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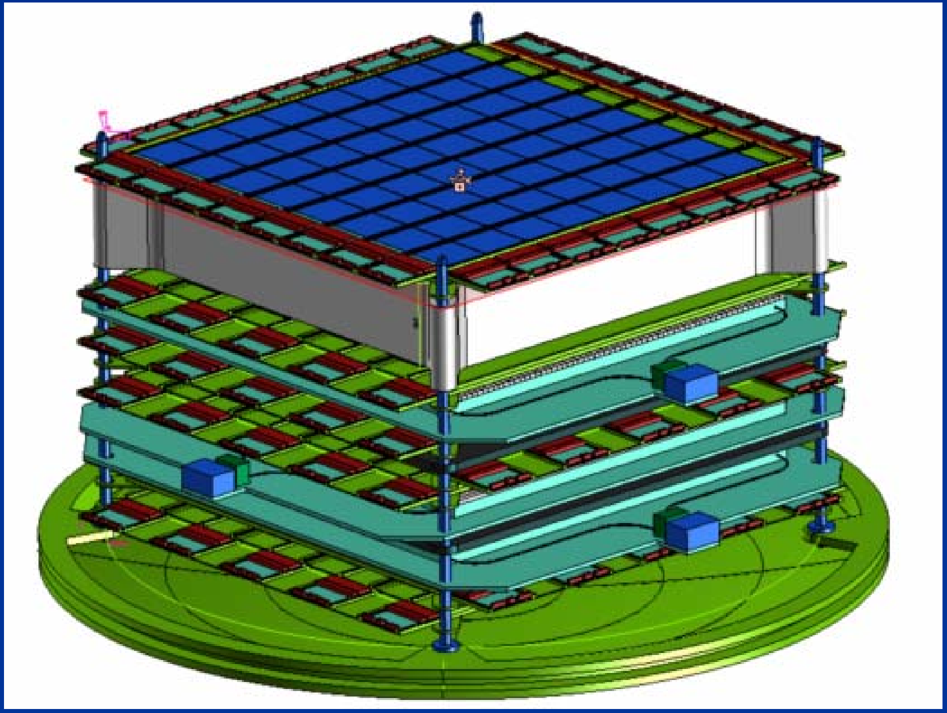
CR spectrum measurement in the knee region with NUCLEON Space Experiment

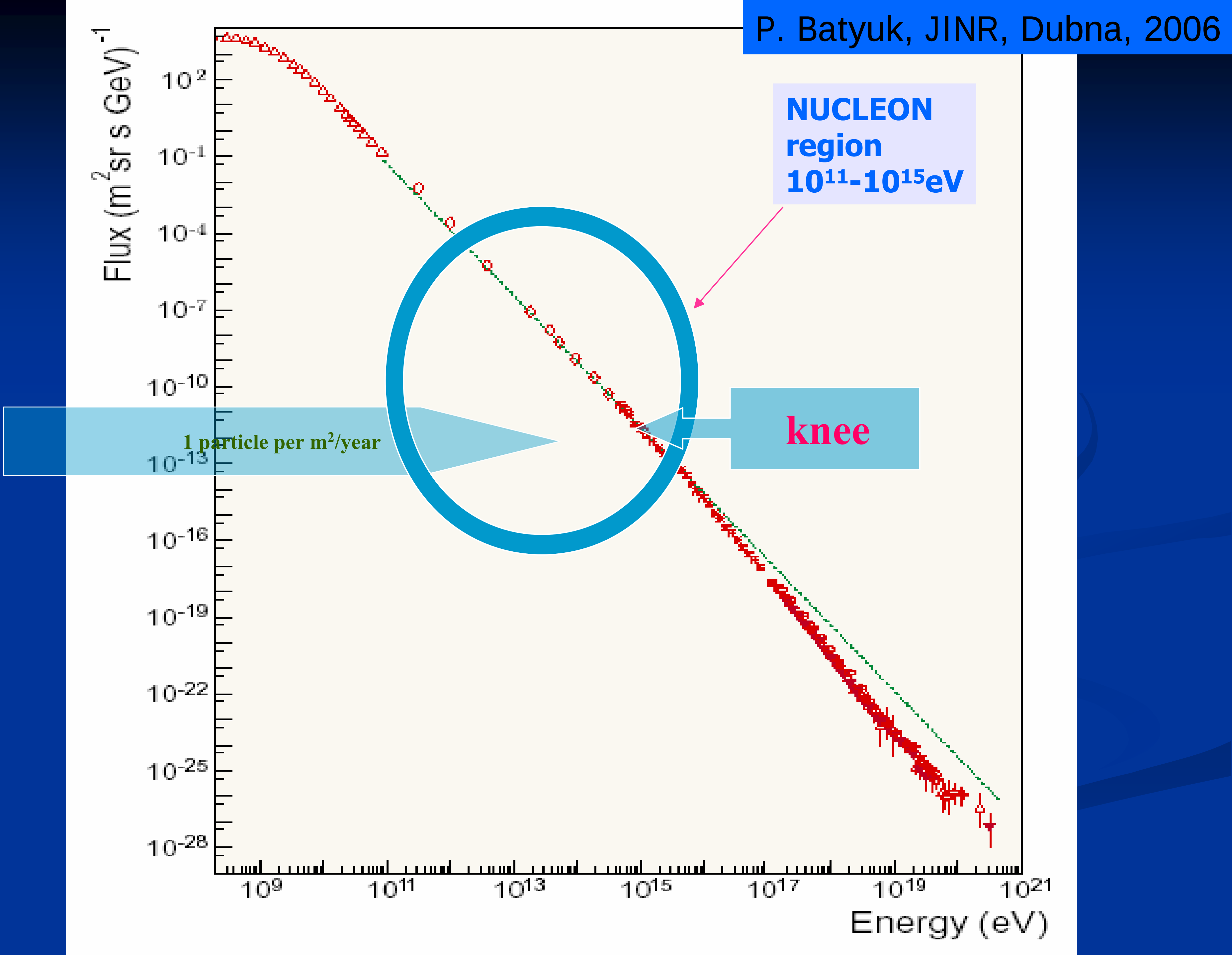
Present status

NUCLEON Space Experiment: 2005-2012



COSMOS satellite, launch 2008, dimension 50x50x20 cm^3, weight ~160 kg, 3 - 5 years with exposure factor ~ 140 m^2•day•sr, power consumption - ~150 W. energy reconstruction accuracy $\Delta E/E$ ~ 80-100%

Data flux ~ 60 MB/day



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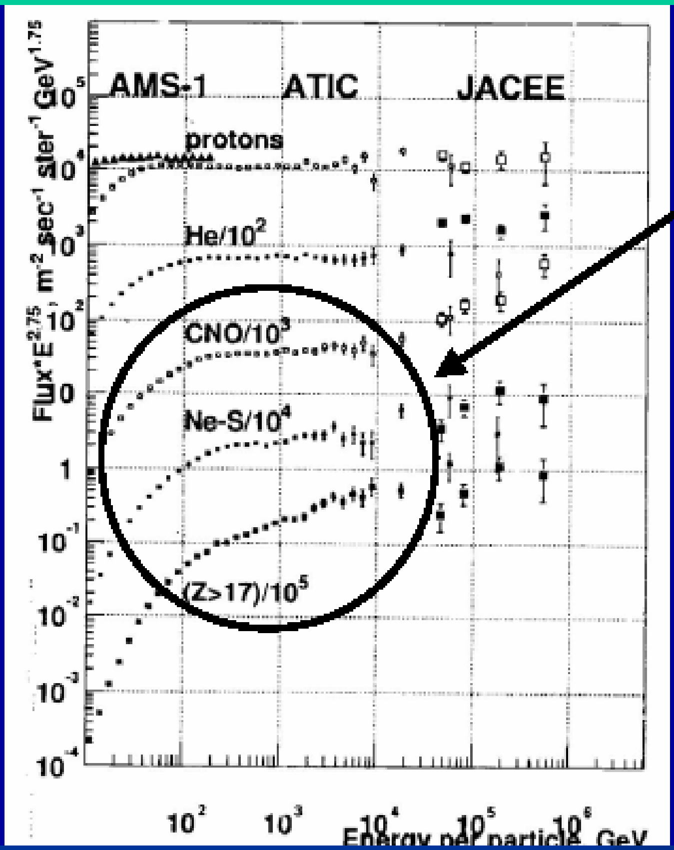
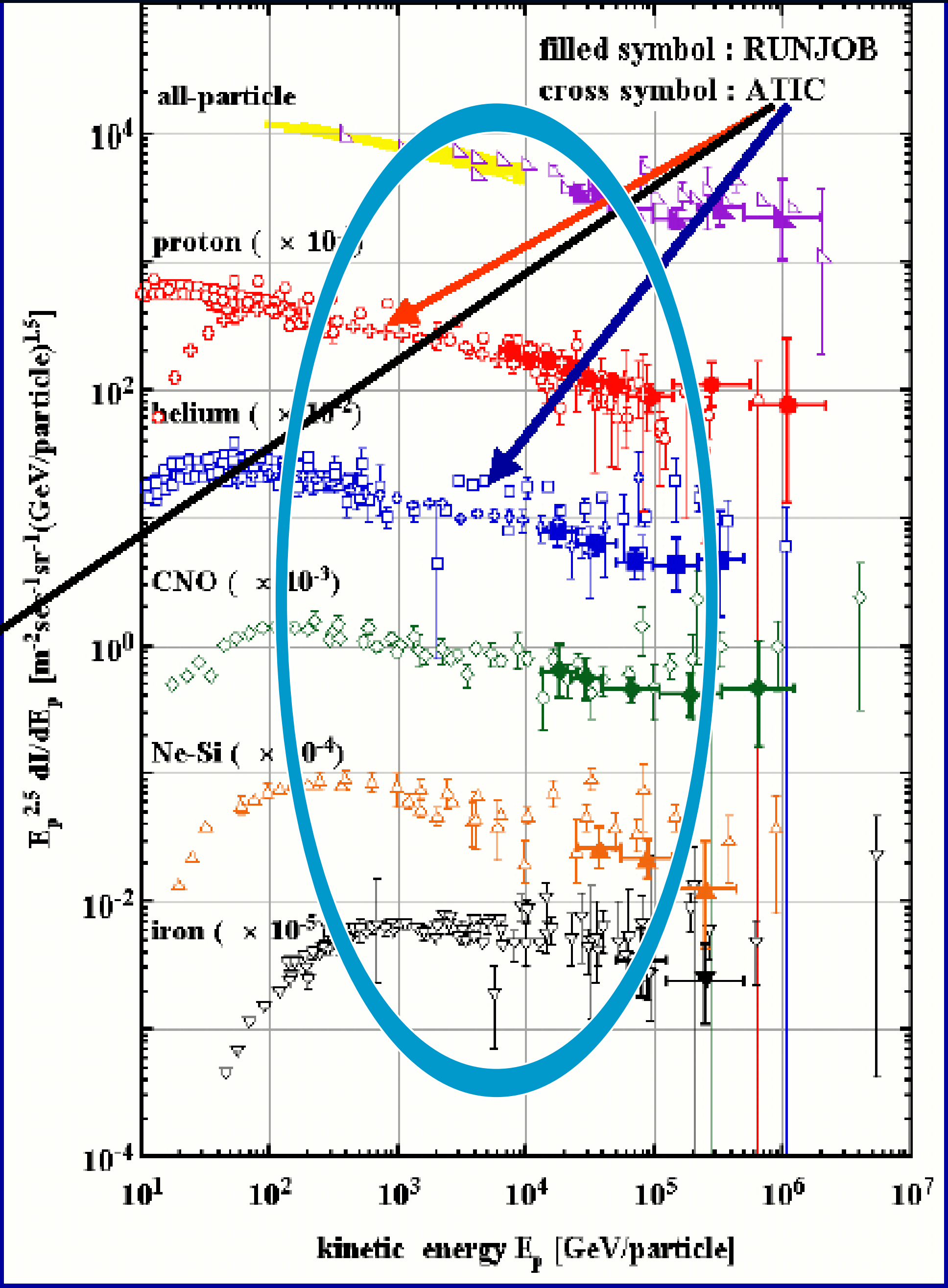
Flux (m^2sr s GeV)^-1
10^2
10^-1
10^-4
10^-7
10^-10
10^-13
10^-16
10^-19
10^-22
10^-25
10^-28
10^9
10^11
10^13
10^15
10^17
10^19
10^21
Energy (eV)
NUCLEON region 10^11-10^15eV
knee
1 particle per m^2/year

2

Better understanding of the CR composition approaching the knee region

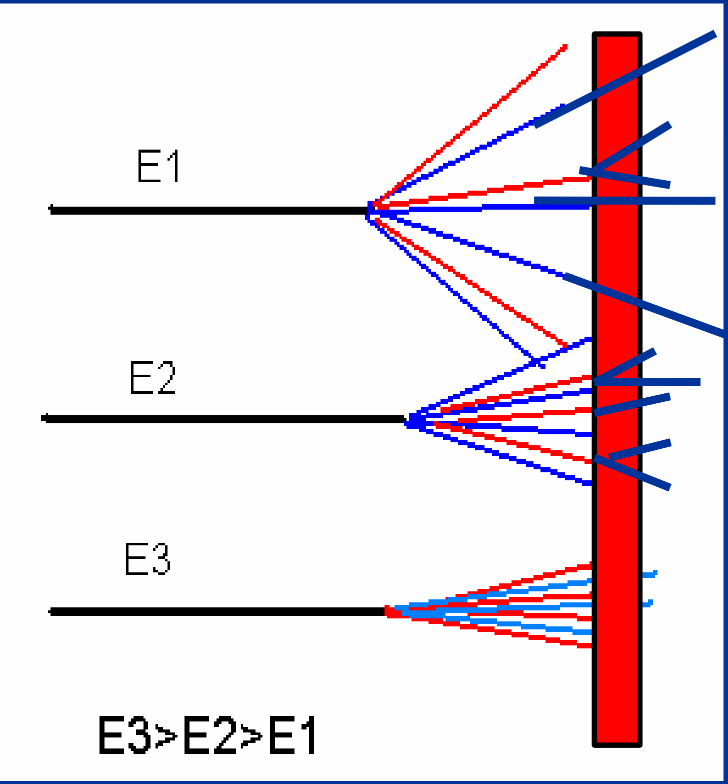




10^{11}-10^{16} eV: Physical problems

- Information of CR sources (SN remnants, pulsars…)
- Information of interstellar and intergalactic space
- Specific problems of the "knee" region $\sim 4 \cdot 10^{15}$ eV
  - Galactic modulation of primordial cosmic rays (PCR) (magnetic fields)
  - Photonuclear fragmentation of heavy nuclei in the vicinity of the source
  - Acceleration in the SN remnants
  - Extragalactic protons of Active Galactic Nuclei (AGN)
  - Change of composition (p, He, CNO, Fe) PCR at the knee region
  - Measurement of electron and photon fluxes at TeV energies

Kinematical method based on the measurements of secondary charged and neutral particle pseudorapidities



$$tg\theta^i_{ls} = (m/E) \cdot tg\,(\theta^i_{cm}/2);$$

Pseudorapidities

$$\eta_i = -\ln tg\,(\theta^i/2)$$

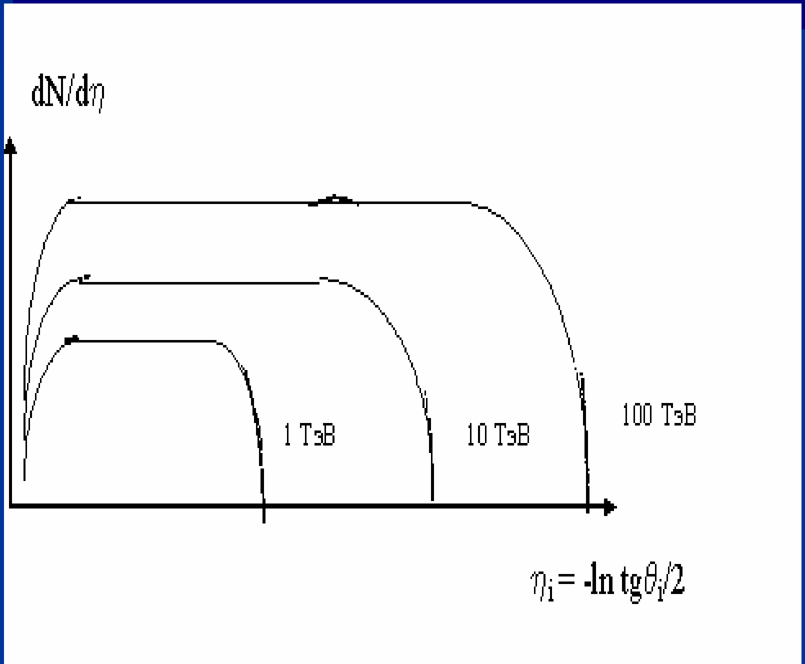
γ - Converter
$\gamma \rightarrow e^+e^-$

Kinematic Light Energy Method (KLEM)

for initial energy E_{true} evaluation

$$S = \sum \eta_i^{\,2} N_i$$

Castagnoli method



$$\langle S \rangle \sim E^{0.8}$$

(KLEM)

$$\langle \eta \rangle \sim \ln E$$

$N_g \quad (E_\gamma)_i$

$N_{ch} \quad (E_{ch})_i$

$N_{before} = N_{ch} + N_\gamma \sim 2N_{ch}$

$\gamma - converter : secondary\ \gamma \ \rightarrow \ narrow\ bunch\ of\ e^-$

$N_{ch} W_{in} \rightarrow repeated\ interactions$

$m_{ch}(E_{ch}) \sim ln\ E_{ch}$

$m_g(E_g) \sim E_\gamma{}^s$

$N_{after} = (1 - W_{in}) N_{ch} + W_{in} N_{ch} m_{ch} + N_g m_g$

$N_{after} \sim N_{before}\ M(E)$

$M(100\ GeV) \sim 3.5$

$M(1000\ TeV) \sim 20$

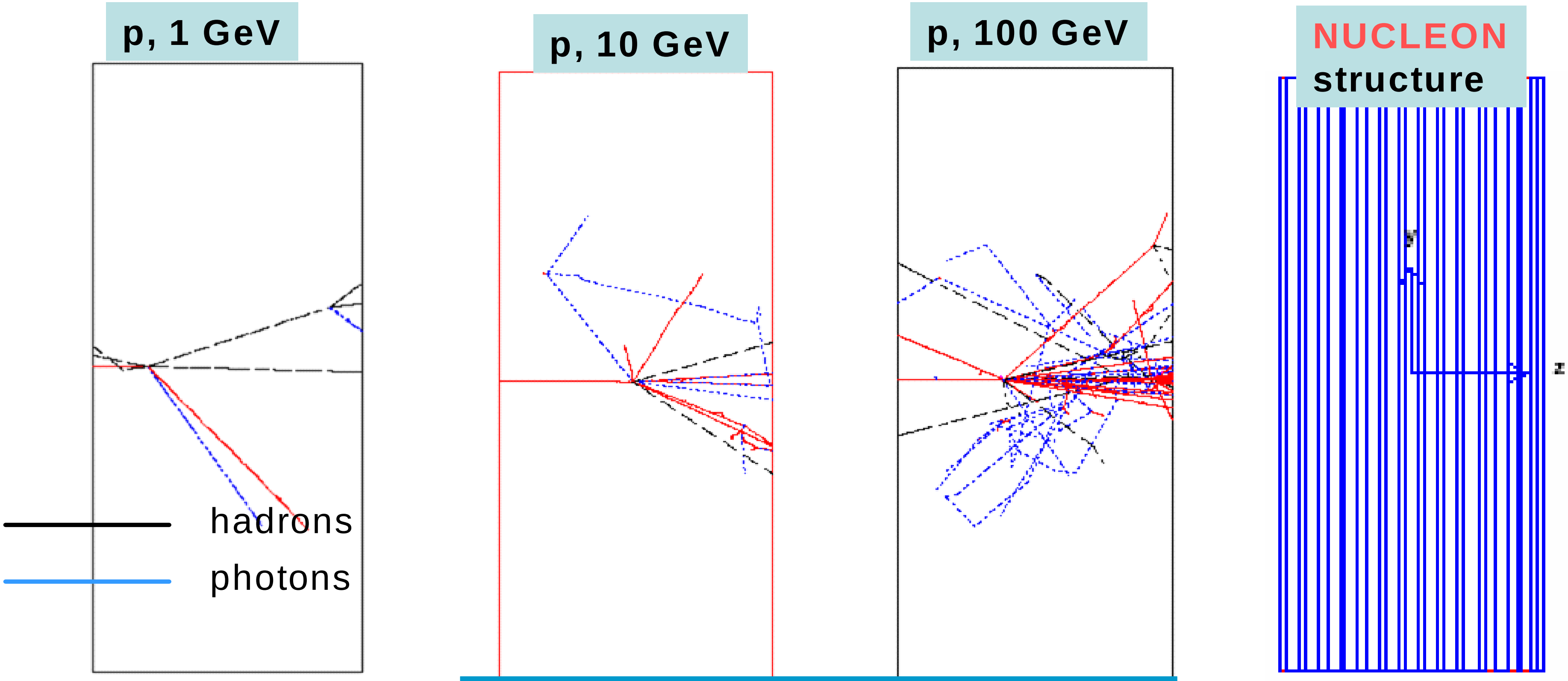
$S = \Sigma \eta^2 N_i$

$\eta_i = -ln\ tg(\theta_i/2) \sim -ln\ (r_i/2H)$

$r_i - distance\ up\ to\ an\ axis\ of\ a\ shower\ i - detector\ in\ which\ N\ particles\ are\ registered$

$H - distance\ up\ a\ point\ of\ interaction$

MC simulation of trigger efficiency and backgrounds, rejection of events with E < 100 GeV



E < 100 GeV events should be rejected by trigger system

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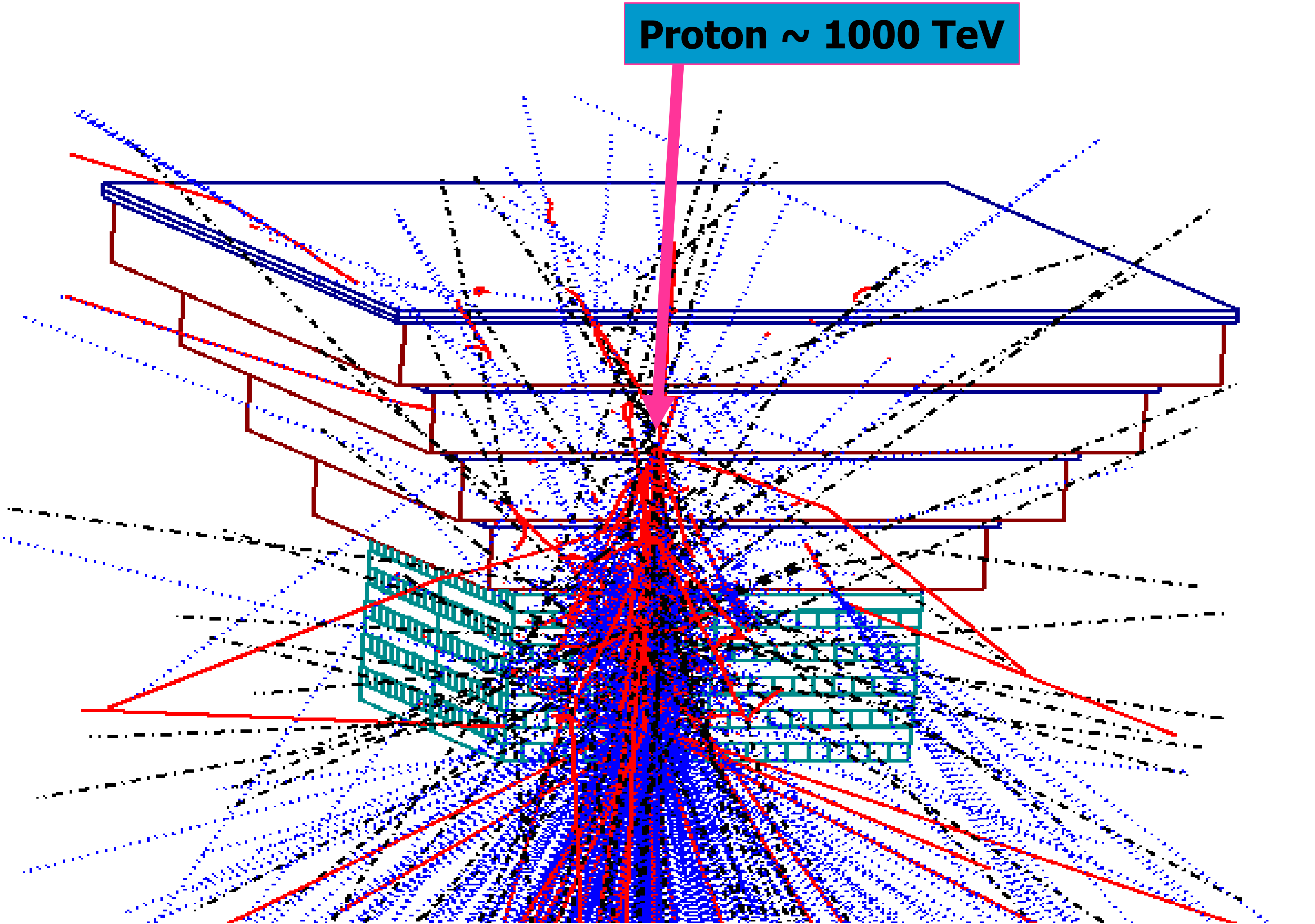
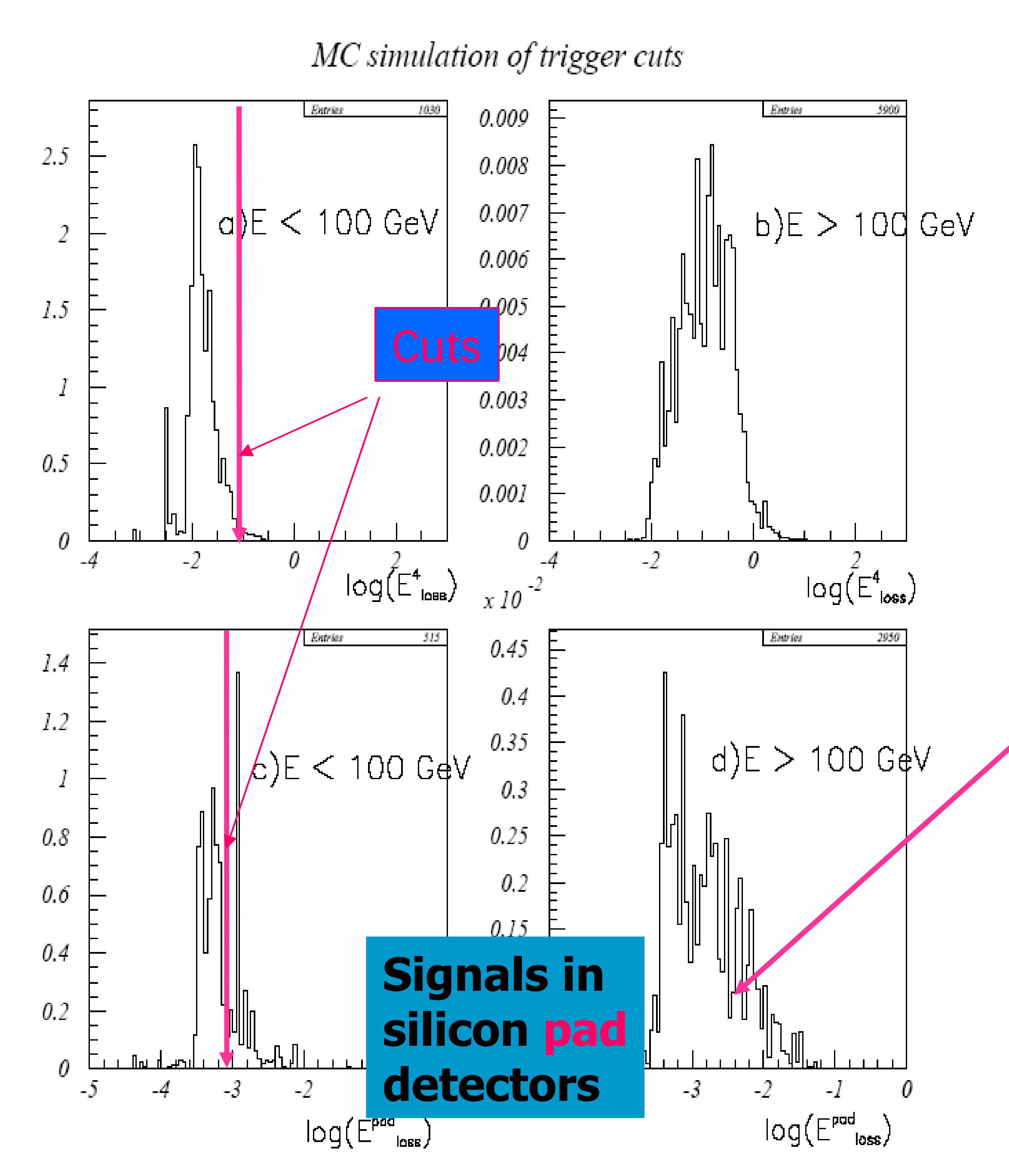
Backscattering effects for the high energy events may be used in the trigger selection cuts





Signals in silicon pad detectors

Signals in last scintillator detector

Backscattering effects for the high energy events may be used in the trigger selection cuts

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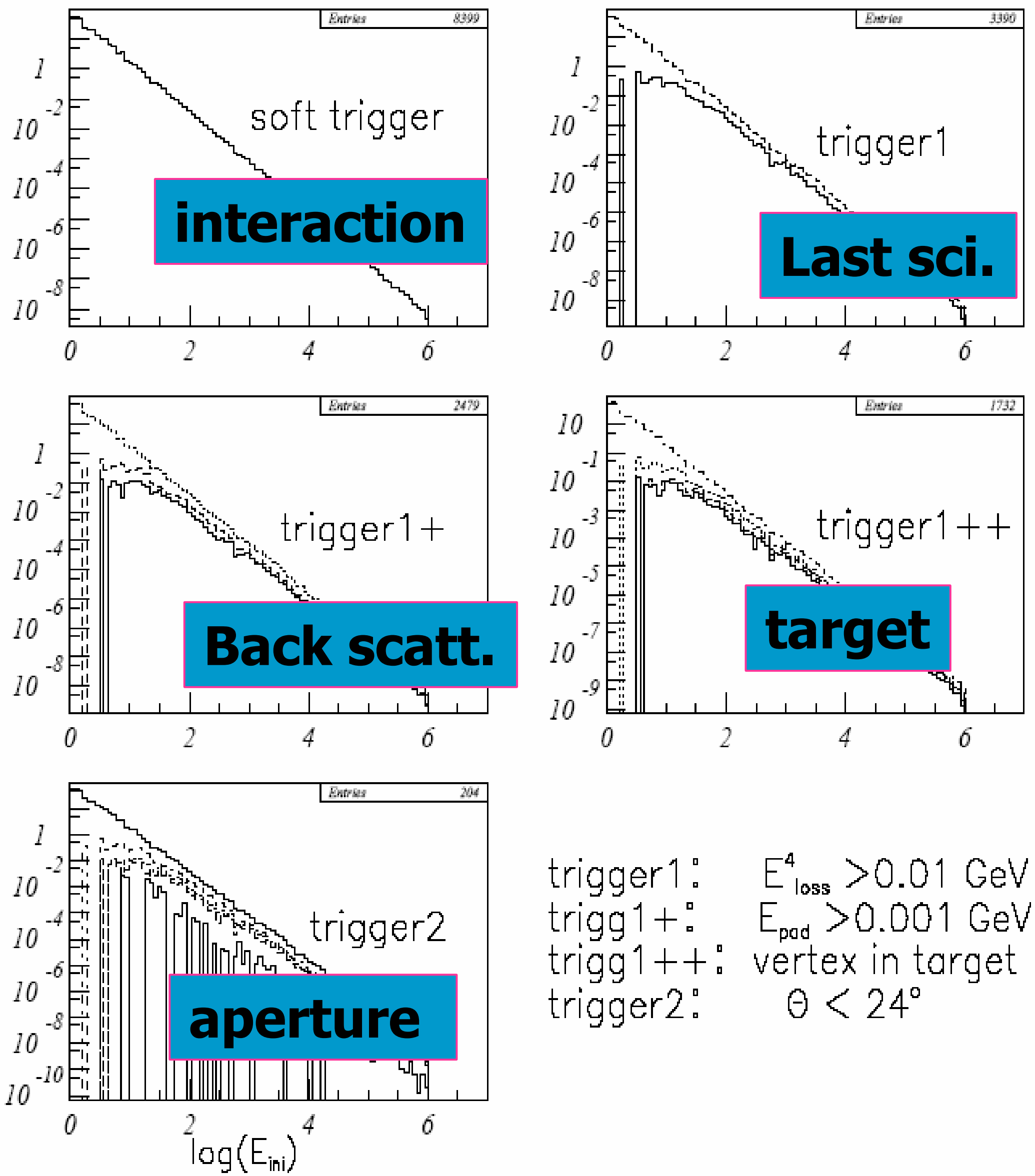
MC simulation of trigger cuts



N_{ini} = 28000
E = 1 – 10^6 GeV

Soft – 8400
Last scint 3390
Back scatt 2480
Alive targ 1730
Θ ≤ 24° 204

E > 100 GeV 182
Trig.eff - ~ 90%

Expected statistics
for 3-5 years data taking

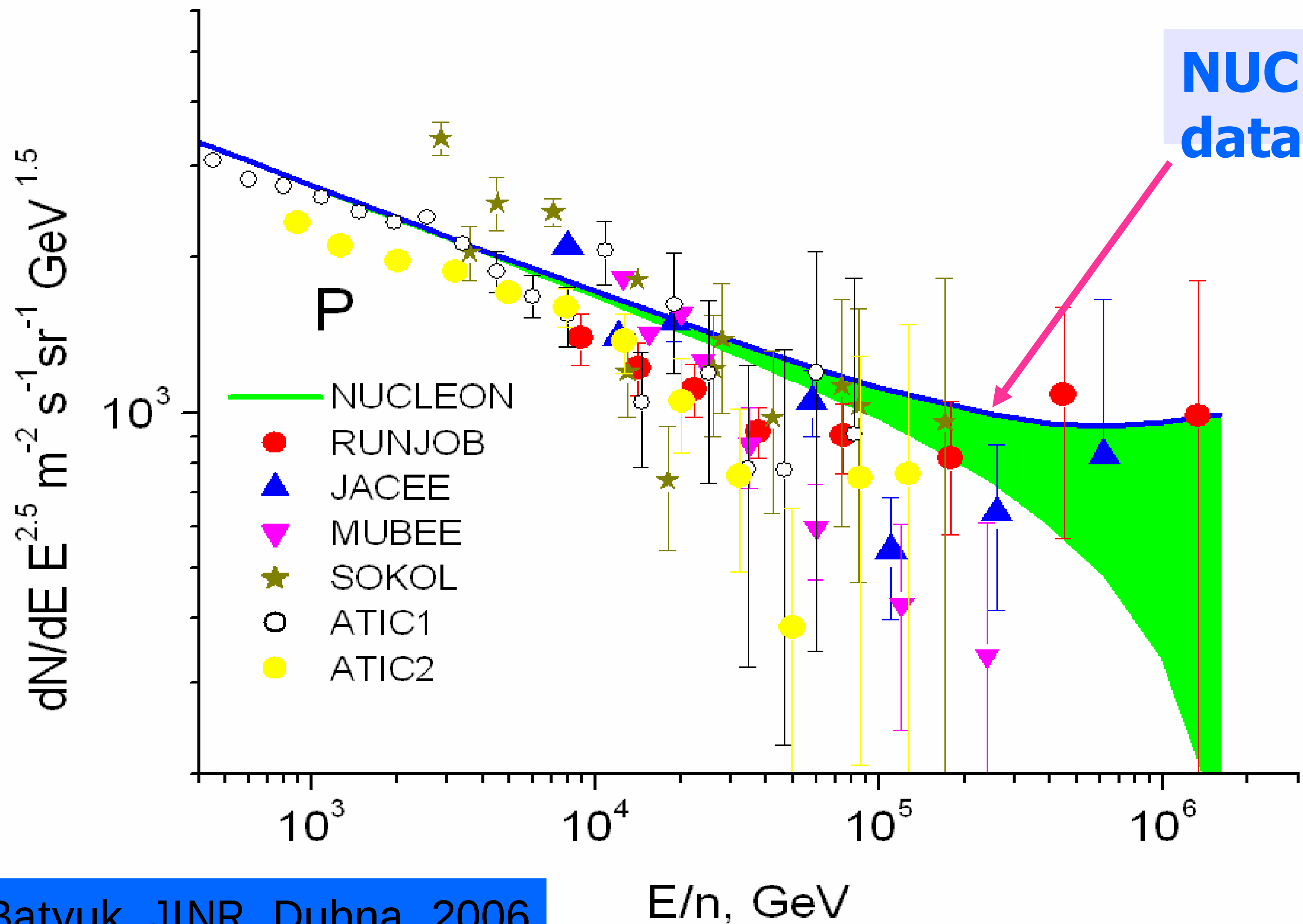
Expected statistics for 5 years of data taking in orbit

Z	>0.1TeV	>1TeV	>10TeV	>100	>1000
All	$1{,}19*10^8$	$2{,}6*10^6$	57700	1300	29,9
1	3,02E7	588000	11500	224	4,36
2	2,51E7	576000	13200	302	6,92
3	892000	25700	742	21,4	0,617
4	301000	5350	95,2	1,69	0,0301
5	844000	9470	106	1,19	0,0134
6	6,16E6	135000	2950	64,5	1,41
7	1,58E6	30000	572	10,9	0,208
8	1,02E7	213000	4440	92,8	1,94
9	221000	4500	91,9	1,88	0,0383
10	2,95E6	67600	1550	35,5	0,813
11	4,81E6	105000	2300	50,4	1,1
12	5,37E6	123000	2820	64,6	1,48
13	930000	20300	445	9,74	0,213
14	6,74E6	120000	2130	37,9	0,674
15	234000	4770	97,4	1,99	0,0406
16	124000	3490	98,5	2,77	0,0782
17	238000	4970	104	2,17	0,0453
18	608000	13900	319	7,3	0,167
19	384000	8600	192	4,31	0,0965
20	1,09E6	21800	435	8,69	0,173
21	234000	5360	123	2,81	0,0645
22	973000	23900	587	14,4	0,353
23	473000	11100	260	6,09	0,143
24	1,1E6	23600	503	10,8	0,23
25	786000	27300	945	32,8	1,14
26	$1{,}58*10^7$	406000	10400	268	6,89

Z>26

Z	>0.1TeV	>1TeV	>10TeV	>100	>1000
27	71100	1350	25,8	0,492	0,00937
28	666000	20600	636	19,7	0,607
29	15700	421	11,3	0,305	0,00821
30	11800	325	8,95	0,247	0,00679
31	2500	70,3	1,98	0,0559	0,00157
32	2920	84,2	2,43	0,0701	0,00202
33	734	21,2	0,61	0,0176	5,08E-4
34	1460	43	1,27	0,0375	0,00111
35	934	28,2	0,852	0,0257	7,77E-4

Proton spectrum to be expected in the NUCLEON experiment (green crosshatched region)



NUCLEON 3 y data taking

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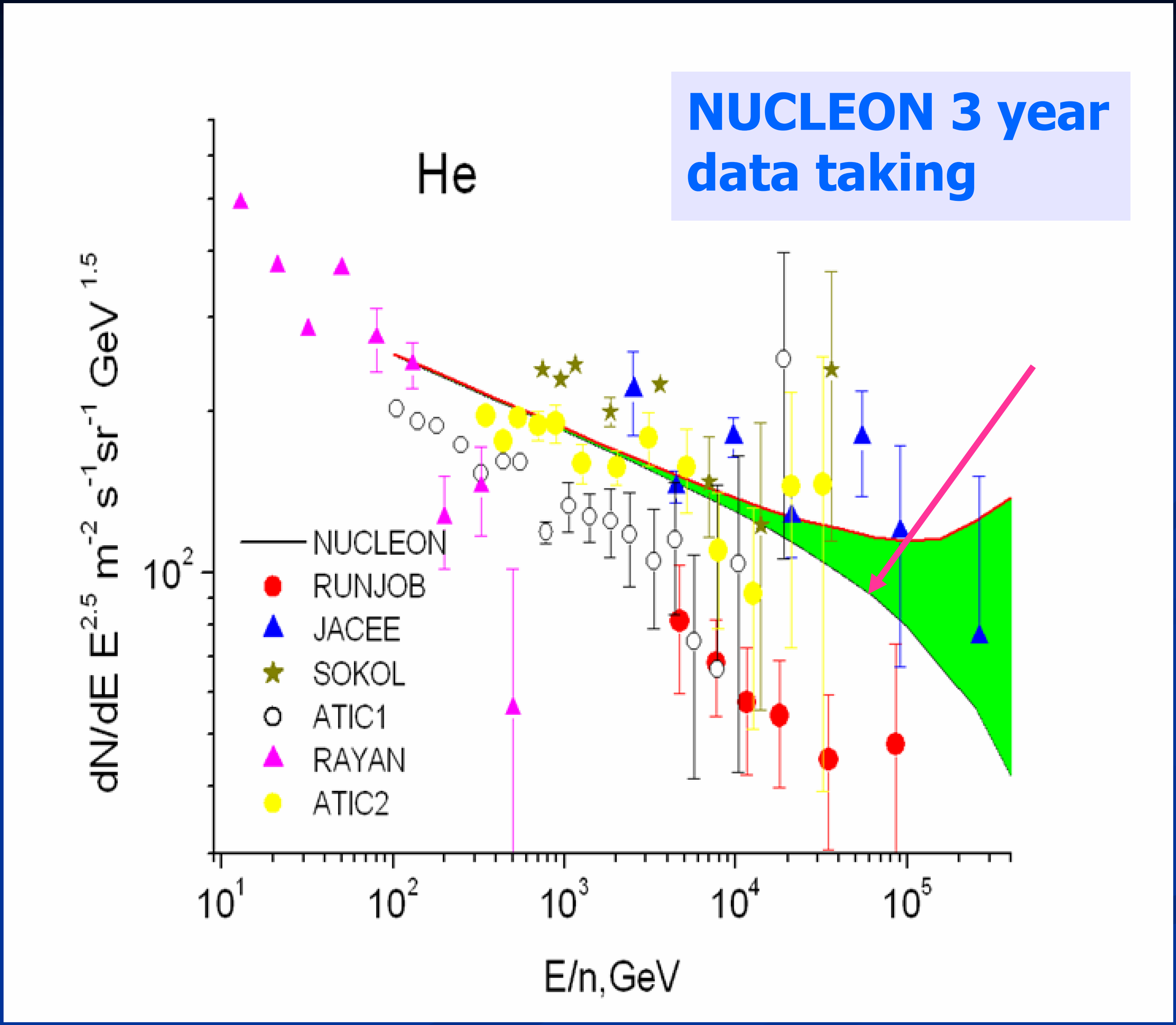
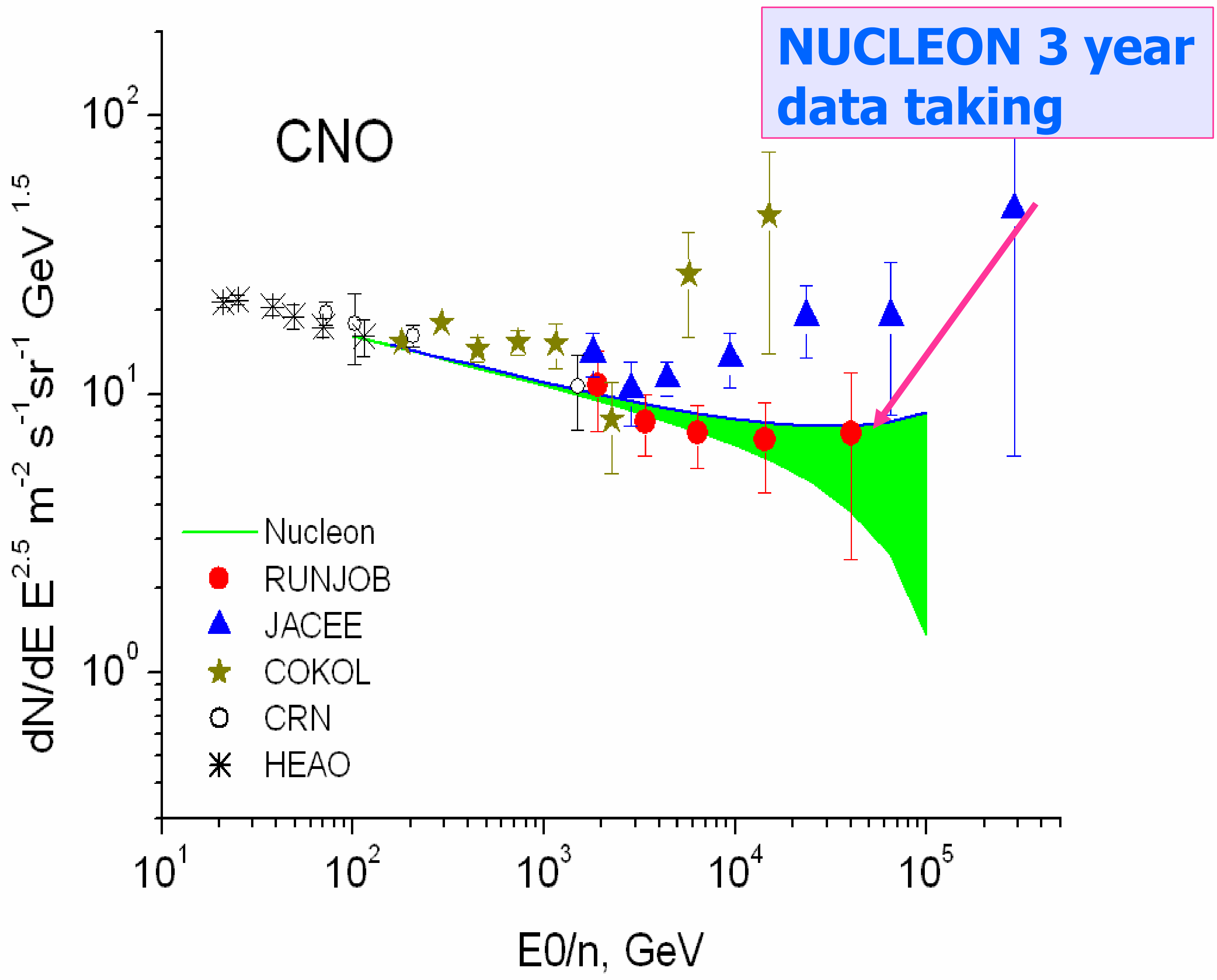
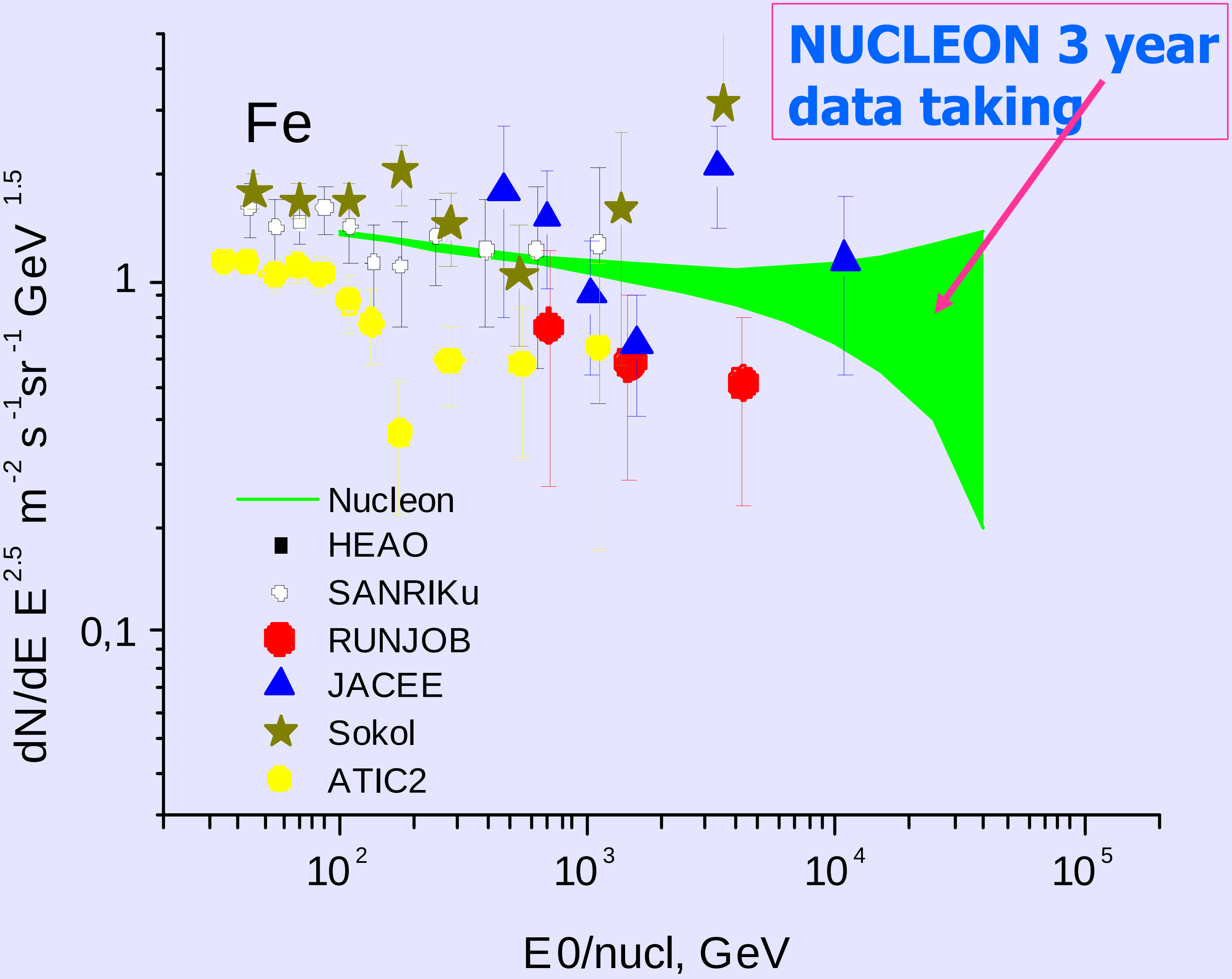

NUCLEON 3 year data taking
He
dN/dE E^2.5 m^-2 s^-1 sr^-1 GeV^1.5
10^2
NUCLEON
RUNJOB
JACEE
SOKOL
ATIC1
RAYAN
ATIC2
10^1
10^2
10^3
10^4
10^5
E/n,GeV


NUCLEON 3 year data taking
CNO
dN/dE E^2.5 m^-2 s^-1 sr^-1 GeV^1.5
E0/n, GeV
Nucleon
RUNJOB
JACEE
COKOL
CRN
HEAO
10^0
10^1
10^2
10^3
10^4
10^5



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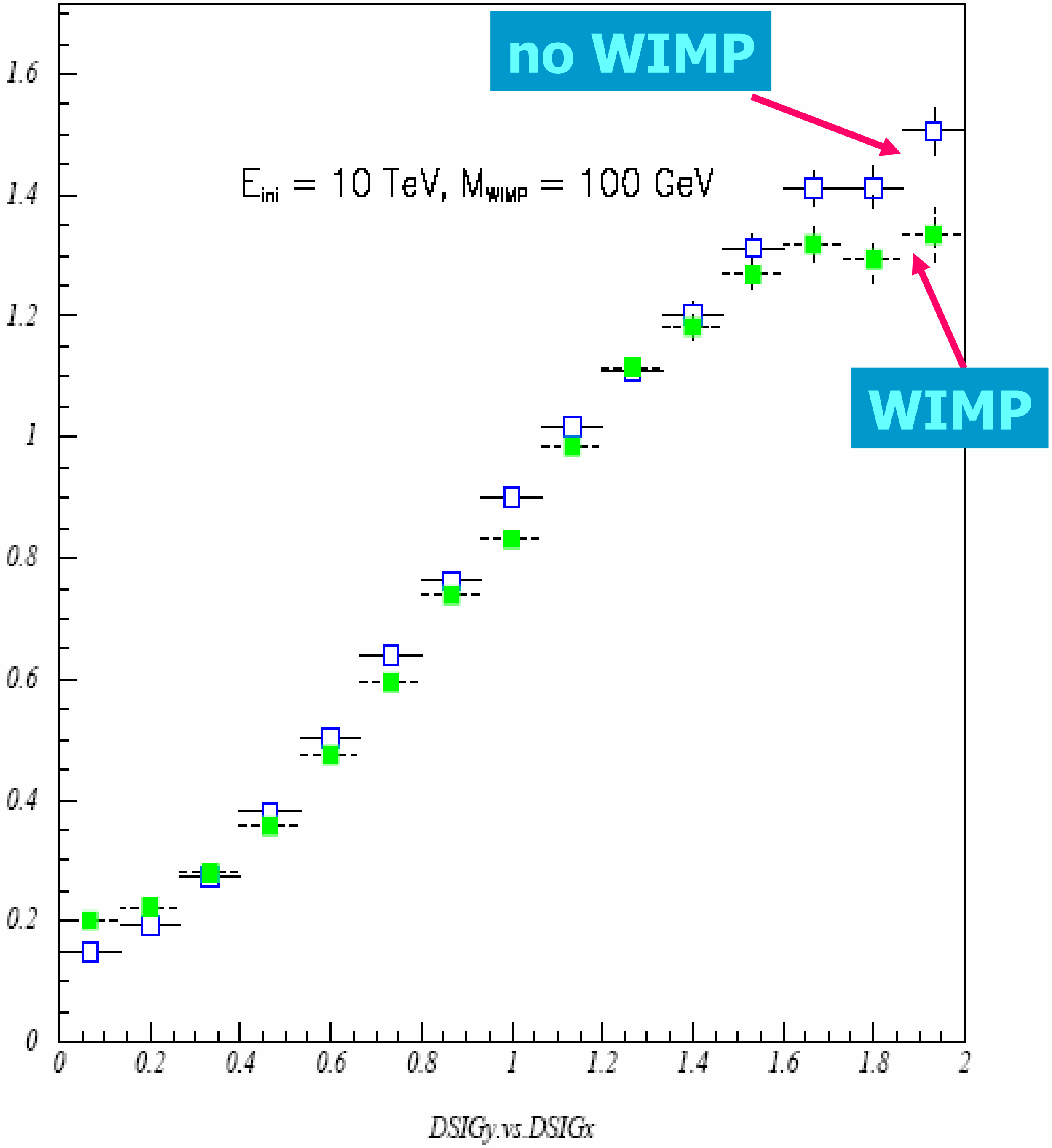
MC simulation of "WIMP" production

- Initial proton energies 10 – 1000 TeV
- M_{WIMP} = 100 – 500 GeV
- WIMP momentum was combine as a random sum of charged and neutral secondary momenta to get invariant mass

$$M_{inv} = M_{WIMP}$$

- WIMP track in detectors was considered as a usual track



First simulation of the WIMPs production:
E_{ini}=10 TeV
M_{WIMP} = 100 GeV

NUCLEON properties in comparision with the planned or existent balloon detectors

Project	Effective geometrical factor	Launch year Location	Global exposition factor GWT (м²ср/сутки)
ATIC	~0.25 м²/ср ~0.15 м²/ср protons ~0.25 м²/ср Fe-nuclei	2004/2005 2-week baloon flight Antarctica	General – 7.0 protons – 4.2 Fe-nuclei – 7.0
TRACER	~ 6.0 м²/ср No data	No data yet 3-months balloon flight Antarctica	General – 540 Protons -0.0 Fe-nuclei– no data
CREAM	~1.3 м²/ср ~0.30 м²/ср protons ~1.3 м²/ср Fe-nuclei	No data 42-days balloon flight Antarctica	General – 56 protons– 17 Fe-nuclei– 56
NUCLEON	~0.34 м²/ср ~0.12 м²/ср protons ~0.3 м²/ср Fe-nuclei	2008-2012, 4-5 years Space flight	protons– 200-220 Fe-nuclei– 460-550