To search for dark matter through line emission

-- a suggestion for China and France cooperation

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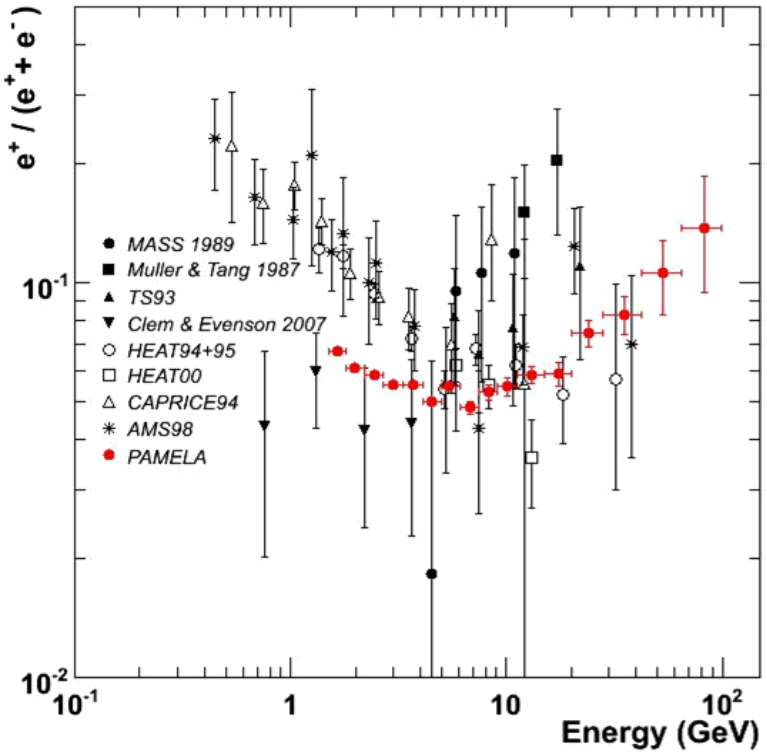
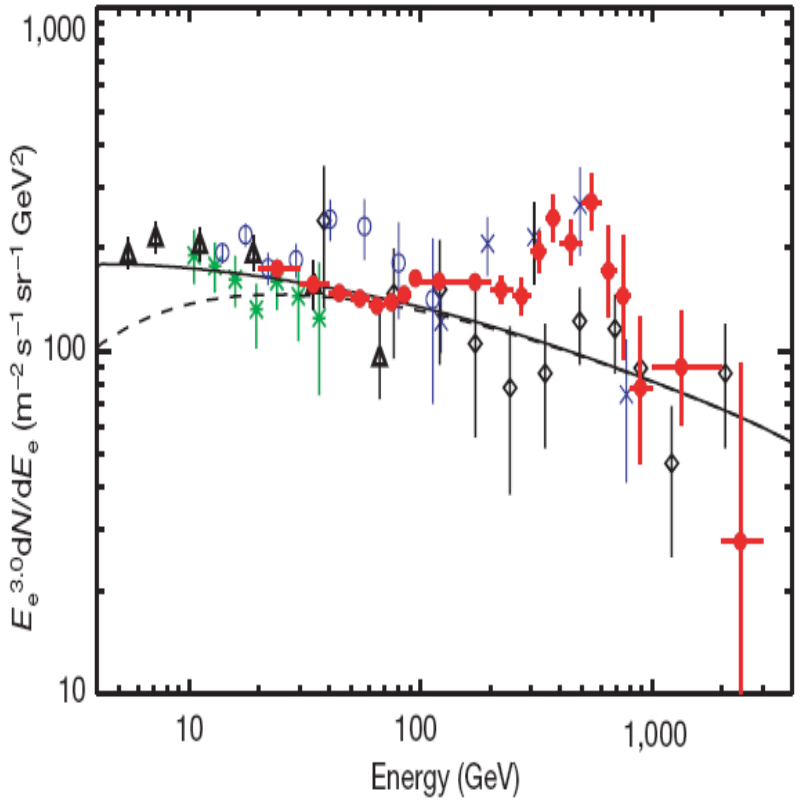
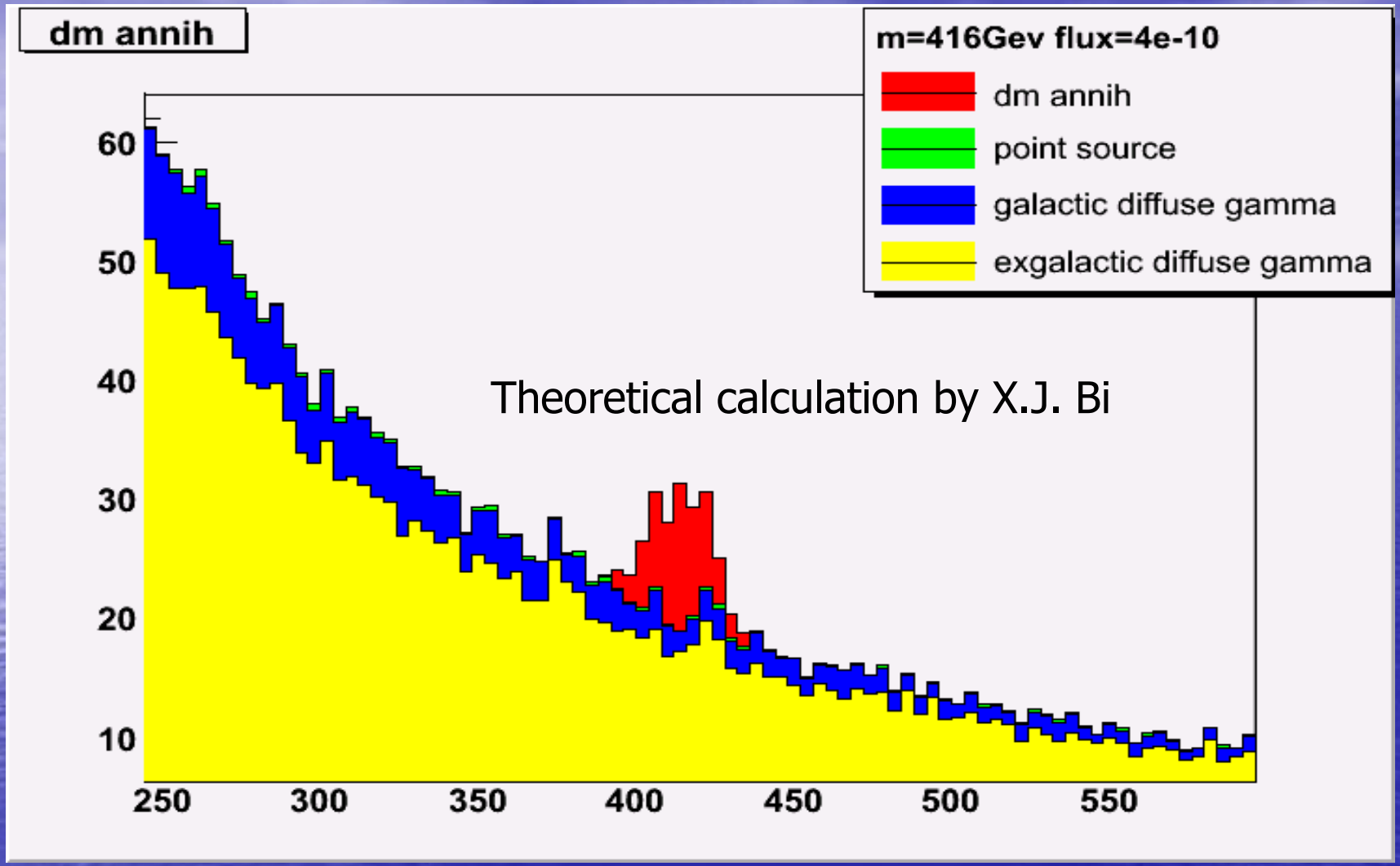
PAMELA and ATIC measurements



Positron ratio

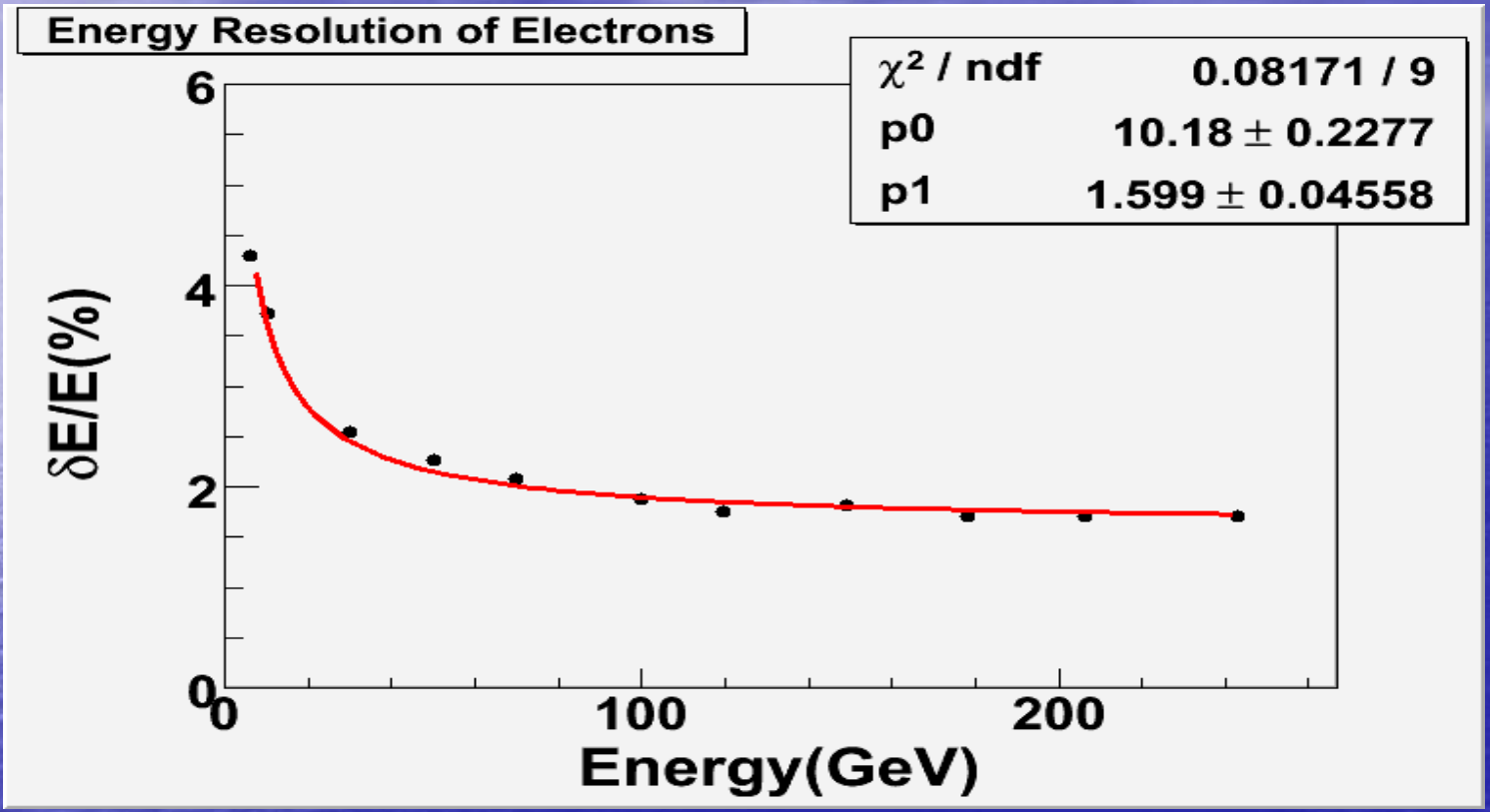


Electron flux



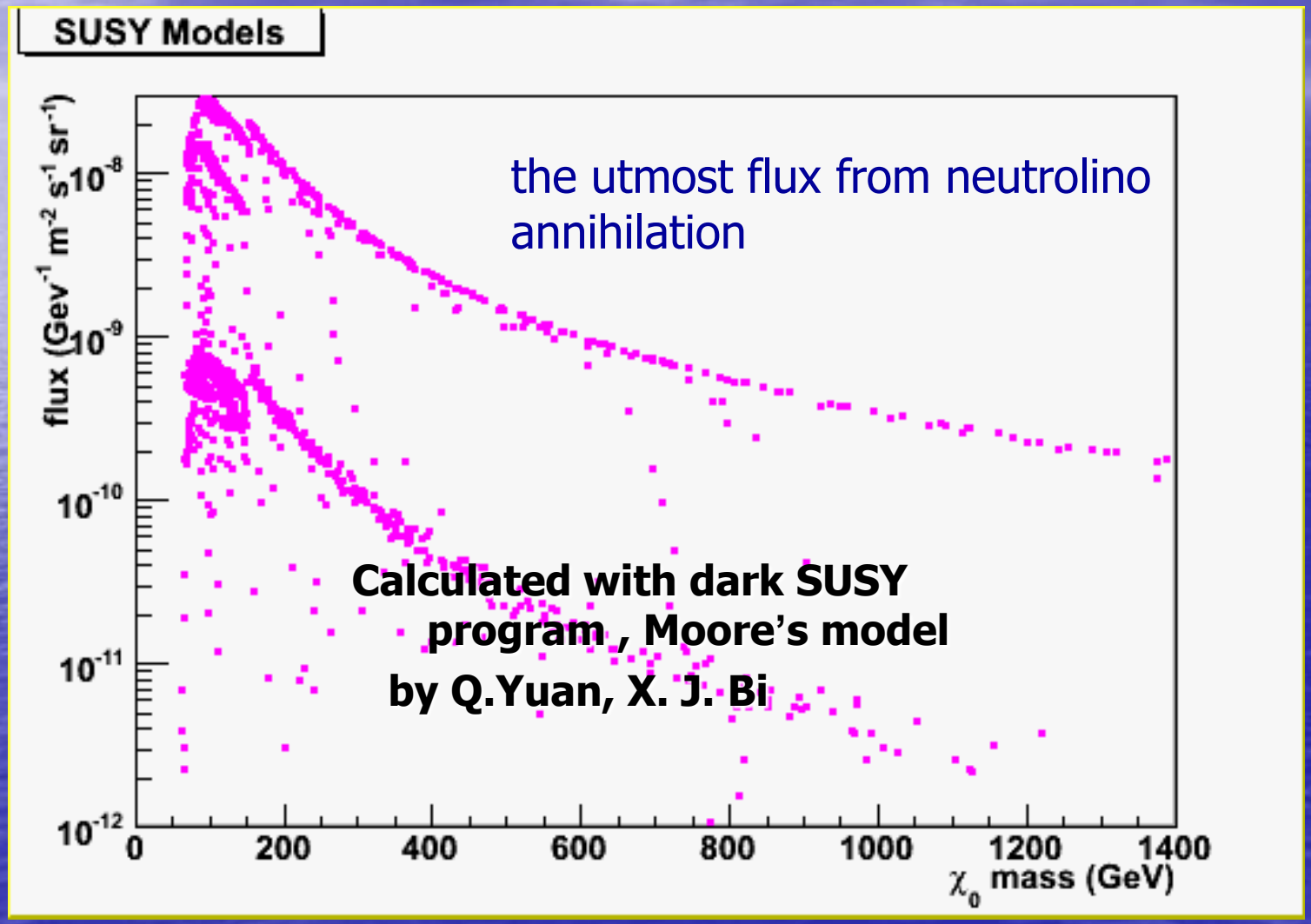
Gamma ray spectrum

AMS02 ECAL capability



AMS can measure gamma ray energy from 1GeV to 2TeV with resolution of 2%

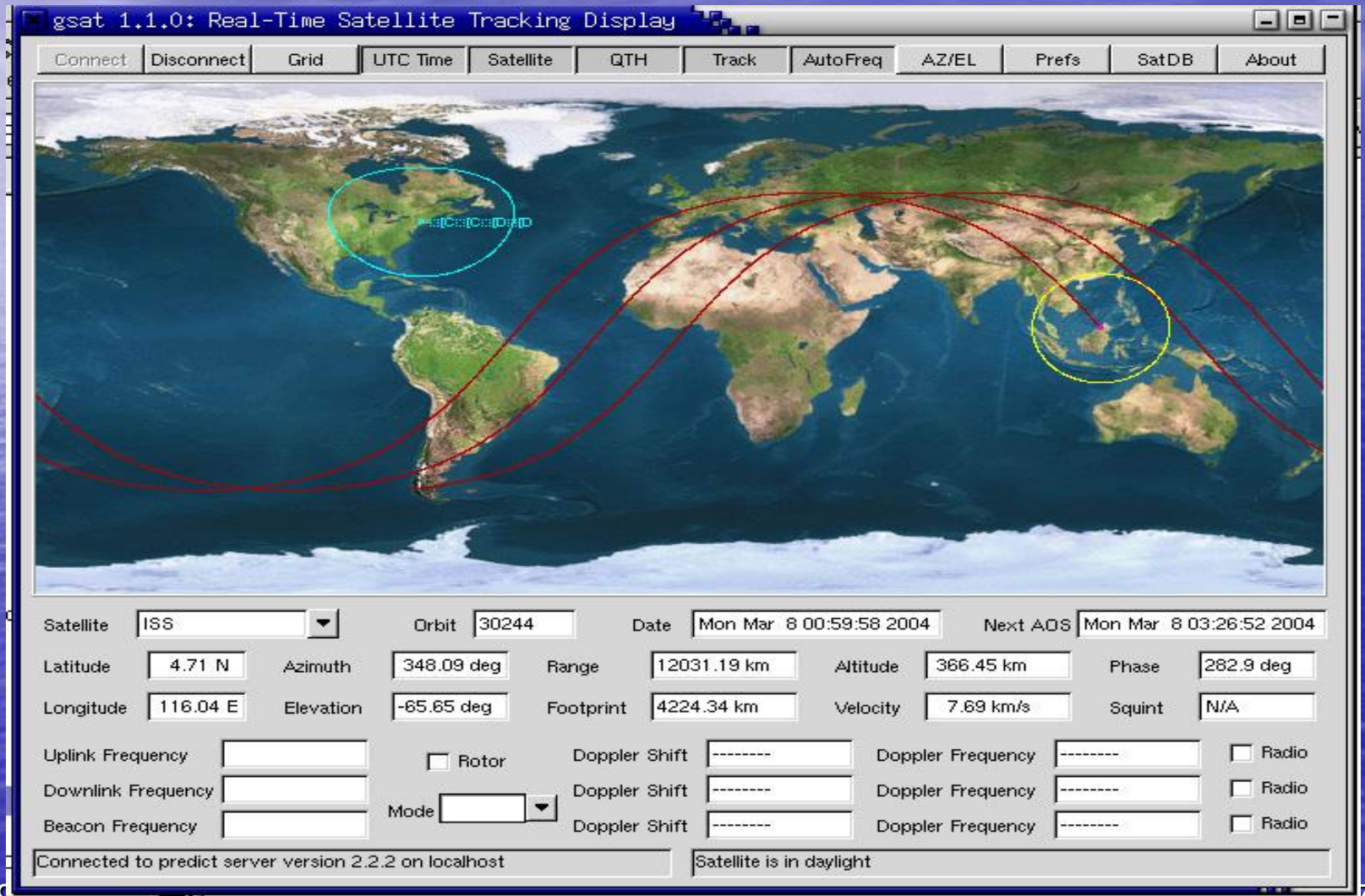
Neutralino mass and flux



Question

What kind of detector is need to observe the utmost flux of line emission from neutralino annihilation?

Fast simulation: put a virtual detector on orbit



Suppose the detector is

- area $1m^2$
- geometry factor $3m^2sr$
- gamma energy measurement 30GeV—4TeV
- energy resolution 2%
- angular resolution 0.5^o
- proton rejection 10^{-7}
- electron rejection 10^{-4}

backgrounds

astro-ph/0510714v2

$$\Phi_{hardron}(E)=1.49\,E^{-2.74}\,\mathrm{cm}^{-2}\mathrm{s}^{-2}\mathrm{sr}^{-1}\mathrm{GeV}^{-1}$$

$$\Phi_{electron}(E)=6.9\times10^{-2}\,E^{-3.3}\,\mathrm{cm}^{-2}\mathrm{s}^{-2}\mathrm{sr}^{-1}\mathrm{GeV}^{-1}$$

$$\Phi_{extra-\gamma}(E)=1.38\times10^{-6}\,E^{-2.1}\,\mathrm{cm}^{-2}\mathrm{s}^{-2}\mathrm{sr}^{-1}\mathrm{GeV}^{-1}$$

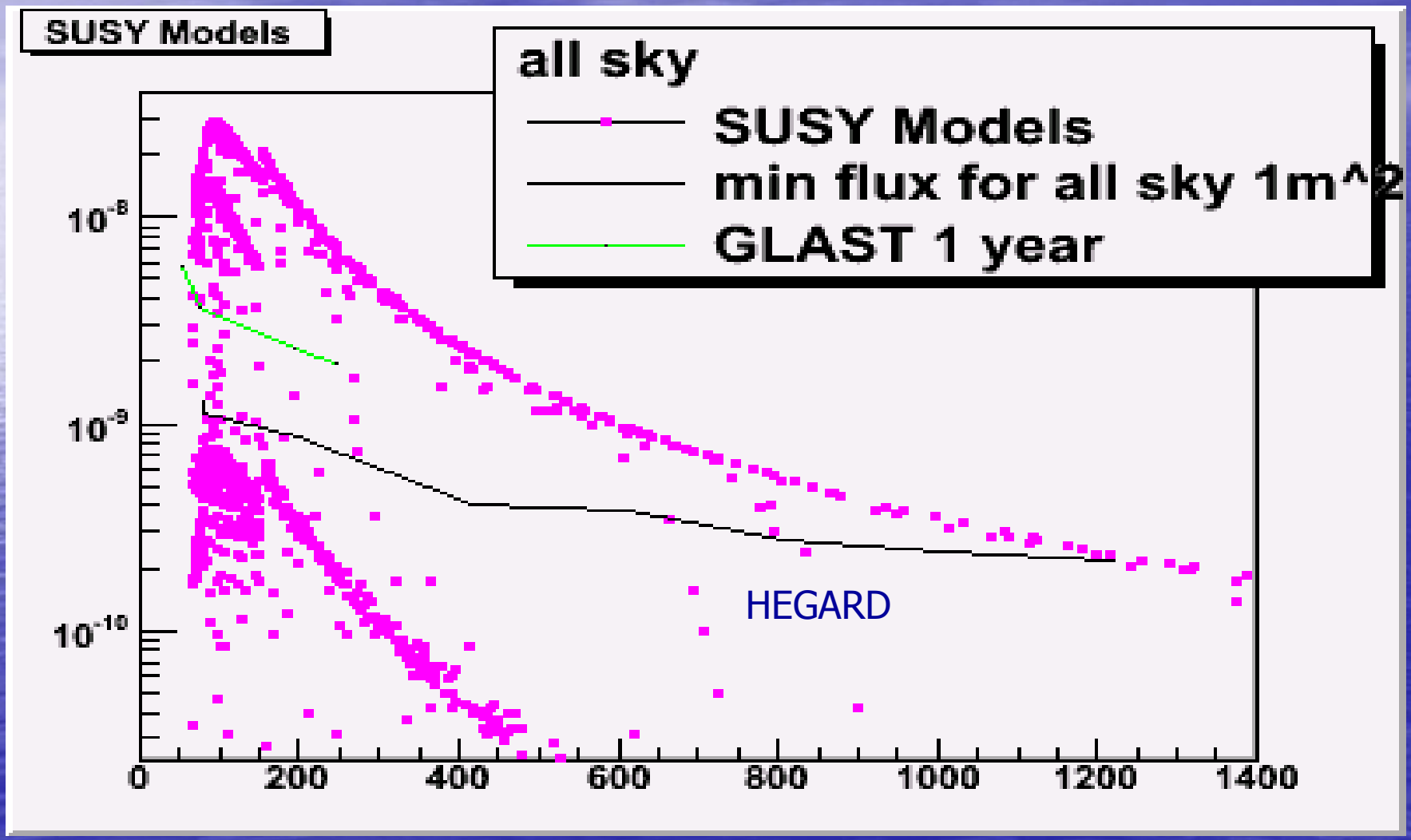
$$\Phi_{galac-\gamma}(E)=N_0(l,b)\,10^{-6}\,E^{-2.7}\,\mathrm{cm}^{-2}\mathrm{s}^{-2}\mathrm{sr}^{-1}\mathrm{GeV}^{-1}$$

$$N_0(l,b)=\begin{cases}\dfrac{1}{\sqrt{1-(l/35)^2}\sqrt{1-(b/1.8)^2}} & l>30\\[2ex] \dfrac{1}{\sqrt{1-(l/35)^2}\sqrt{1-(b/(1.1+|l|0.022))^2}} & l\le 30\end{cases}$$

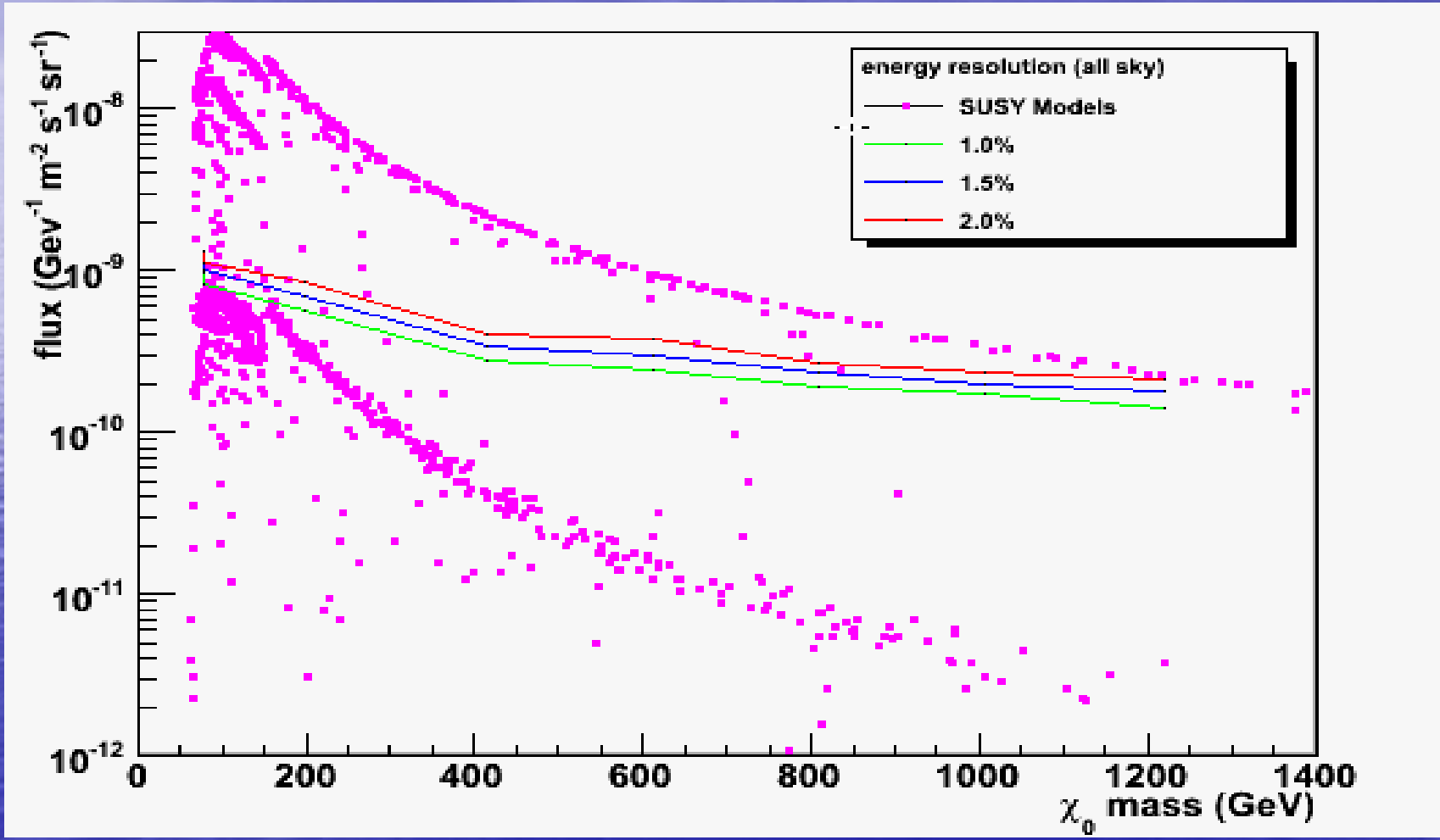
$$\Phi_{2EG\_j1746\_2852}(E)=7.6\times10^{-11}\,(E/1047\mathrm{MeV})^{-1.7}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{MeV}^{-1}?$$

And signal from neutralino annihilation

One year sensitivity



Detectability vs. energy resolution



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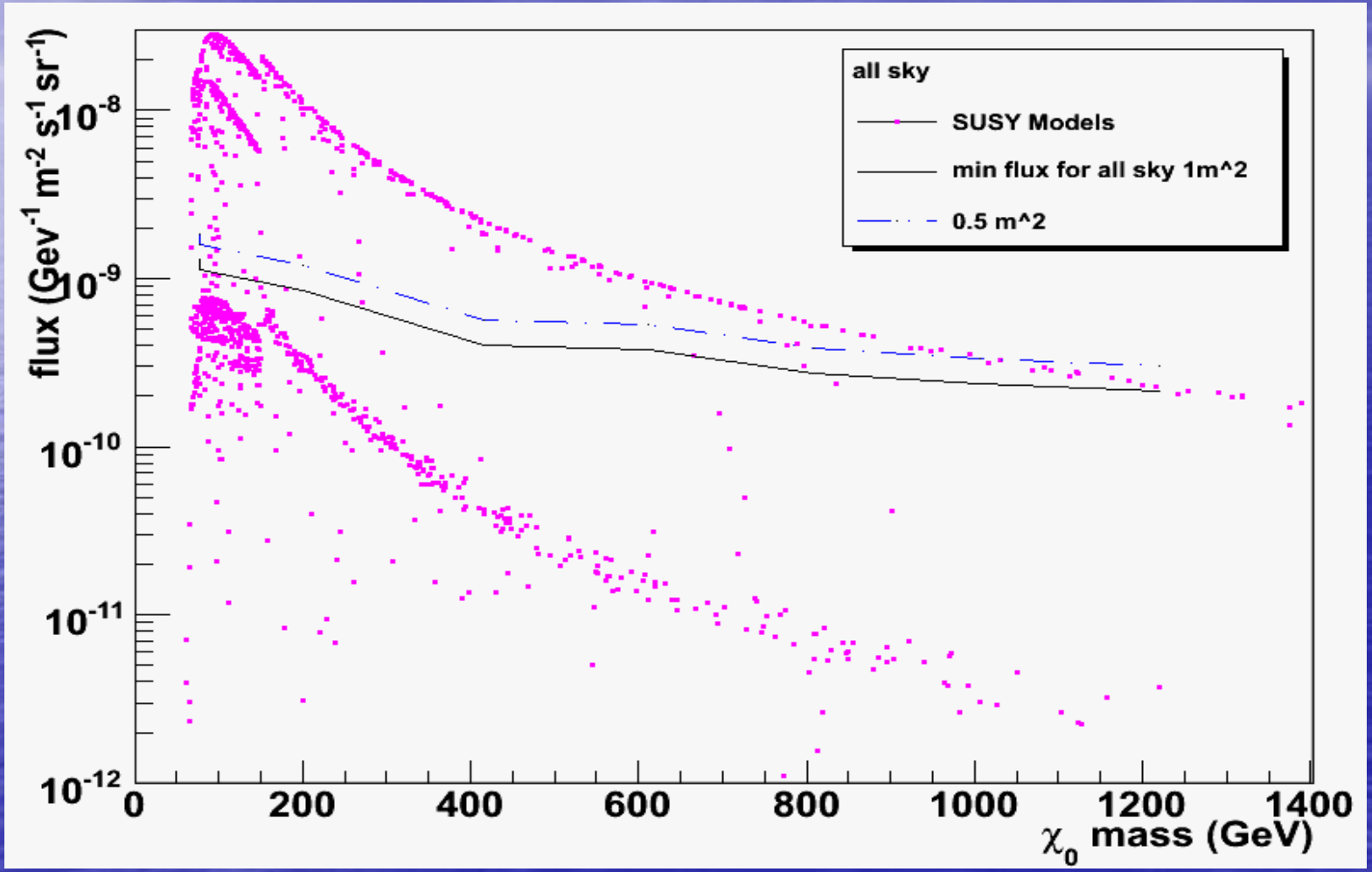
Detectability vs. detector area



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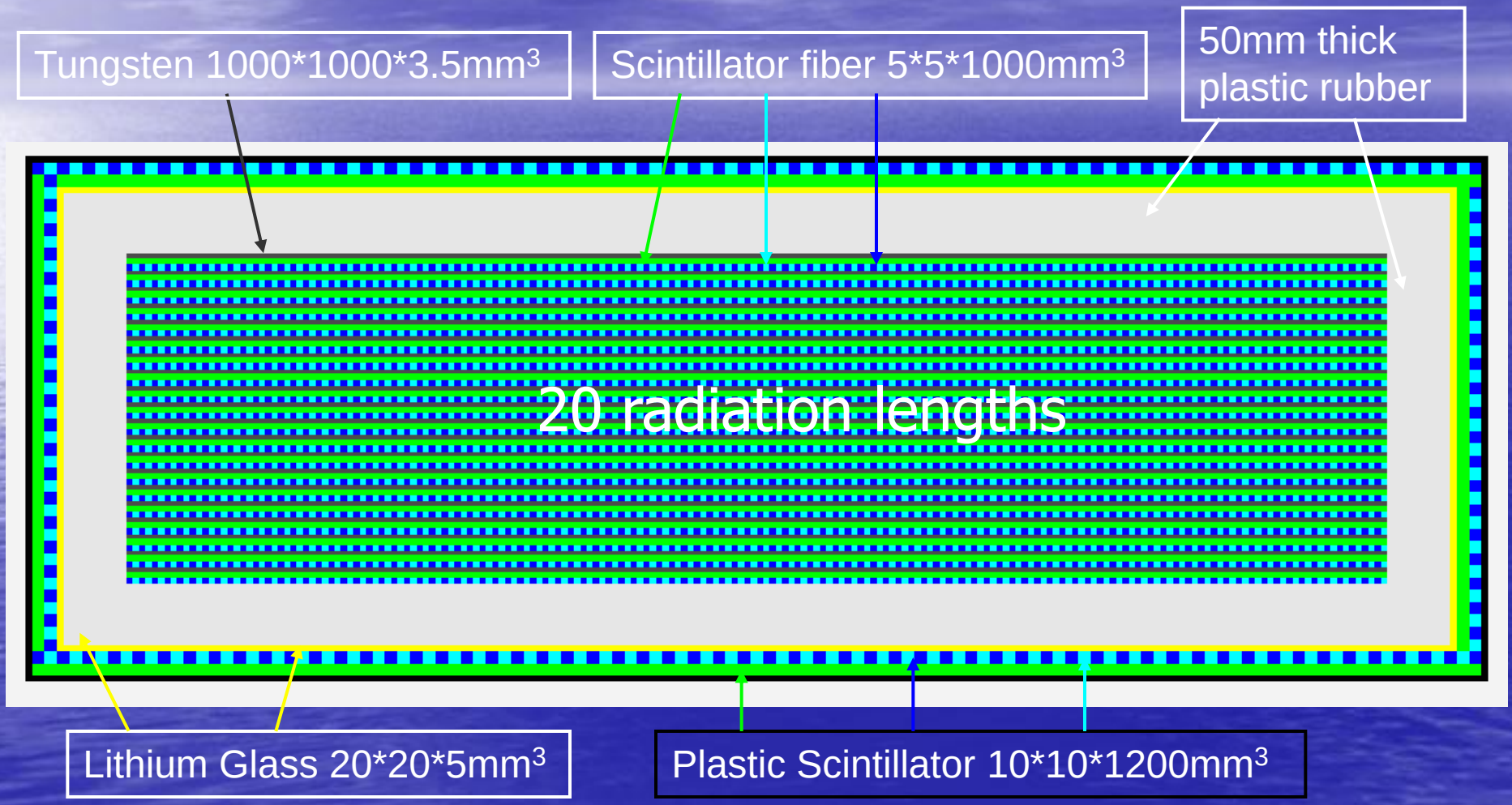
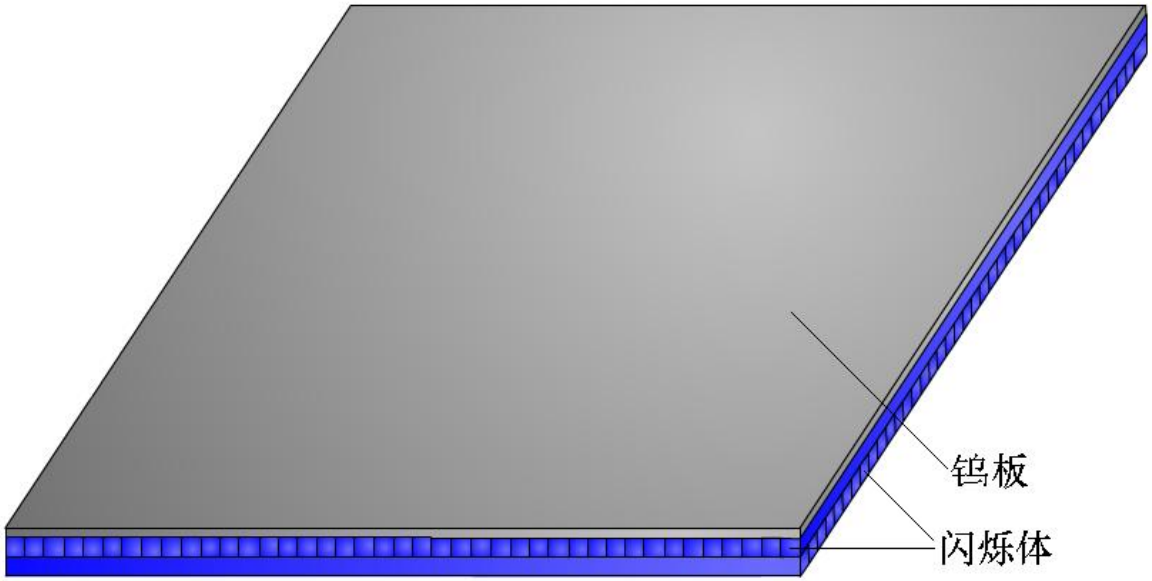
Preliminary design

(High Energy Gamma Ray detector, HEGARD)



One layer of the ECAL



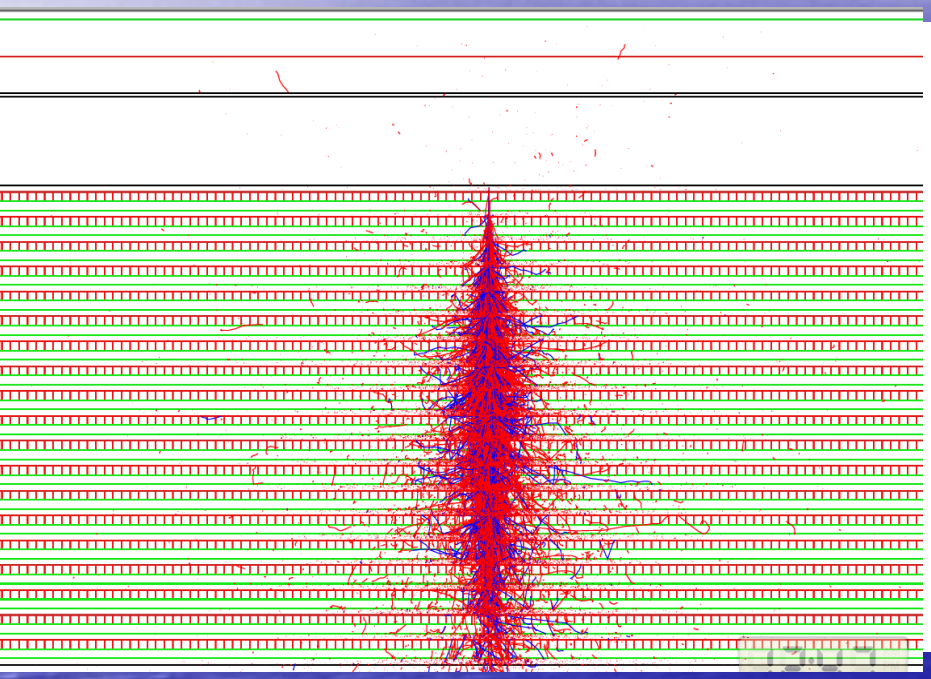
One layer = one radiation length, 20 layers in total

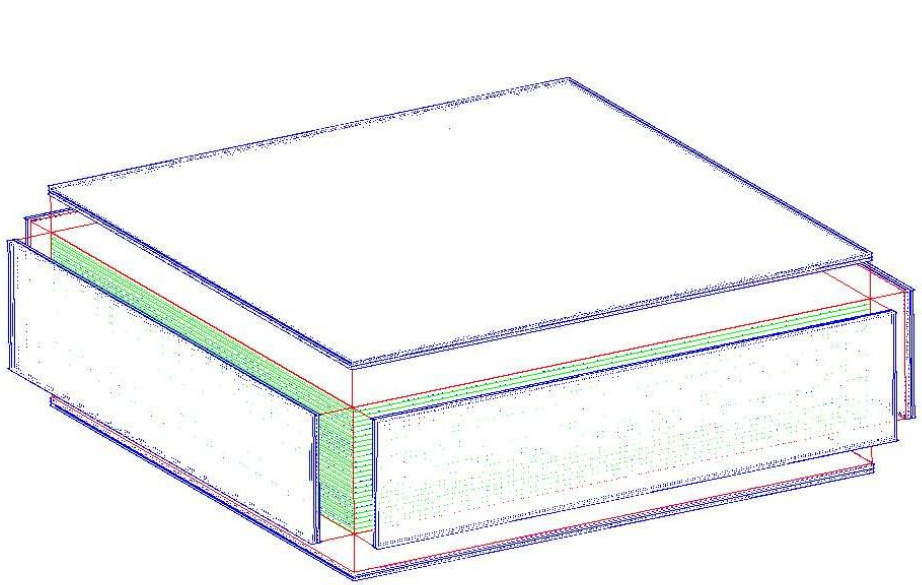
Weight and Acceptance

ECAL size m^2	naked detector kg	support kg	area m^2	geo. factor m^2sr
0.71x0.71	854	85	0.5	1.5
1.00x1.00	1707	154	1	3
1.40x1.40	3414	276	2	6
1.73x1.73	5121	393	3	9

$1m^2$ scenario meets the minimum requirement

MC simulation with G4



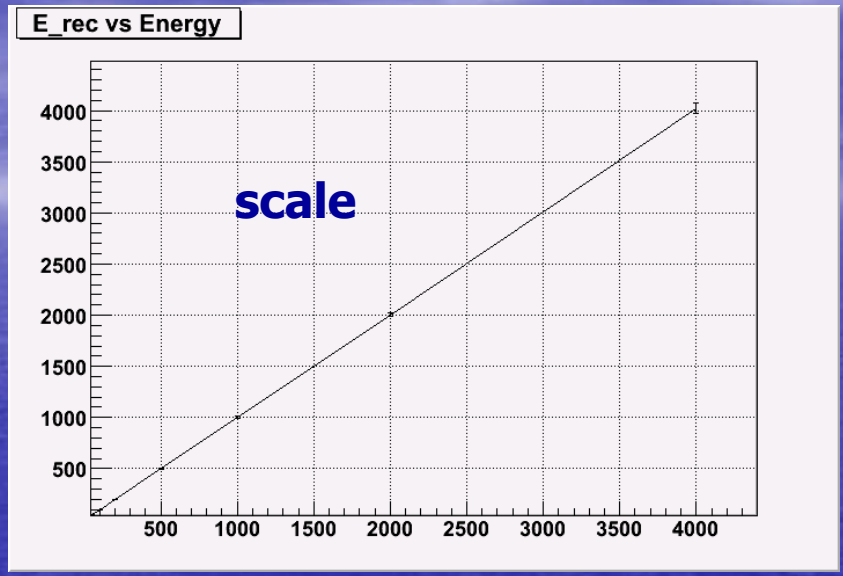


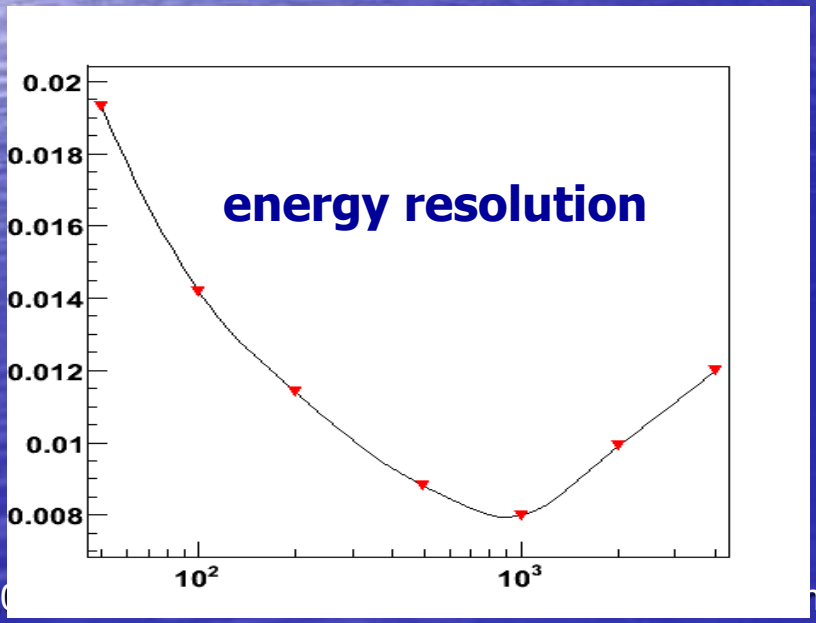
Hits level

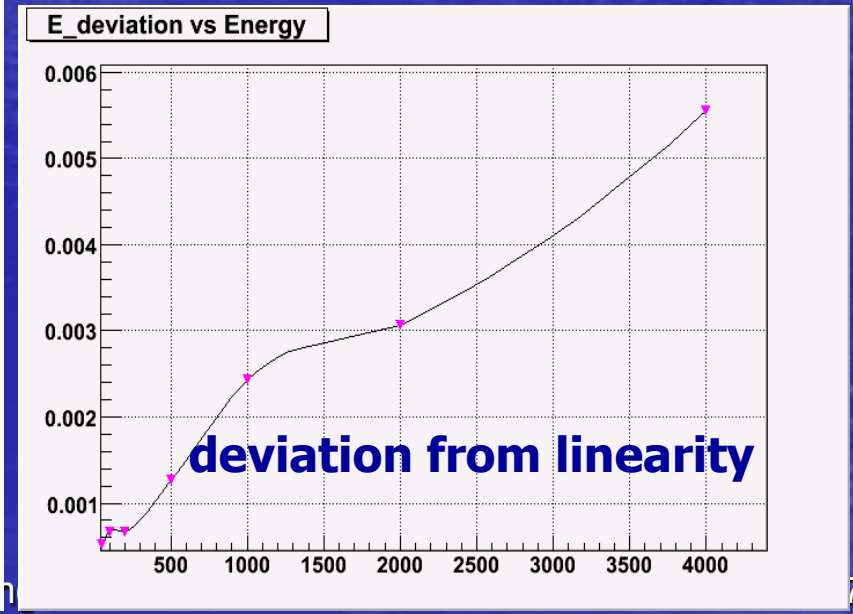
Energy measurement

From 30GeV to 4TeV , energy resolution better than 2%

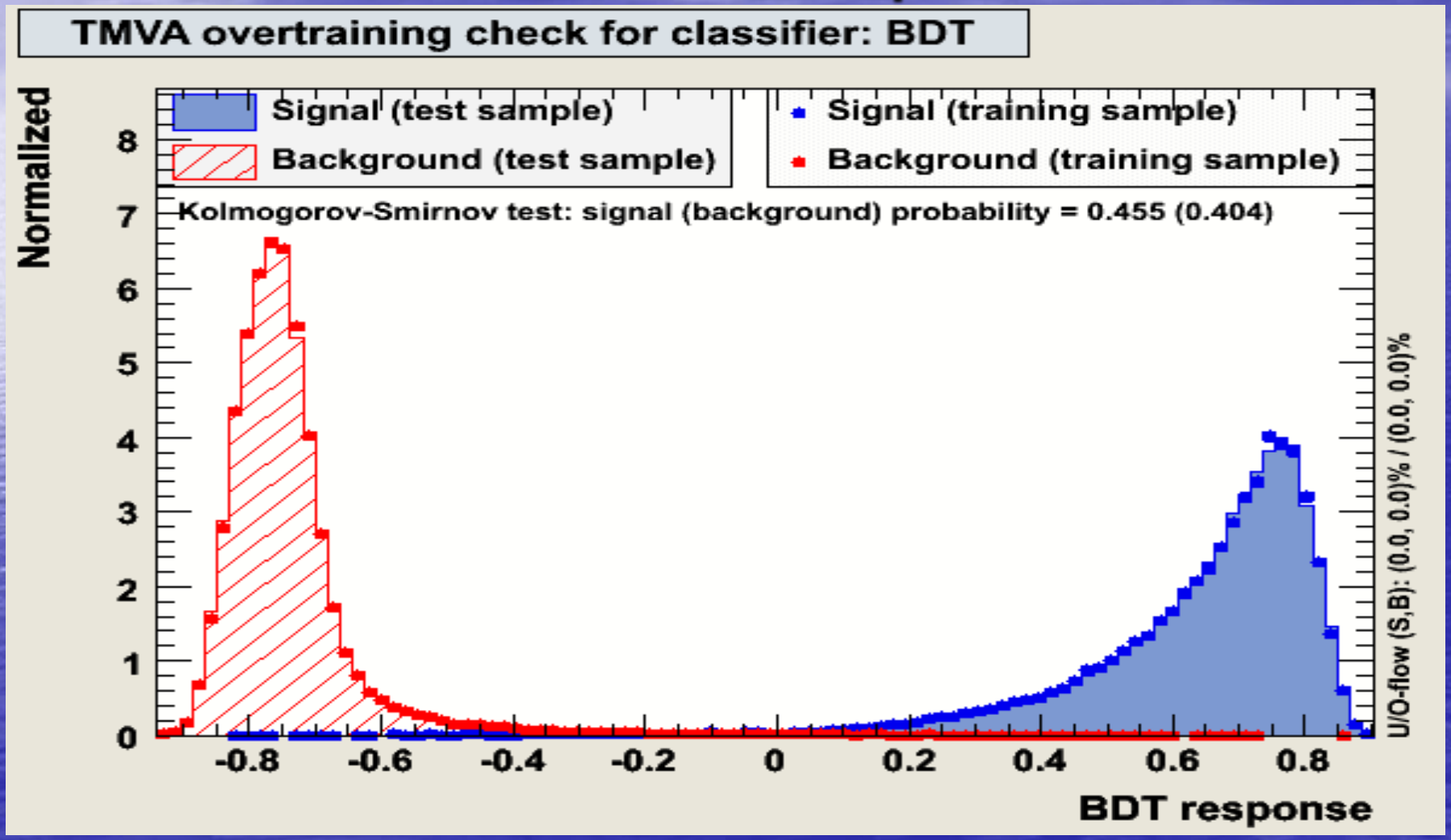
(leakage corrected)



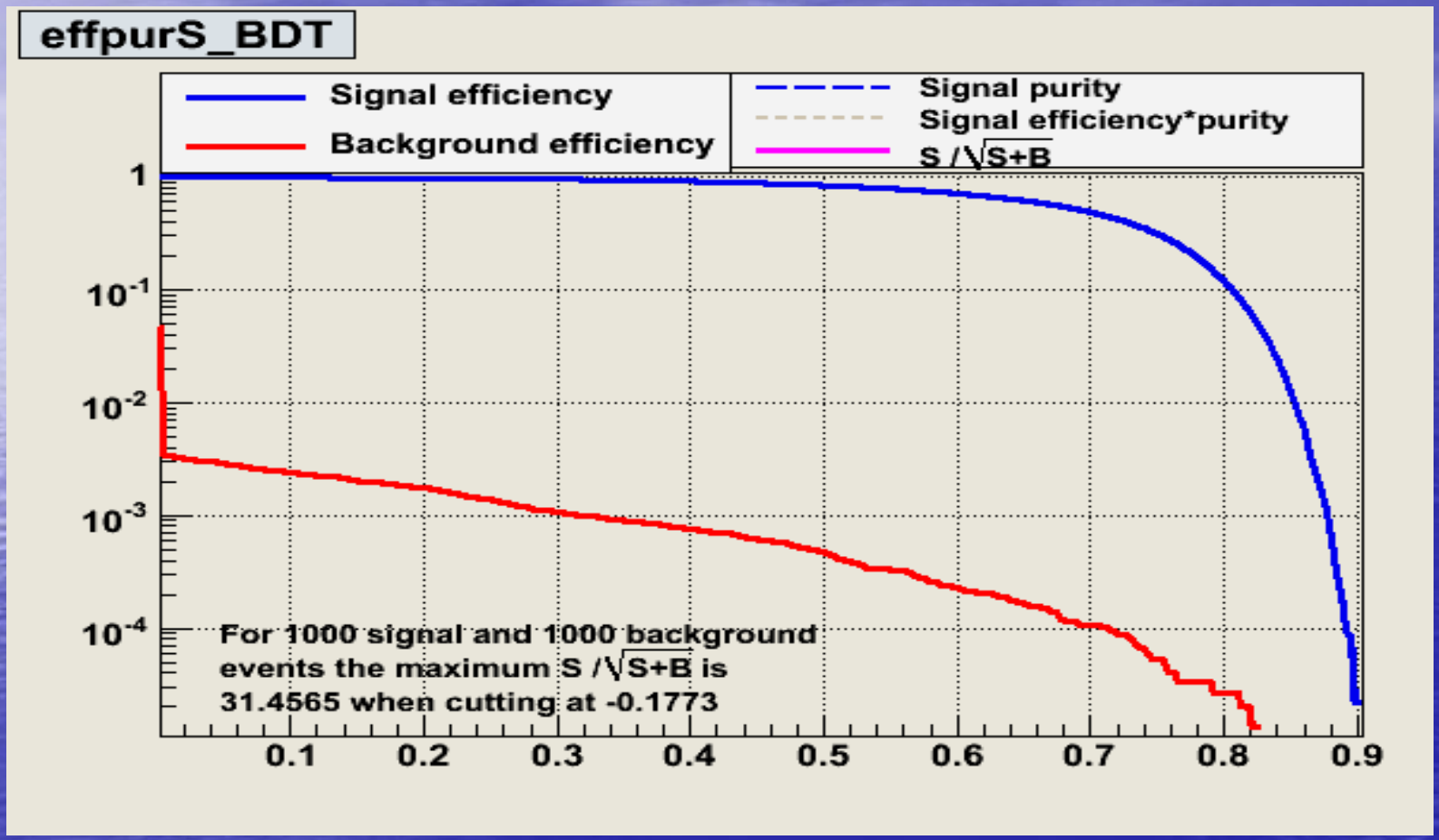




Gamma/proton separation from shower shape



γeff. vs. p eff.


effpurS_BDT
Signal efficiency
Background efficiency
Signal purity
Signal efficiency*purity
S /√S+B
1
10-1
10-2
10-3
10-4
For 1000 signal and 1000 background events the maximum S /√S+B is 31.4565 when cutting at -0.1773
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Gamma/proton separation

- Shower shape 10^{-4}
- neutron detection 10^{-1}
- charge detection 10^{-4}

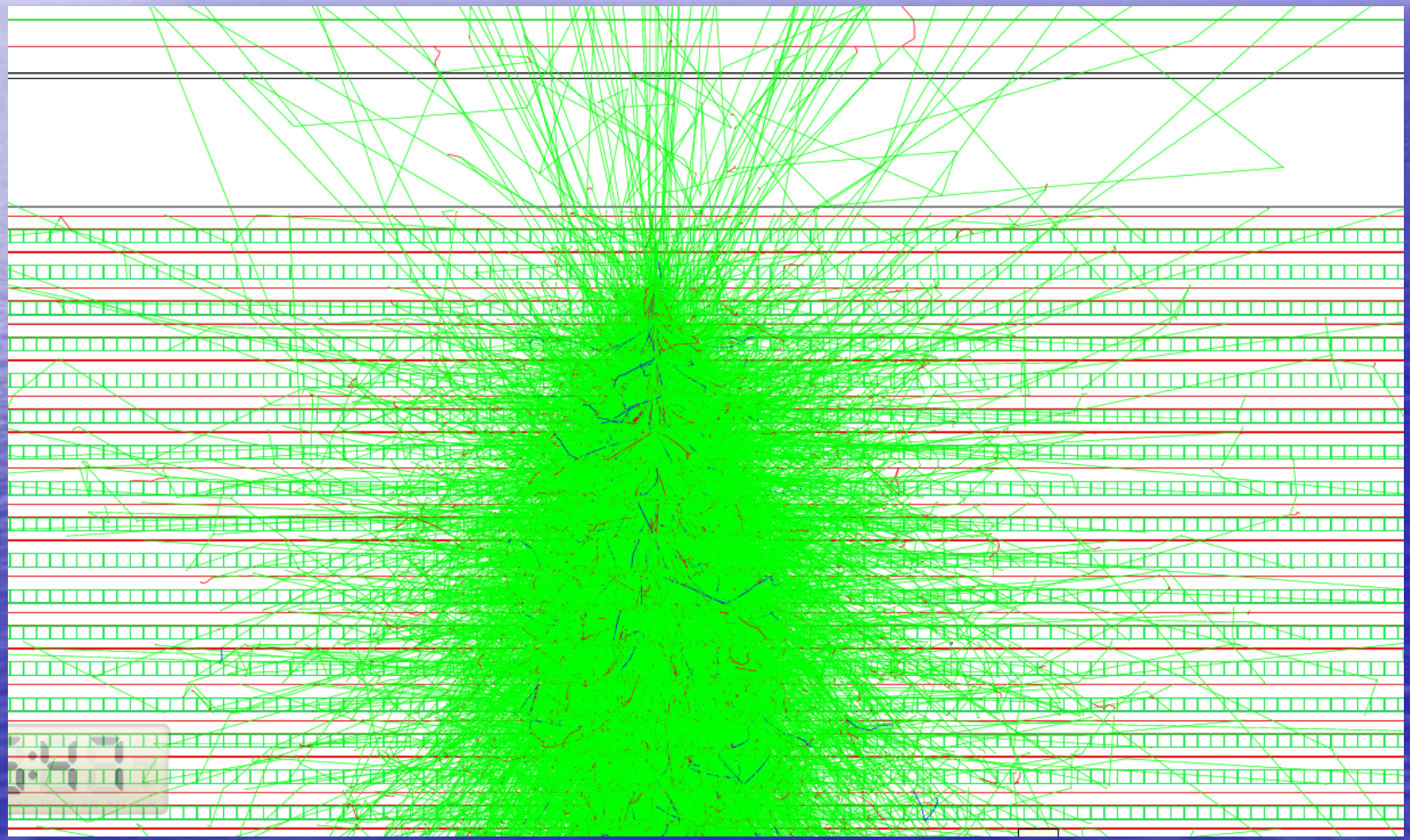
In total : better than 10^{-7}

meets the requirement

γ/e separation

- Veto efficiency 0.9999, i.e., only 10^{-4} electron can contaminate gamma
- The problem is gamma efficiency

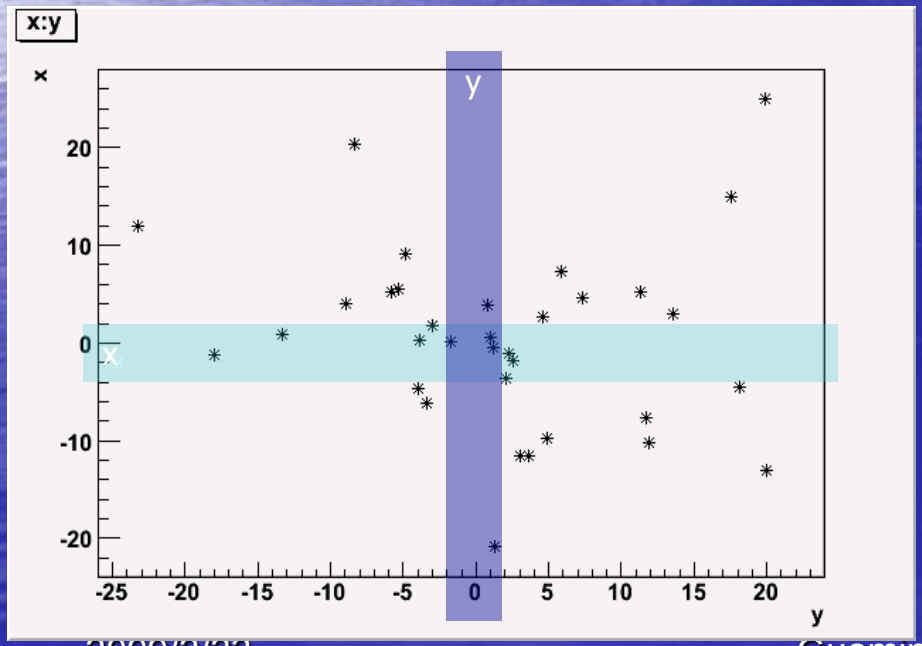
Gamma efficiency reduced by Backlash

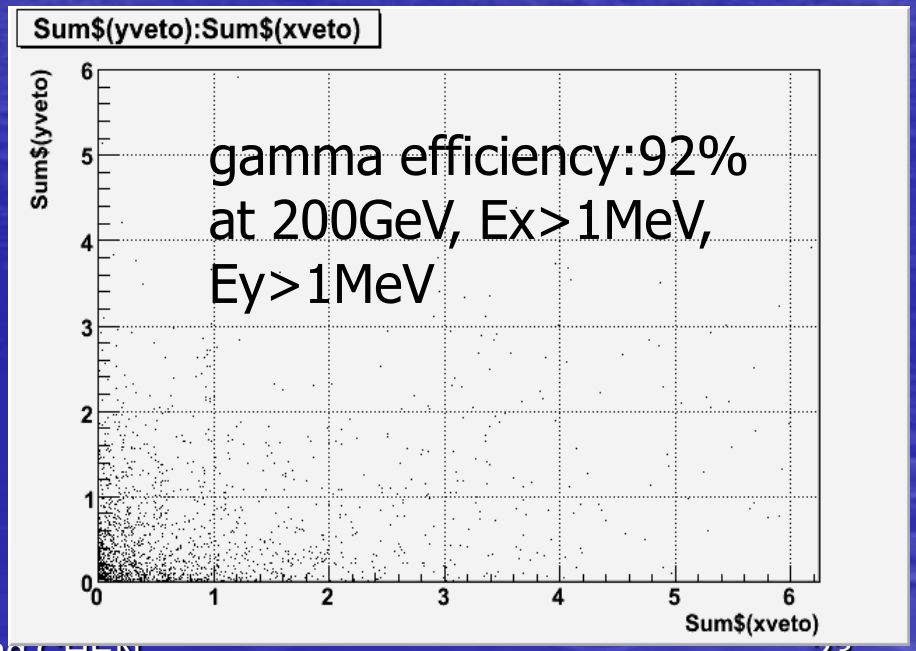


Backlash solution

For the electrons in the backlash:
1)Using plastic rubber to absorb it

For the gammas in backlash:
2）ID with position 3）ID with energy





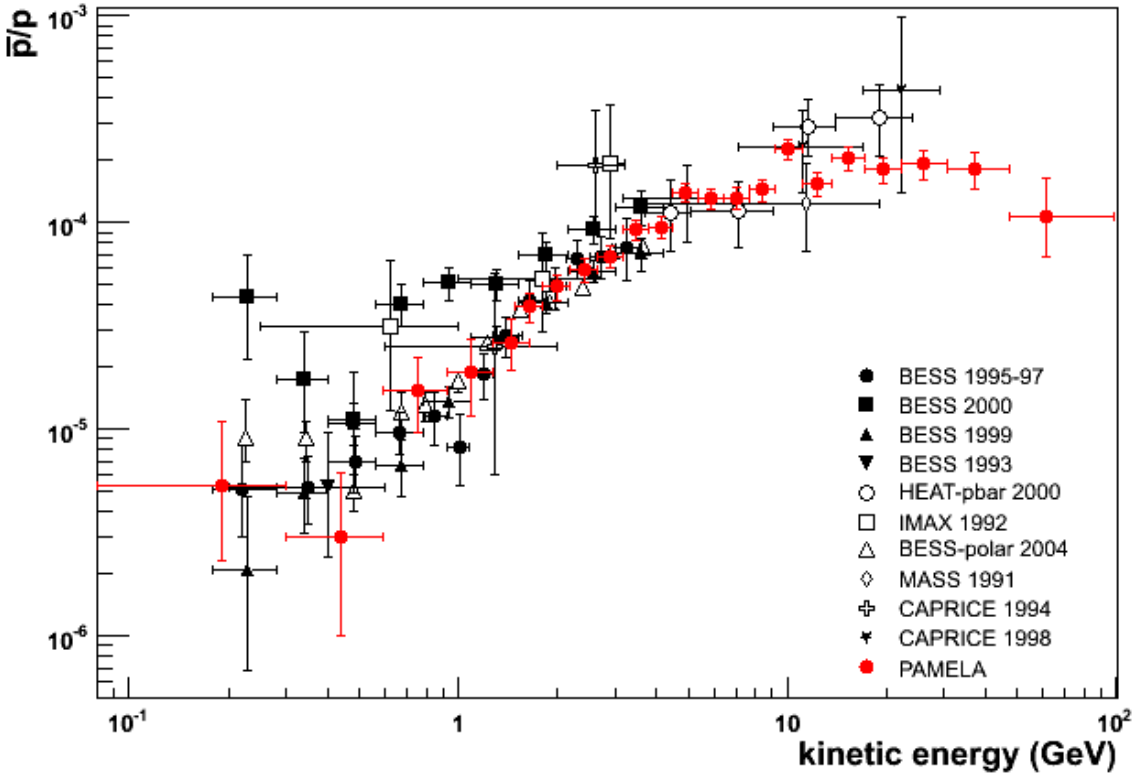
HEGARD concept

- size 112x112x40 cm^3
- weight 2000kg
- power consumption 500W
- time resolution 1ns
- area 1m^2
- geometry factor 3m^2sr
- gamma energy measurement 30GeV—4TeV
- energy resolution 2%
- angular resolution 0.5^o
- proton rejection 10^{-7}
- electron rejection 10^{-4}

Conclusion

The preliminary designed detector can meet the minimum requirement to observe the line emission from neutralino annihilation. But the design is open, you are welcome for cooperation!

backup


p̄/p
10^-3
10^-4
10^-5
10^-6
10^-1
1
10
10^2
kinetic energy (GeV)
BESS 1995-97
BESS 2000
BESS 1999
BESS 1993
HEAT-pbar 2000
IMAX 1992
BESS-polar 2004
MASS 1991
CAPRICE 1994
CAPRICE 1998
PAMELA