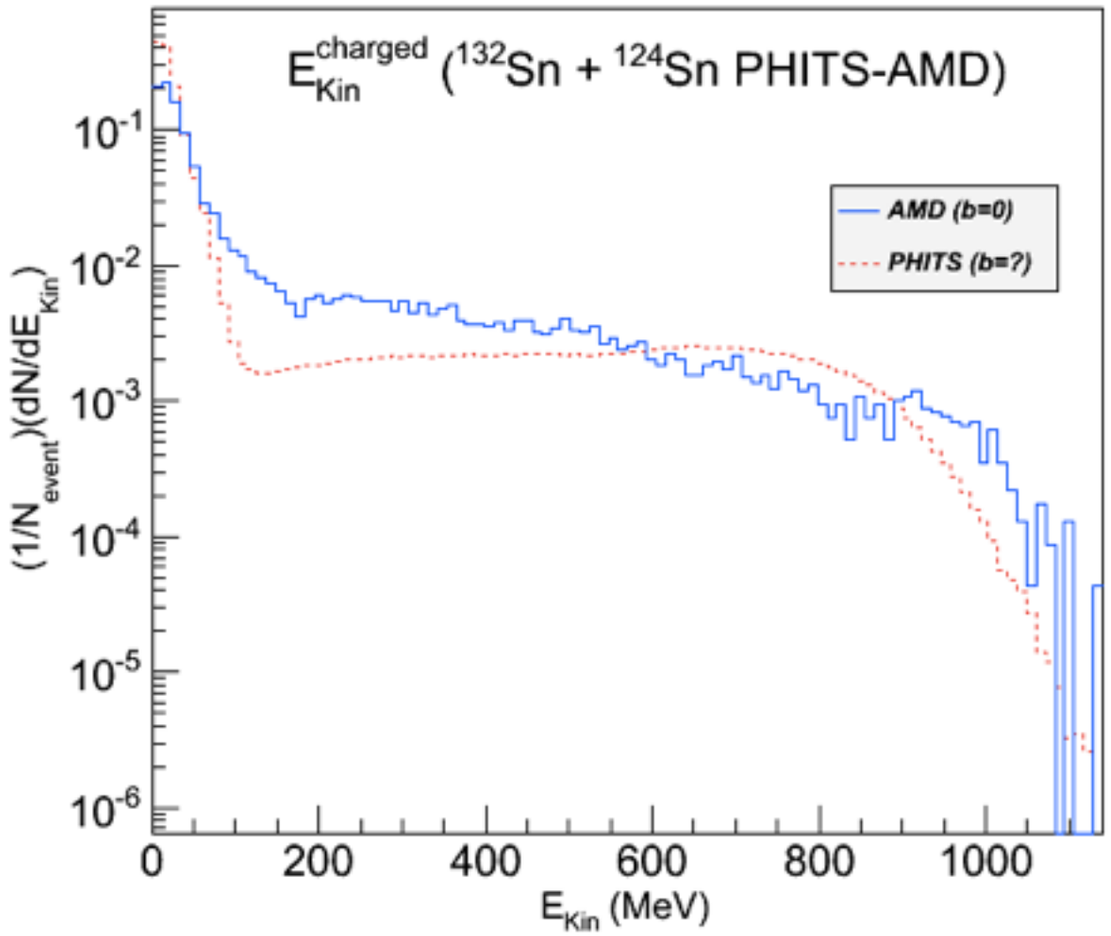
neutron

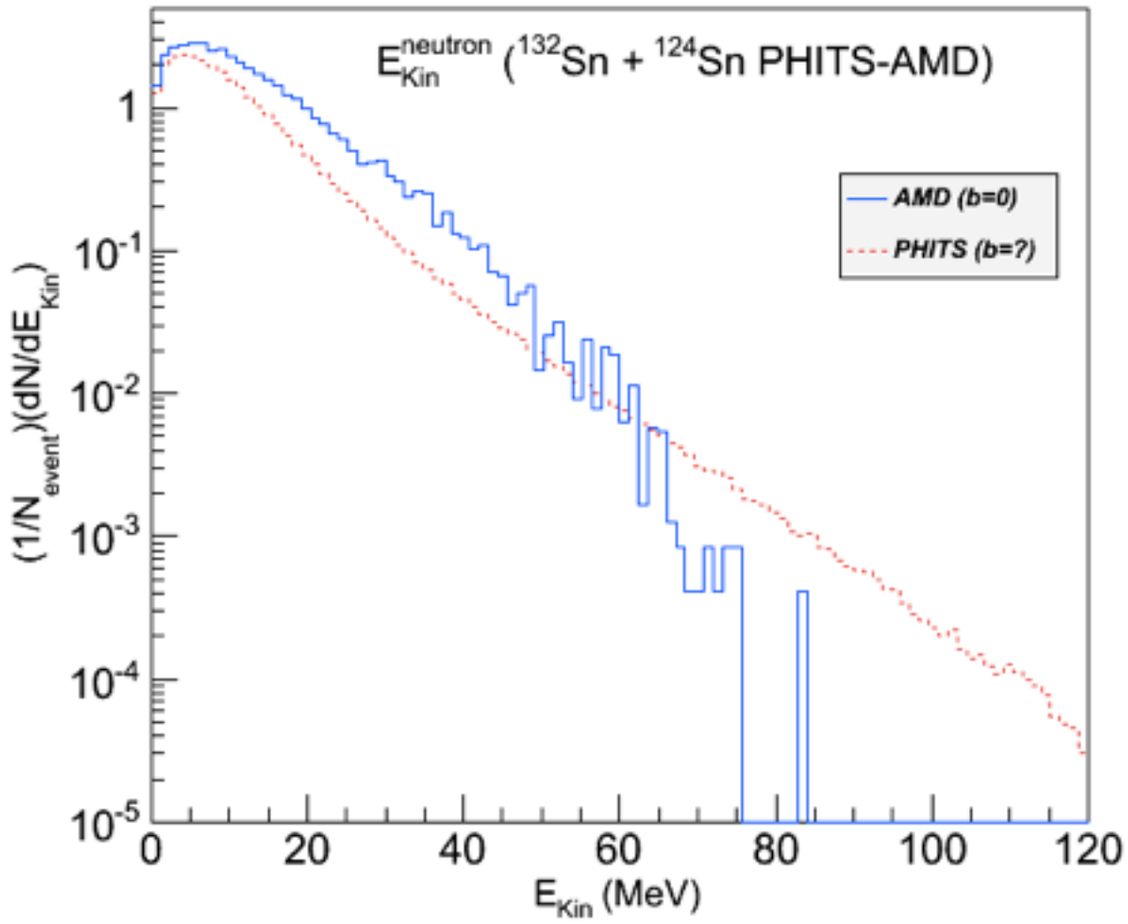
AMD&PHITS – Theta Distribution (Charged/Neutron)





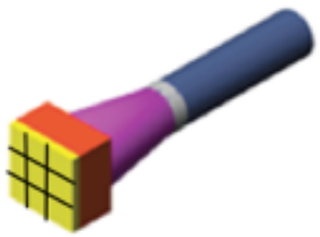
AMD&PHITS – Kinetic Energy (Charged/Neutron)

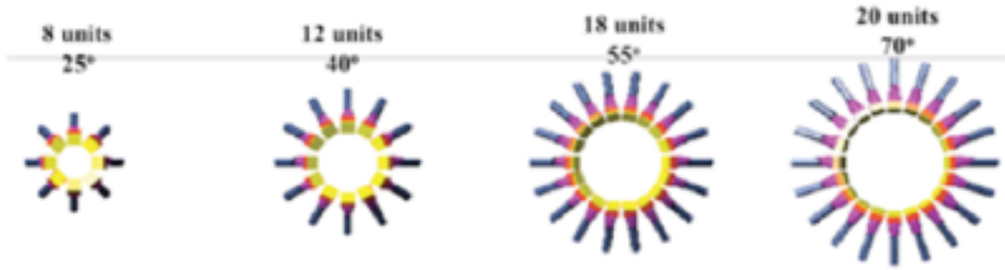




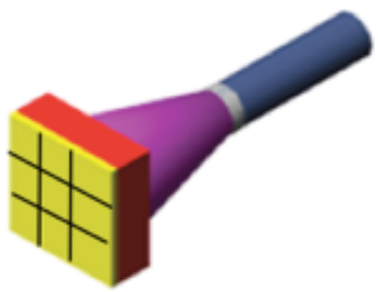
SiCsI Geometry

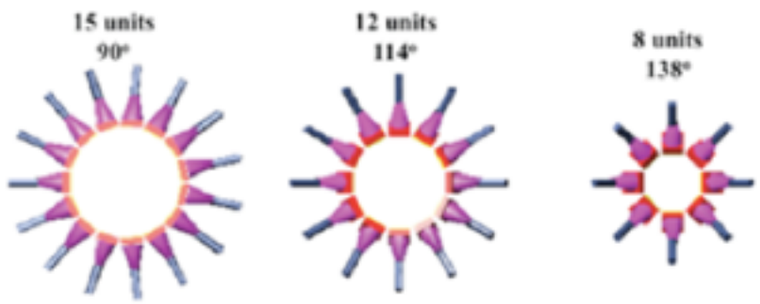
Total 58 detector units
($17.5^{o} < \theta_{lab} < 77.5^{o}$)
9 x 9 x 0.01 cm^3 Si (3 x 3 Pad)
9 x 9 x 5 cm^3 CsI (PMT readout)





Total 35 detector units
($78^{o} < \theta_{lab} < 150^{o}$)
15 x 15 x 0.01 cm^3 Si (3 x 3 Pad)
15 x 15 x 5 cm^3 CsI (PMT readout)

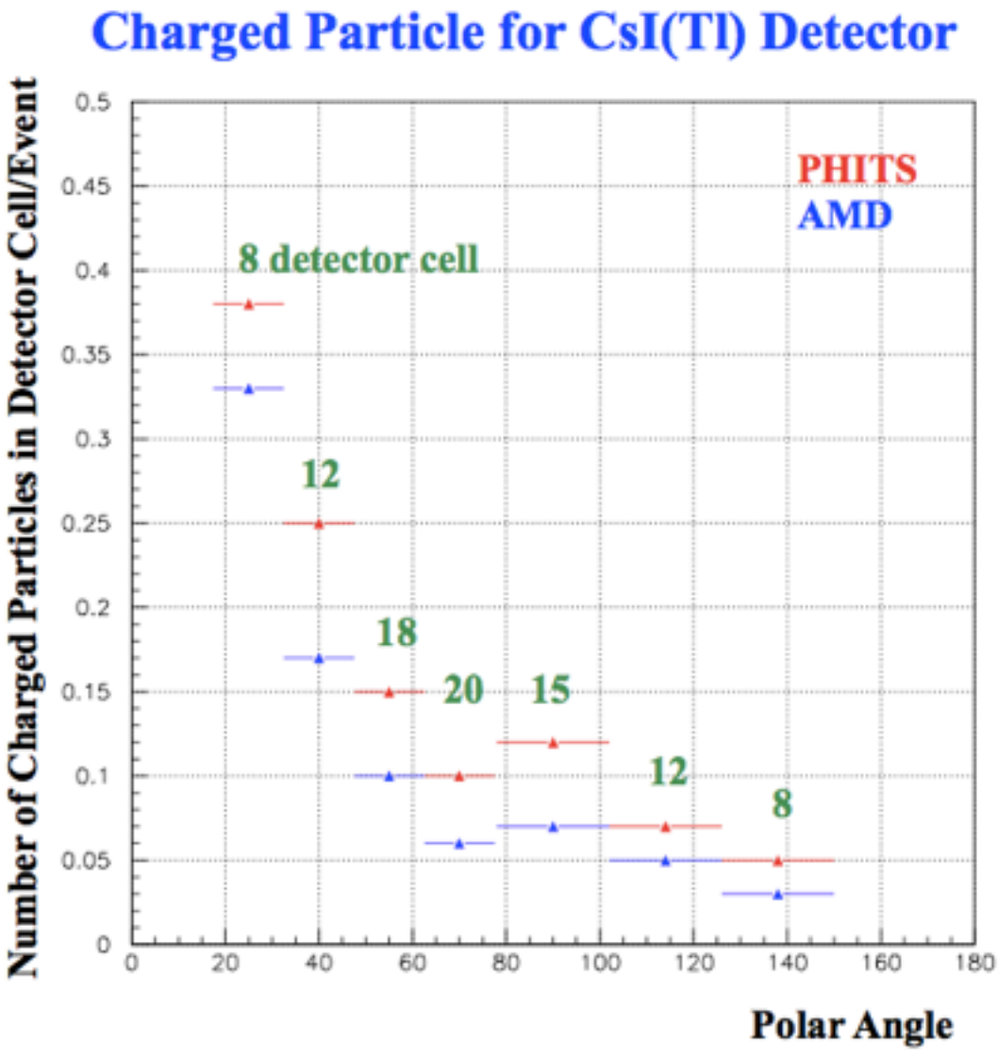


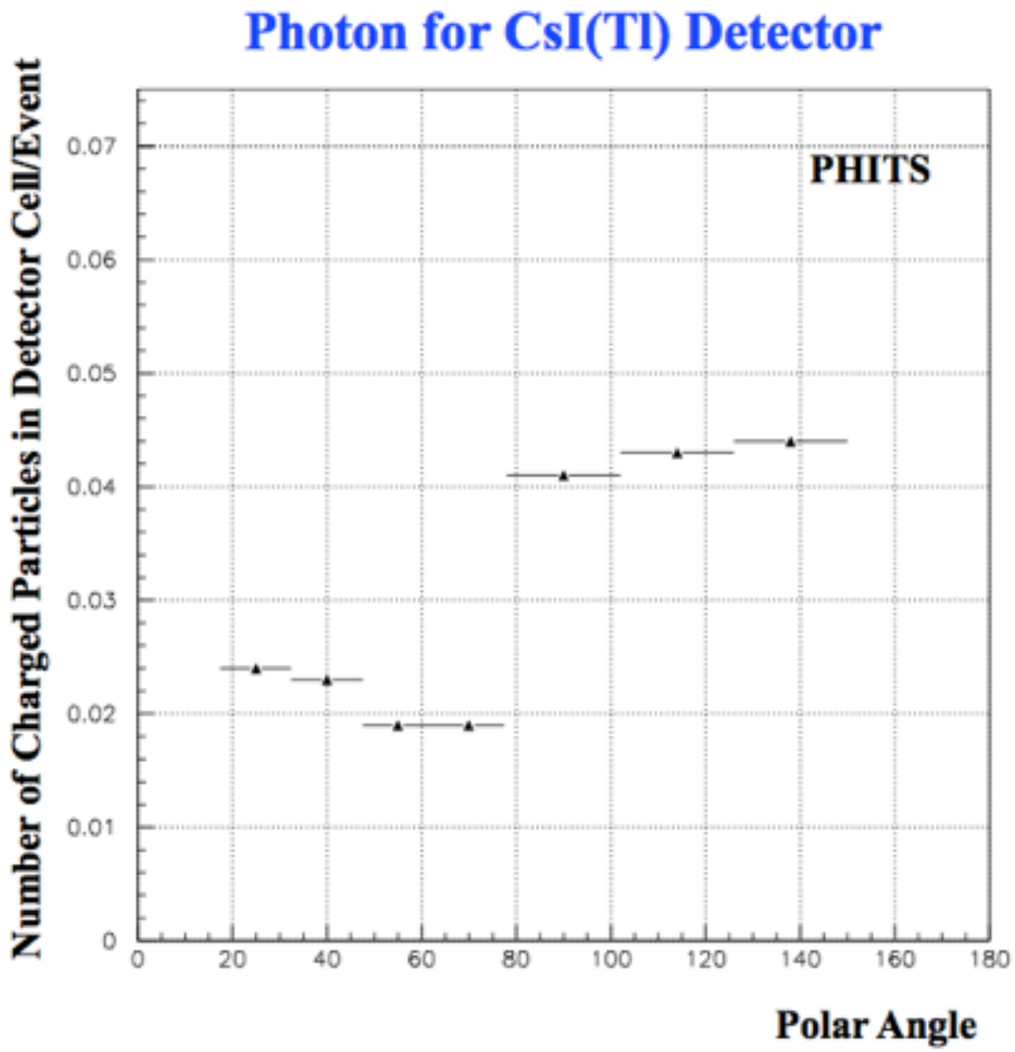


GEANT4 Simulation is going on

Si-CsI detector:
(ΔE-E technique for charged particle measurement as well as γ measurement)
- **Energy resolution from simulation study**
  - **Si: 0.5% of FWHM**
    (Energy resolution < 2% required for charged particle)
  - **CsI: 2.0% of FWHM**
    (Energy resolution < 5% required for max. 30 MeV γ-ray)

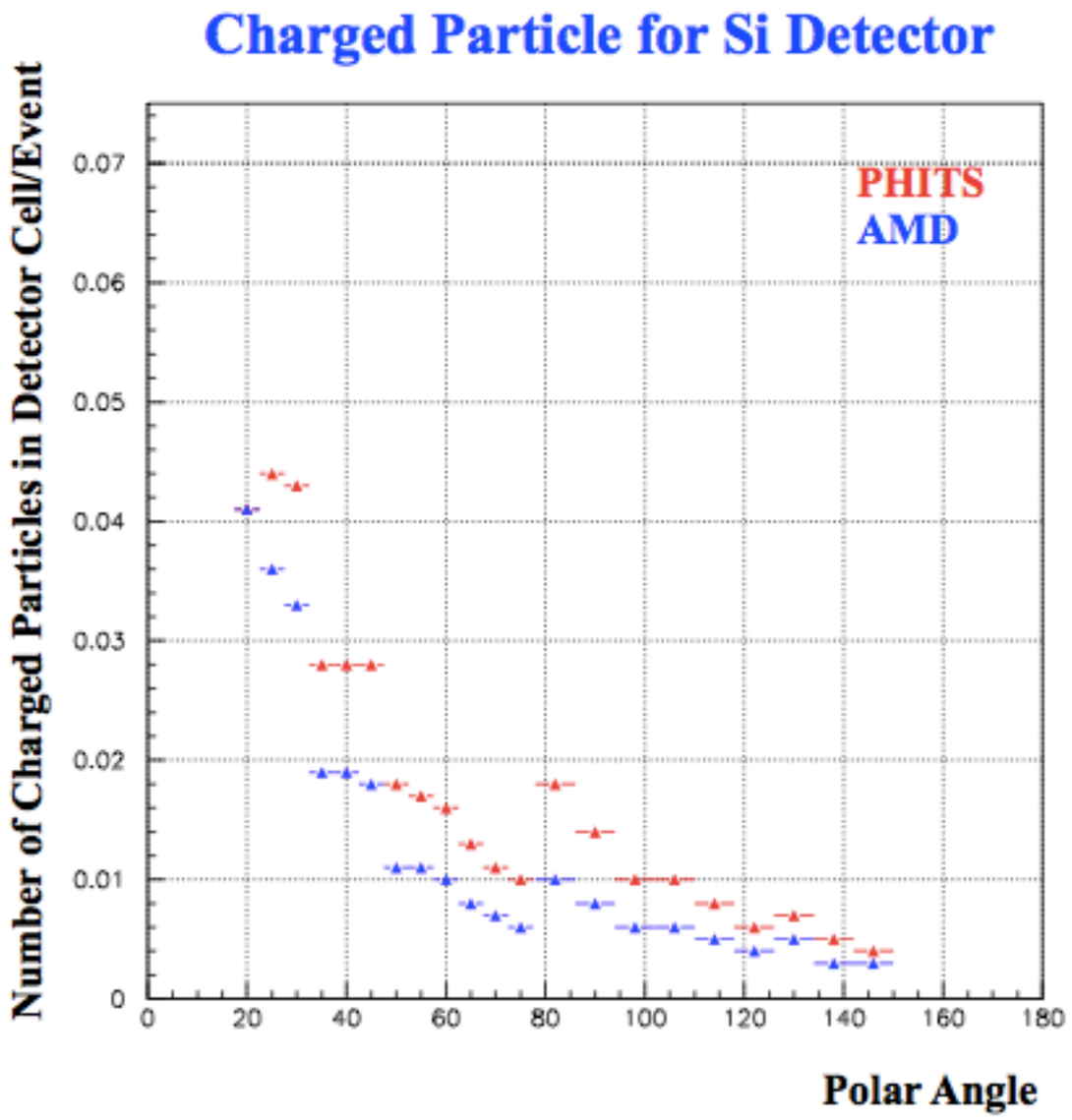
Design of SiCsI for LAMPS-L



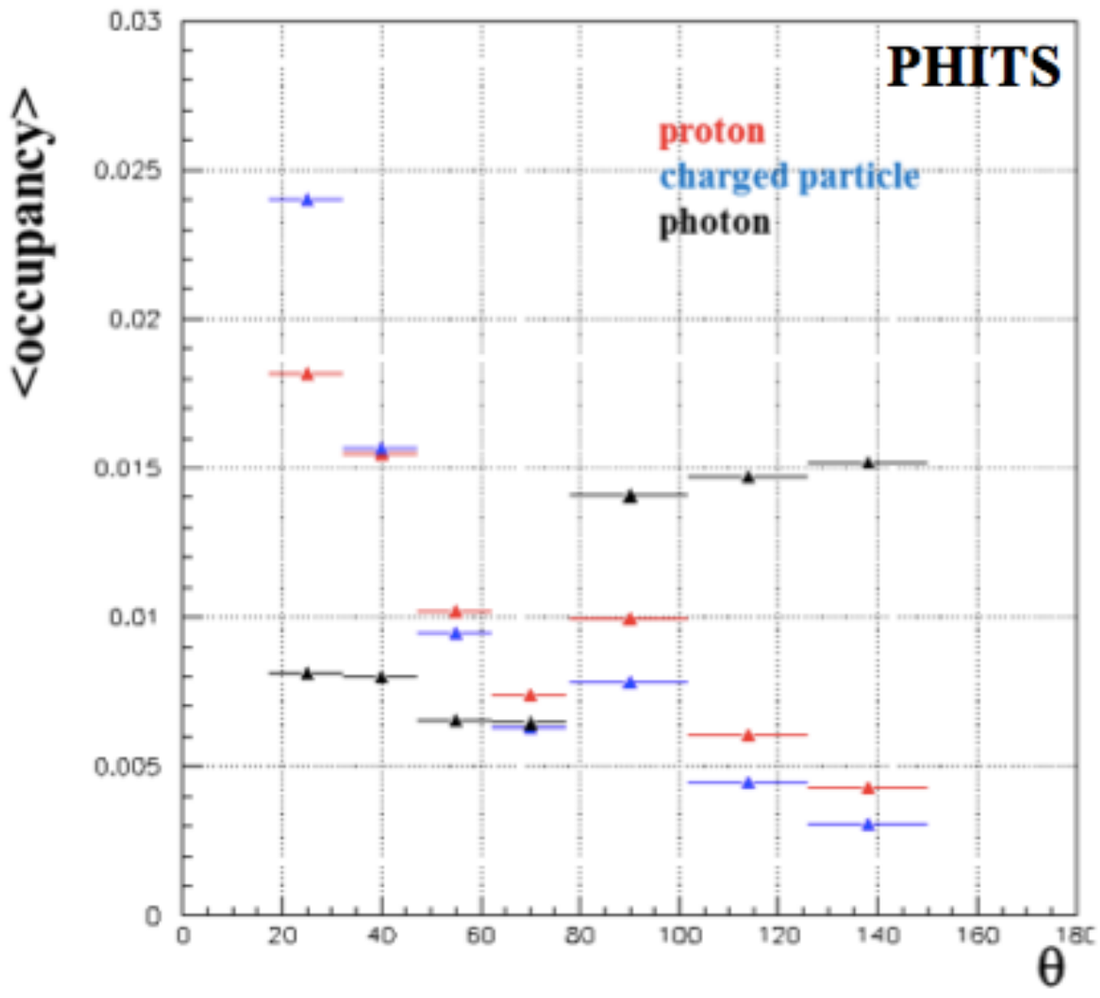


CsI(T1) cover polar angle 17.5° ~ 150°
17.5° ~ 77.5° : 4 detector pieces 15° interval
78° ~ 150° : 3 detector pieces 15° interval

Design of SiCsI for LAMPS-L

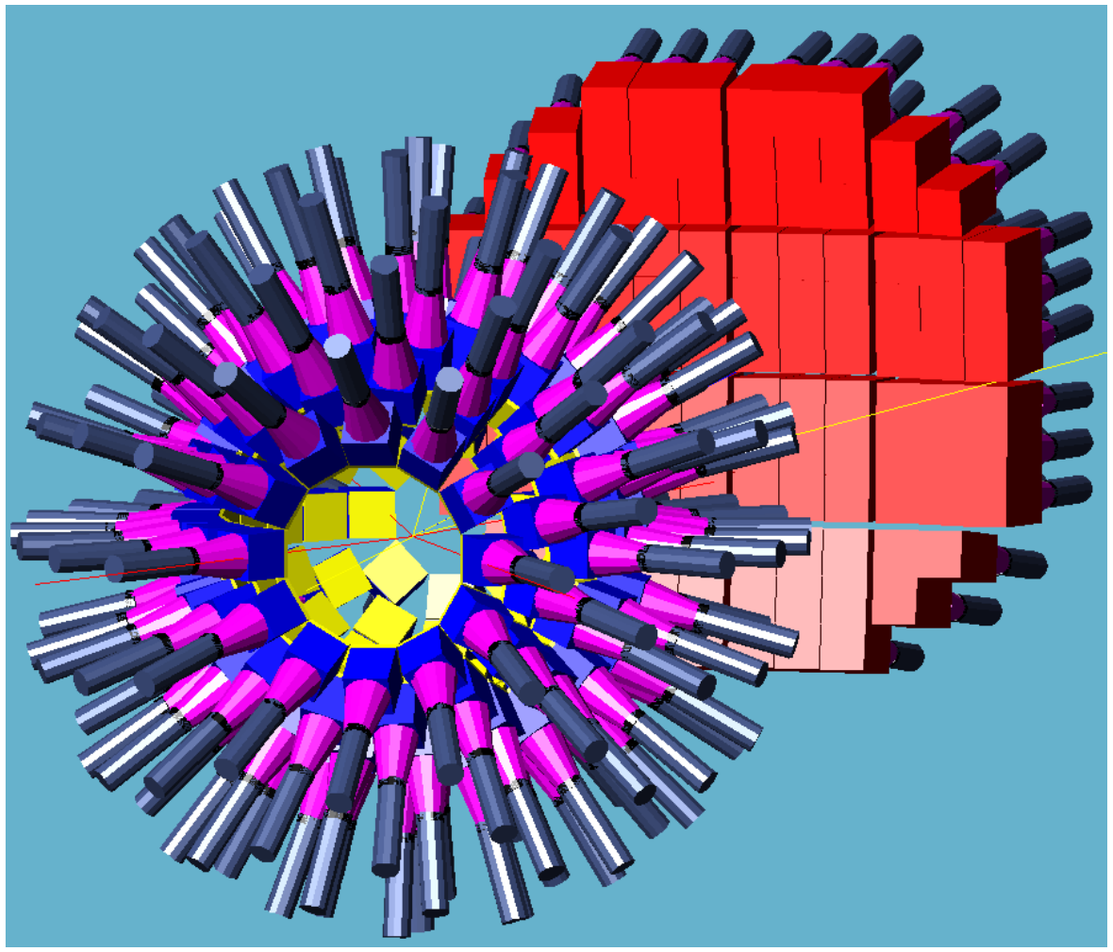


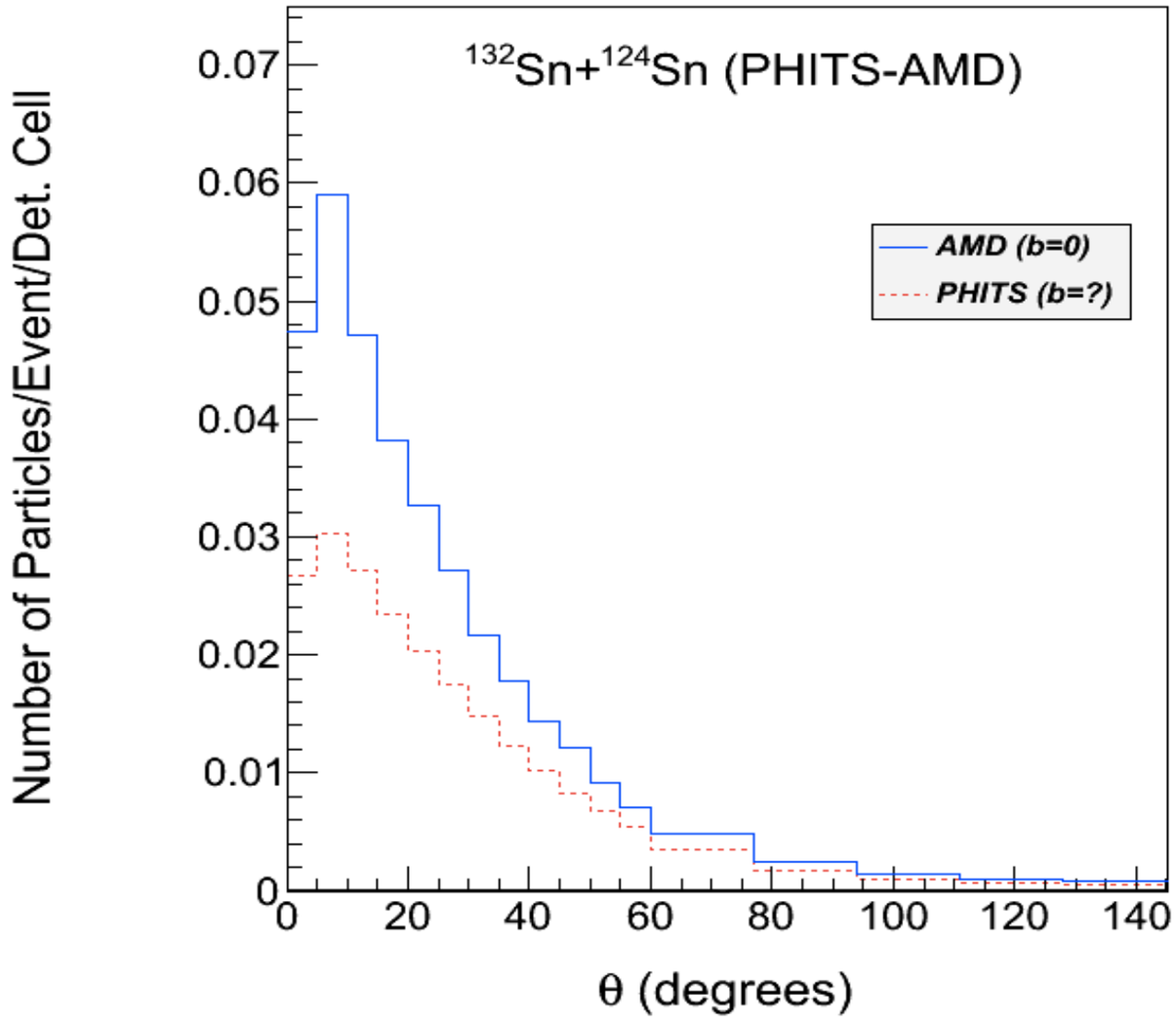
Divided unit CsI(Tl) polar angle coverage into 3



Si-CsI detector unit coverage of polar angle tuned to be <occupancy> < 0.1

Design of Neutron detector for LAMPS-L

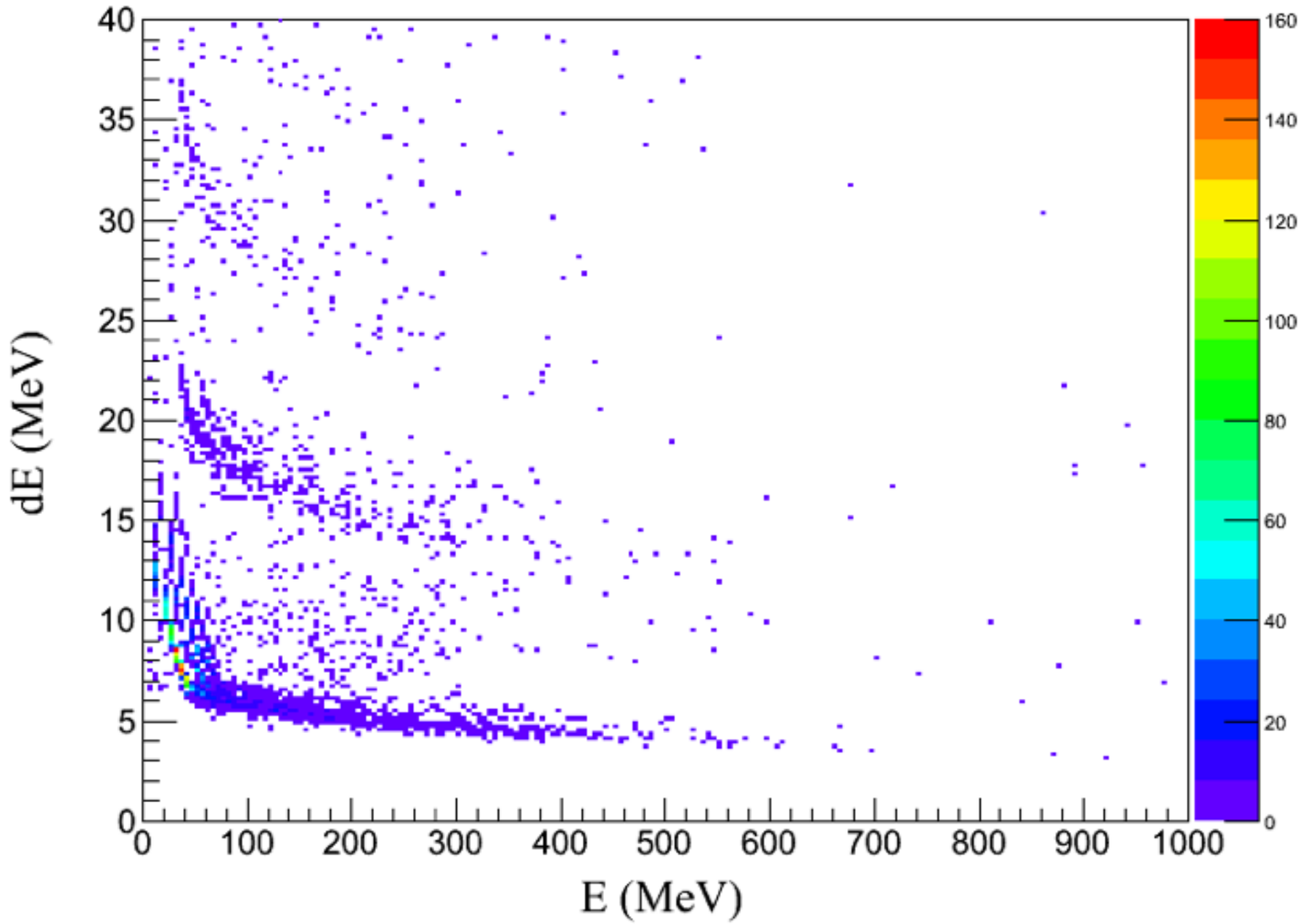


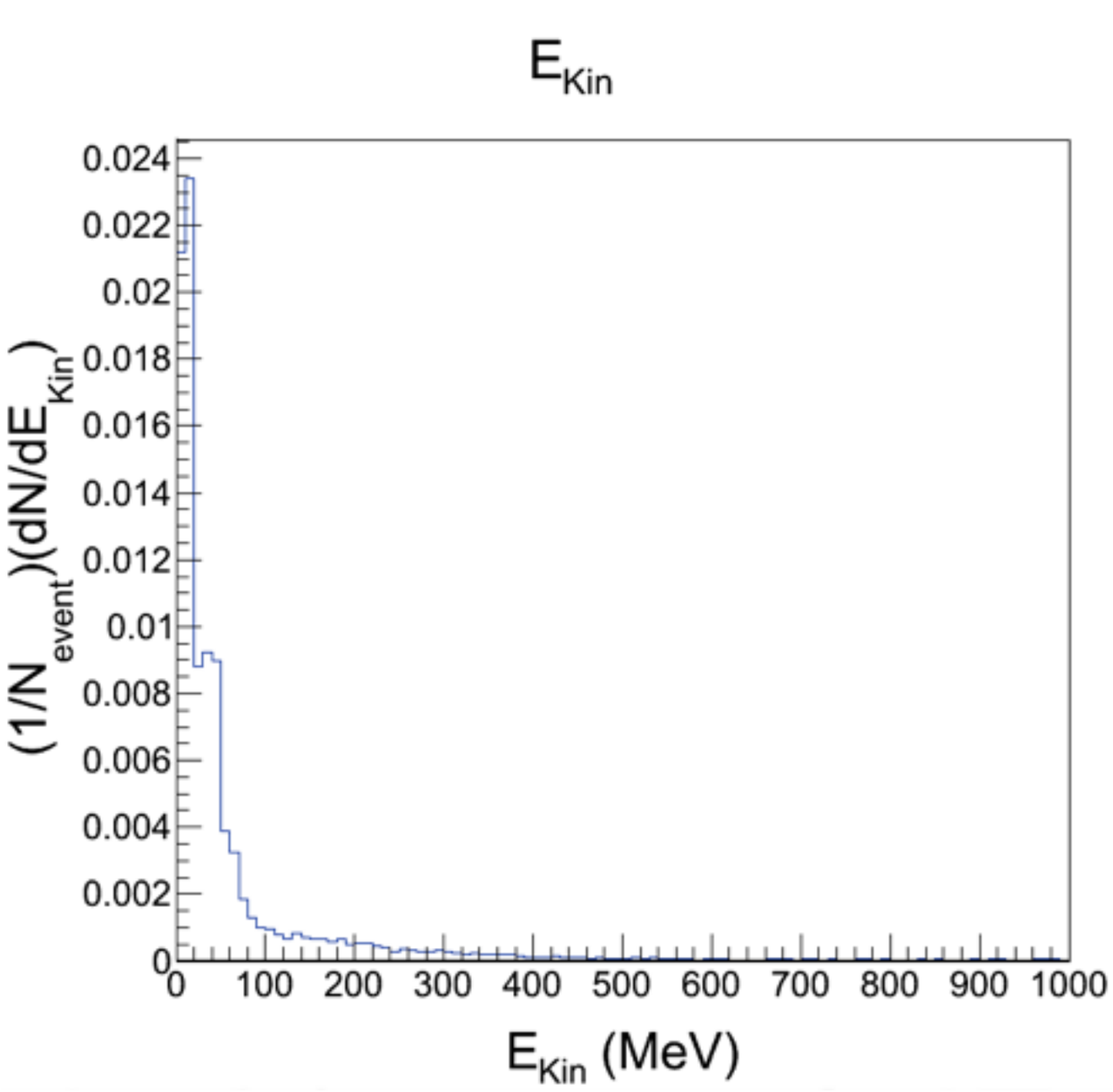


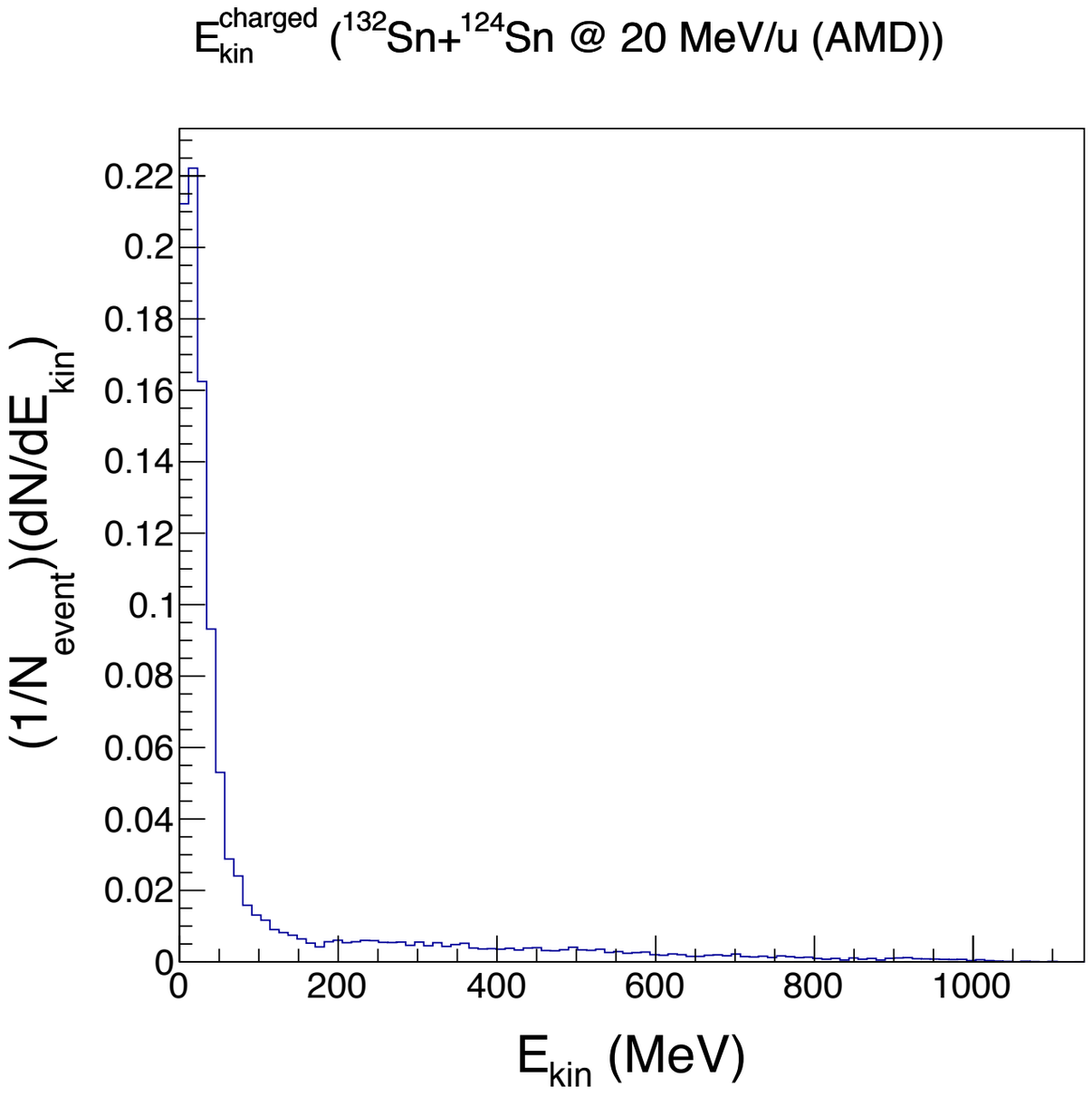
Detector Size : 10x10 cm^2 (1Detector)

Back - up

Design of SiCsI for LAMPS-L




E_{Kin}
$(1/N_{event})(dN/dE_{Kin})$
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0 100 200 300 400 500 600 700 800 900 1000
E_{Kin} (MeV)


$E_{kin}^{charged}$ (^{132}Sn+^{124}Sn @ 20 MeV/u (AMD))
$(1/N_{event})(dN/dE_{kin})$
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 200 400 600 800 1000
E_{kin} (MeV)

: PHITS, **Photons**

$< N_{photon} > = N_{Det} \times R$ (for **CsI Detector)**

S : Area of one detector (**X=√S**), **r= 40cm** (Distance from target),

N(△θ) : Number of particles per event, **N_Det** : Number of detectors.

Bin	N(△θ)	N_Det	S(cm^2)	X(cm)	R
1 : (17.5°<θ<32.5°)	0.19	8	81.0	9.0	0.024
2 : (32.5°<θ<47.5°)	0.28	12	81.0	9.0	0.023
3 : (47.5°<θ<62.5°)	0.34	18	81.0	9.0	0.019
4 : (62.5°<θ<77.5°)	0.38	20	81.0	9.0	0.019
5 : (77.5°<θ<102°)	0.61	15	225.0	15.0	0.041
6 : (102°<θ<126°)	0.51	12	225.0	15.0	0.043
7 : (126°<θ<150°)	0.35	8	225.0	15.0	0.044
Sum	2.66	93			

: PHITS : AMD, **Charged Particles**

$< N_{charged} > = N_{Det} \times R$ (for **Si Detector**)

S : Area of one detector (**X=√S**), **r= 40cm** (Distance from target),

N(△θ) : Number of particles per event, **N_Det** : Number of detectors.

Bin	N(△θ)	N_Det	S(cm^2)	X(cm)	R	N(△θ)	N_Det	S(cm^2)	X(cm)	R
1 : (17.5°<θ<22.5°)	0.99	24	9.0	3.0	0.041	0.99	24	9.0	3.0	0.041
2 : (22.5°<θ<27.5°)	1.05	24	9.0	3.0	0.044	0.87	24	9.0	3.0	0.036
3 : (27.5°<θ<32.5°)	1.02	24	9.0	3.0	0.043	0.81	24	9.0	3.0	0.033
4 : (32.5°<θ<37.5°)	1.00	36	9.0	3.0	0.028	0.68	36	9.0	3.0	0.019
5 : (37.5°<θ<42.5°)	1.00	36	9.0	3.0	0.028	0.68	36	9.0	3.0	0.019
6 : (42.5°<θ<47.5°)	1.00	36	9.0	3.0	0.028	0.63	36	9.0	3.0	0.018
7 : (47.5°<θ<52.5°)	0.97	54	9.0	3.0	0.018	0.62	54	9.0	3.0	0.011
8 : (52.5°<θ<57.5°)	0.92	54	9.0	3.0	0.017	0.59	54	9.0	3.0	0.011
9 : (57.5°<θ<62.5°)	0.84	54	9.0	3.0	0.016	0.49	54	9.0	3.0	0.010
10 : (62.5°<θ<67.5°)	0.76	60	9.0	3.0	0.013	0.42	60	9.0	3.0	0.008
11 : (67.5°<θ<72.5°)	0.68	60	9.0	3.0	0.011	0.39	60	9.0	3.0	0.007
12 : (72.5°<θ<77.5°)	0.58	60	9.0	3.0	0.010	0.36	60	9.0	3.0	0.006
13 : (77.5°<θ<86°)	0.82	45	25.0	5.0	0.018	0.45	45	225.0	15.0	0.010
14 : (86°<θ<94°)	0.60	45	25.0	5.0	0.014	0.38	45	225.0	15.0	0.008
15 : (94°<θ<102°)	0.46	45	25.0	5.0	0.010	0.27	45	225.0	15.0	0.006
16 : (102°<θ<110°)	0.36	36	25.0	5.0	0.010	0.21	36	225.0	15.0	0.006
17 : (110°<θ<118°)	0.28	36	25.0	5.0	0.008	0.18	36	225.0	15.0	0.005
18 : (118°<θ<126°)	0.22	36	25.0	5.0	0.006	0.16	36	225.0	15.0	0.004
19 : (126°<θ<134°)	0.17	24	25.0	5.0	0.007	0.11	24	225.0	15.0	0.005
20 : (134°<θ<142°)	0.13	24	25.0	5.0	0.005	0.08	24	225.0	15.0	0.003
21 : (142°<θ<150°)	0.10	24	25.0	5.0	0.004	0.06	24	225.0	15.0	0.003
Sum	13.95	837				9.43	837			

: PHITS : AMD, **Neutron**

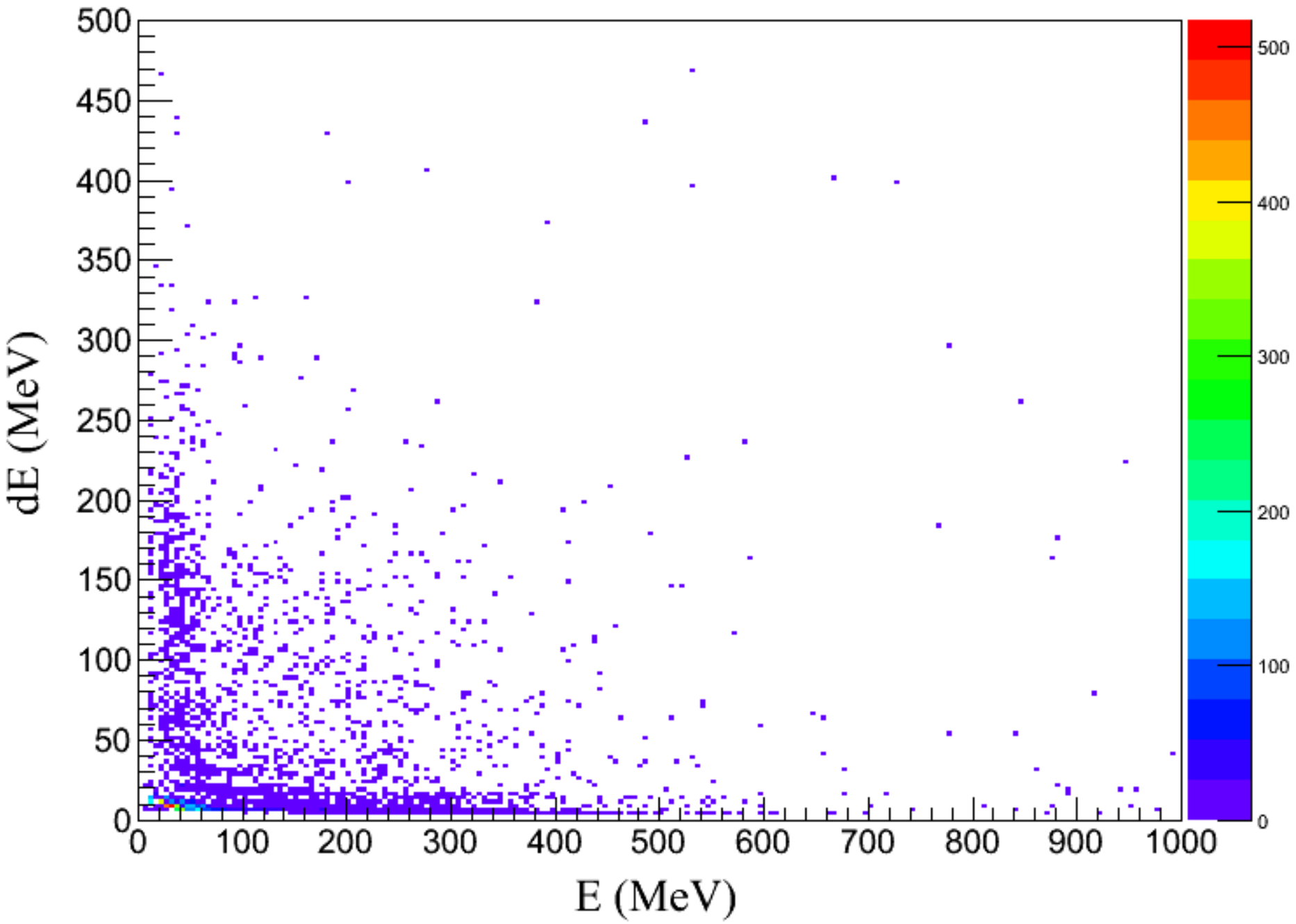
$< N_{neutron} > = N_{Det} \times R$ (for **Neutron Detector**)

S : Area of one detector (**X=√S**), **r= 300cm** (Distance from target),

N(△θ) : Number of particles per event, **N_Det** : Number of detectors.

Bin	N(△θ)	N_Det	S(cm^2)	X(cm)	R	N(△θ)	N_Det	S(cm^2)	X(cm)	R
1 : (0°<θ<5°)	0.37	14	100.0	10.0	0.026	0.66	14	100.0	10.0	0.047
2 : (5°<θ<10°)	1.09	36	100.0	10.0	0.030	2.13	36	100.0	10.0	0.059
3 : (10°<θ<15°)	1.74	64	100.0	10.0	0.027	3.01	64	100.0	10.0	0.047
4 : (15°<θ<20°)	2.25	96	100.0	10.0	0.023	3.66	96	100.0	10.0	0.038
5 : (20°<θ<25°)	2.59	128	100.0	10.0	0.020	4.18	128	100.0	10.0	0.033
6 : (25°<θ<30°)	2.76	158	100.0	10.0	0.017	4.28	158	100.0	10.0	0.027
7 : (30°<θ<35°)	2.78	188	100.0	10.0	0.015	4.07	188	100.0	10.0	0.022
8 : (35°<θ<40°)	2.66	216	100.0	10.0	0.012	3.85	216	100.0	10.0	0.018
9 : (40°<θ<45°)	2.46	242	100.0	10.0	0.010	3.47	242	100.0	10.0	0.014
10 : (45°<θ<50°)	2.21	266	100.0	10.0	0.008	3.24	266	100.0	10.0	0.012
11 : (50°<θ<55°)	1.93	288	100.0	10.0	0.007	2.63	288	100.0	10.0	0.009
12 : (55°<θ<60°)	1.67	308	100.0	10.0	0.005	2.20	308	100.0	10.0	0.007
13 : (60°<θ<77°)	3.97	1141	100.0	10.0	0.003	5.57	1141	100.0	10.0	0.005
14 : (77°<θ<94°)	2.16	1281	100.0	10.0	0.001	3.11	1281	100.0	10.0	0.002
15 : (94°<θ<111°)	1.18	1225	100.0	10.0	0.001	1.77	1225	100.0	10.0	0.001
16 : (111°<θ<128°)	0.66	1036	100.0	10.0	0.0006	0.96	1036	100.0	10.0	0.0009
17 : (128°<θ<145°)	0.37	756	100.0	10.0	0.0005	0.58	756	100.0	10.0	0.0007
Sum	32.85	7443				49.37	7443			

Design of SiCsI for LAMPS-L



$^{132}Sn+^{124}Sn$ - AMD&PHITS

	AMD	PHITS
Number of Events	N(event) = 2010	N(event) = 272018
Number of particles (per event)	<N> = 62.047	<N>=52.040
Number of Neutrons (per event)	< neutron> = 49.783 (80.23%)	< neutron>=33.138 (63.68%)
Number of Charged Particles (per event)	< charged>= 12.265 (19.77%)	< charged>=15.986 (30.72%)
Number of Protons (per event)	< proton> = 5.213 (8.40%)	< proton>=10.059 (19.33%)
Number of Gammas	no gammas	<gammas>=2.916 (5.60%)