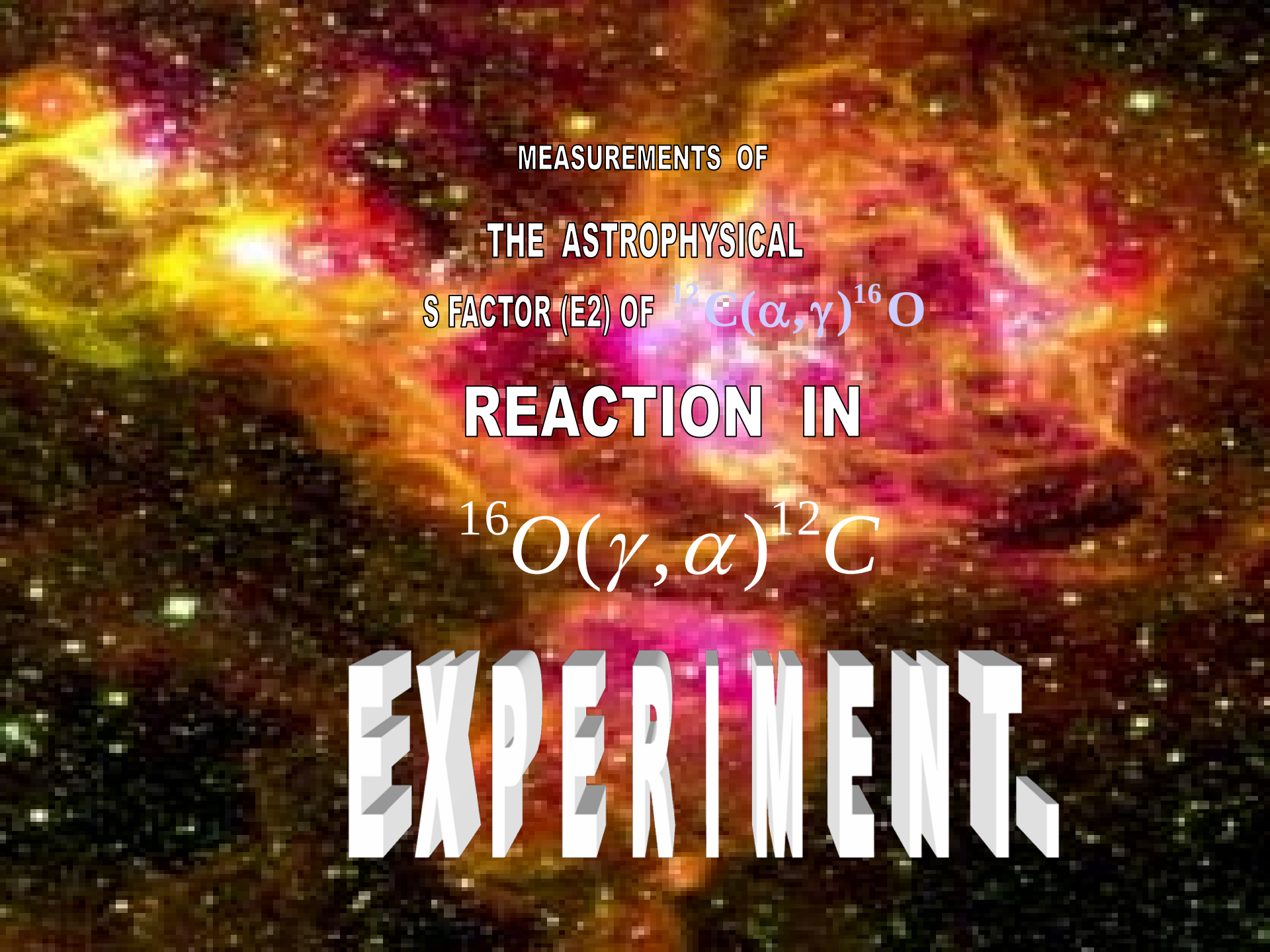
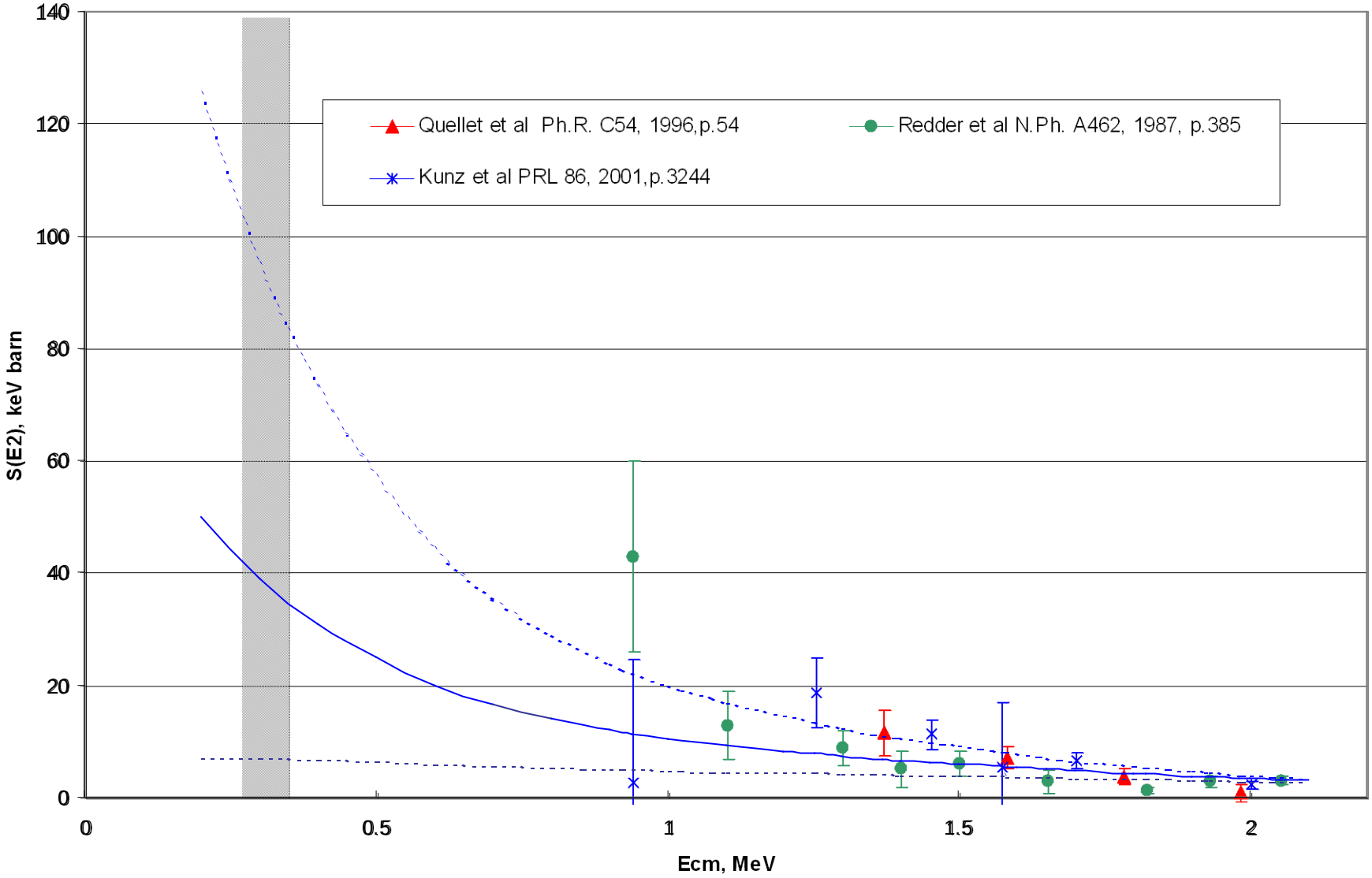

MEASUREMENTS OF
THE ASTROPHYSICAL
S FACTOR (E2) OF $^{12}C(\alpha,\gamma)^{16}O$
REACTION IN
$^{16}O(\gamma,\alpha)^{12}C$
EXPERIMENT.

EXISING EXPERIMENTAL DATA



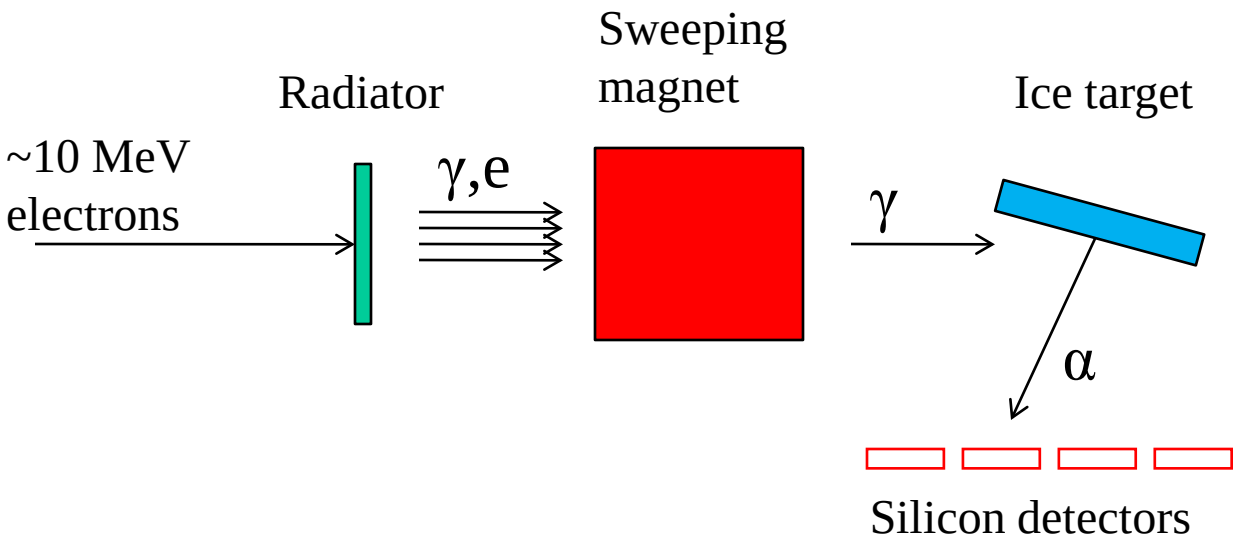
Cross-section of $^{16}O(\gamma,\alpha)^{12}C$ reaction via $^{12}C(\alpha,\gamma)^{16}O$.

$$\sigma_{\gamma,\alpha} = \mathbf{R} * \sigma_{\alpha,\gamma}$$

$$\mathbf{R} = \frac{\mathbf{g}_{\alpha} \cdot \mathbf{g}_{\mathbf{C12}}}{\mathbf{g}_{\gamma} \cdot \mathbf{g}_{\mathbf{O16}}} \cdot \frac{(\mathbf{k}_{\alpha+\mathbf{C12}})^2}{(\mathbf{k}_{\gamma+\mathbf{O16}})^2},$$

$E_{c.m}$, MeV	0.6	1.0	1.6
ω, MeV	7.762	8.162	8.762
R	49.5	74.6	104
$\sigma_{\alpha,\gamma}(E2)$, cm^2	$9.47 \cdot 10^{-38}$	$1.15 \cdot 10^{-35}$	$2.70 \cdot 10^{-34}$
$\sigma_{\gamma,\alpha}(E2)$, cm^2	$4.69 \cdot 10^{-36}$	$8.60 \cdot 10^{-34}$	$2.80 \cdot 10^{-32}$

New proposal



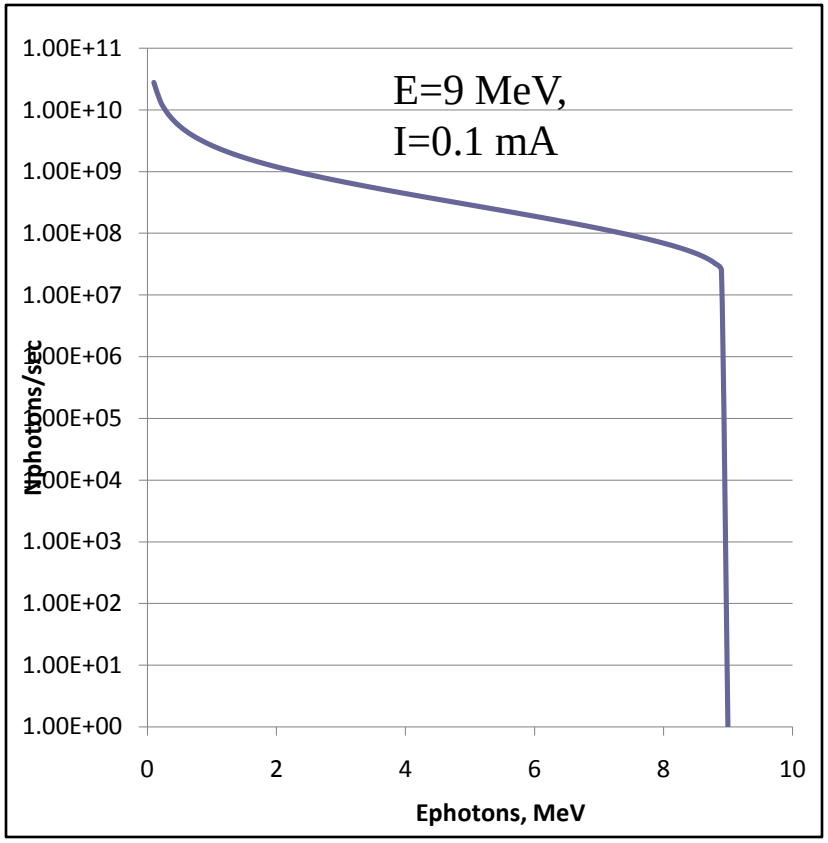
0.75 MeV α-particles range in ice is ~8 μm. To increase luminosity γ beam strikes the target at shallow angle $\theta \approx 1/\gamma \approx .05$. Detectors must have very thin dead layer (less than 1 μm)

Experiment conditions

The following assumptions were made to estimate the expected accuracy of the experiment.

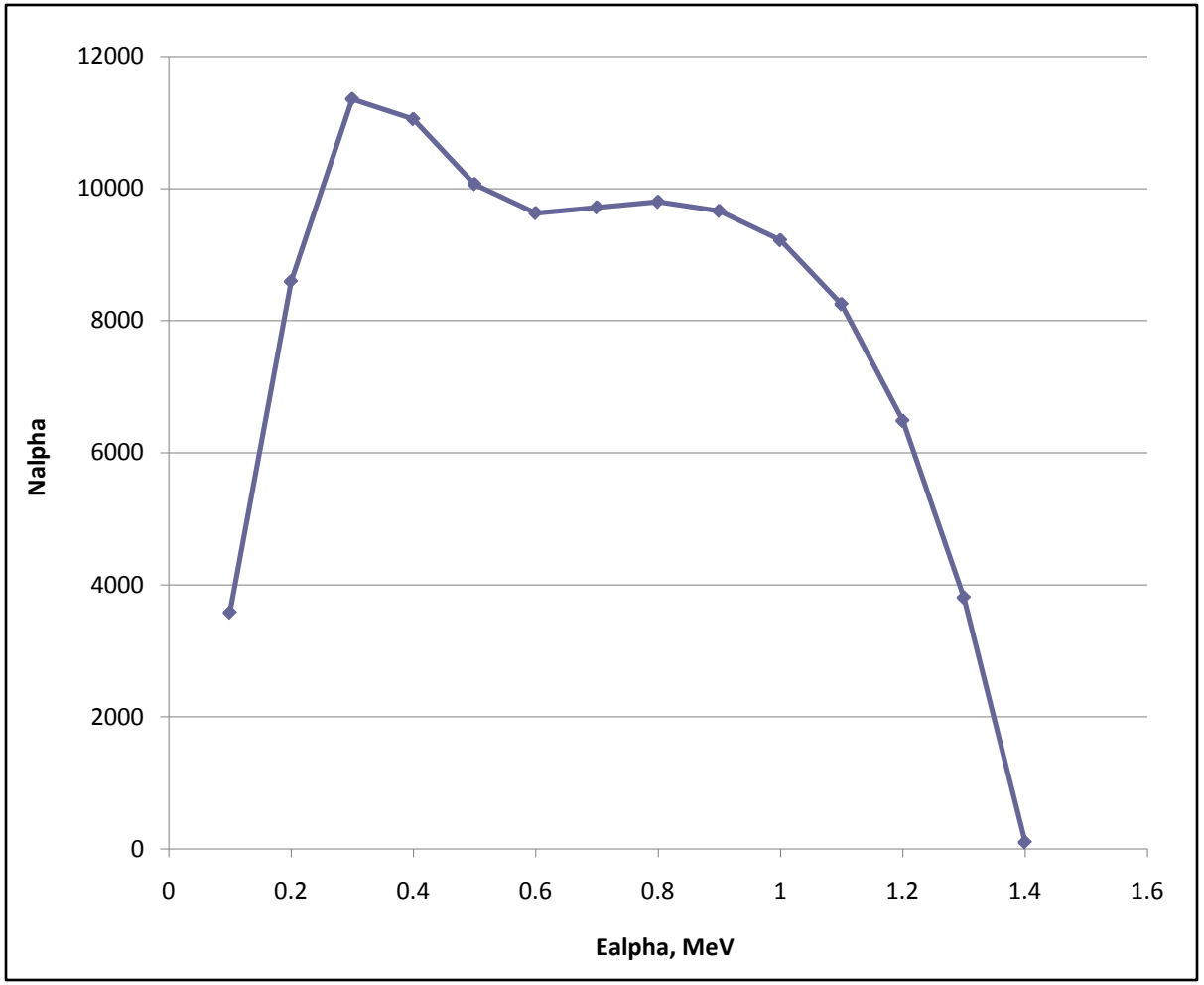
- The electron current 100 μA
- The detectors cover 10 % of 4π
- Each point statistics is accumulated over 30*20=600 h
- The total cross-section is measured, without separation on E1 and E2 parts. The separation is possible using the angular distribution of the α-particles, but it is difficult to estimate the resulting accuracy without very detailed analysis.

Bremsstrahlung spectrum

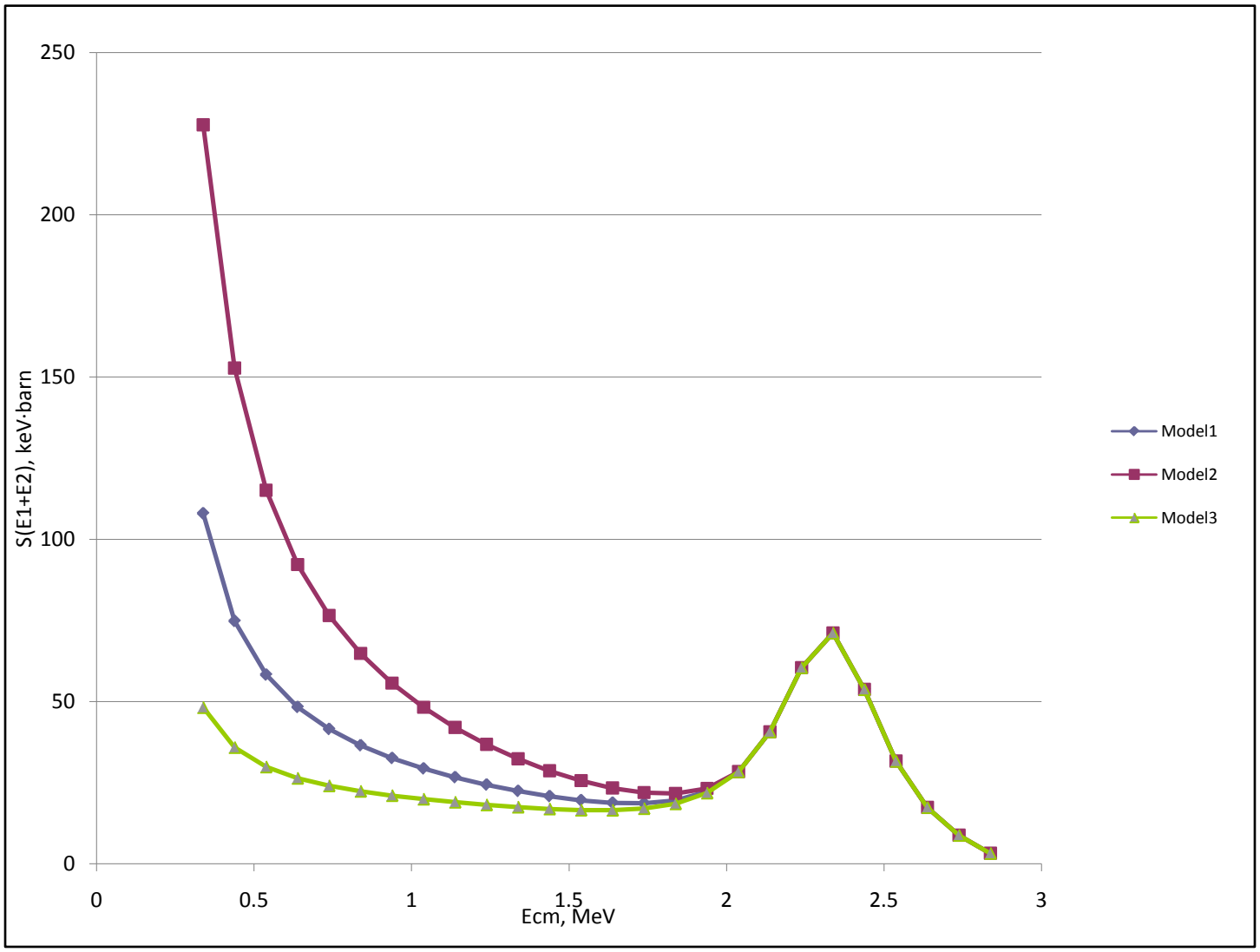


Since the cross section drops very fast with the photon energy, only photons with the highest energy will contribute to the counting rate.

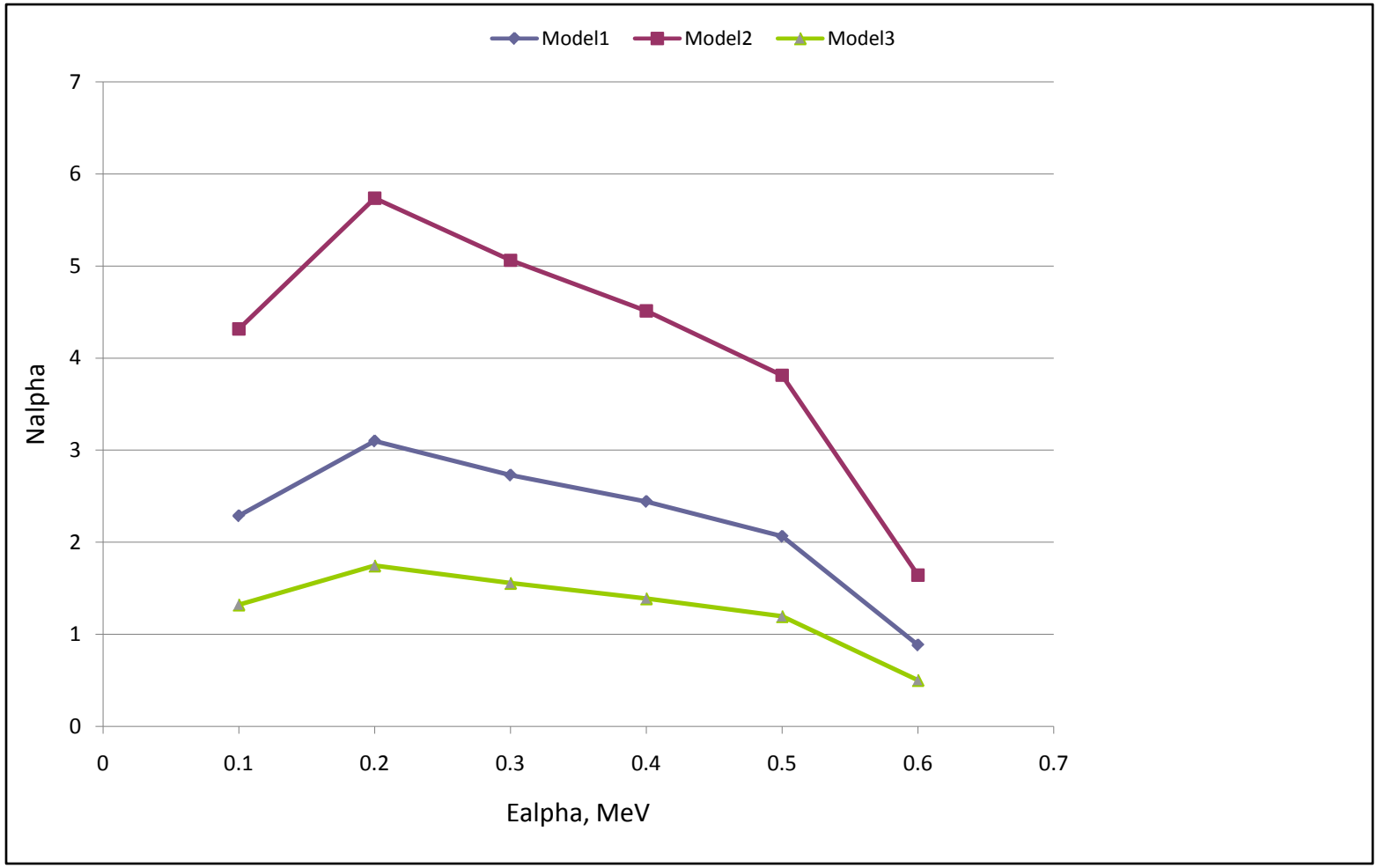
Spectrum of alphas in detectors



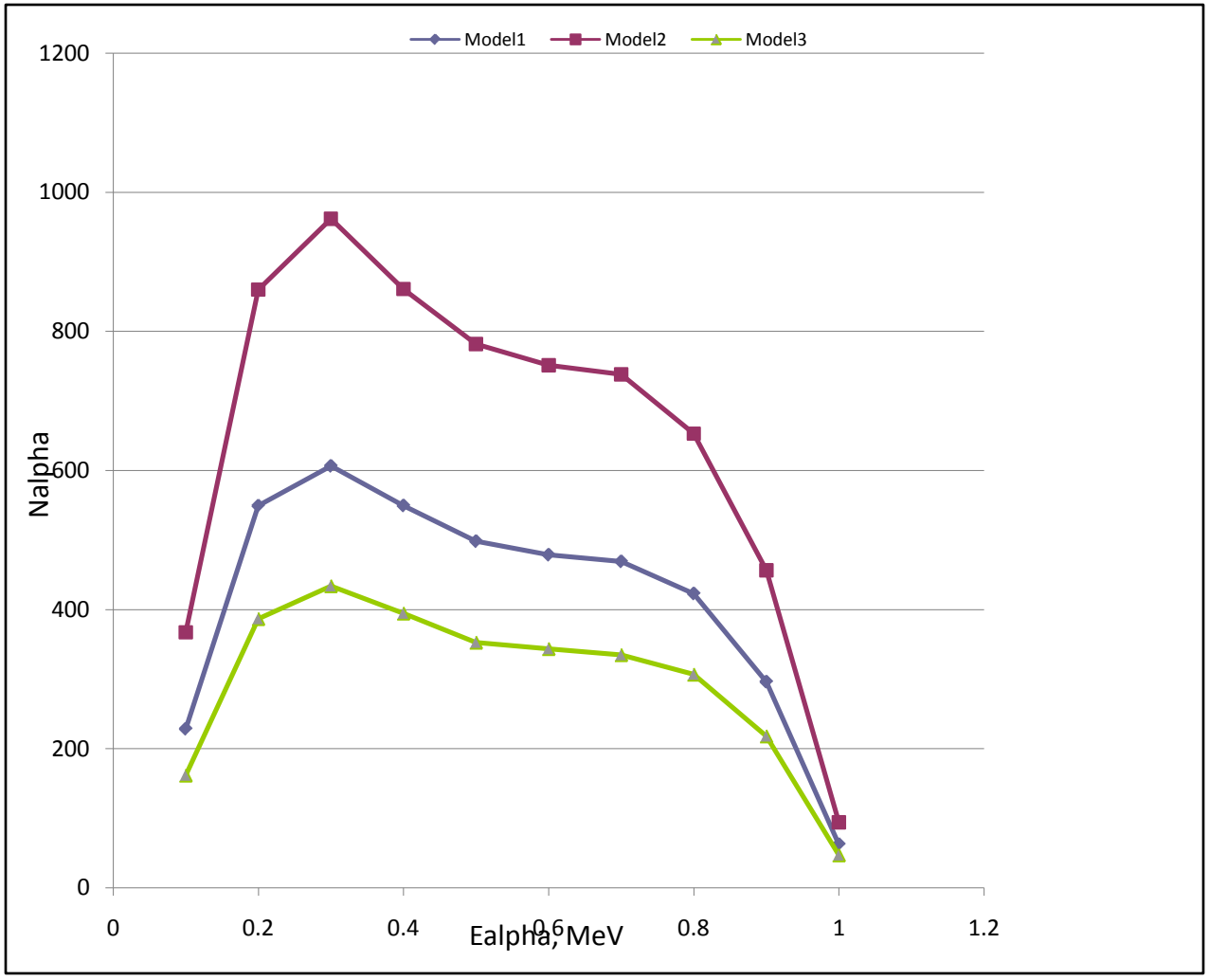
Three different models of S-factor



Ebeam=8 MeV

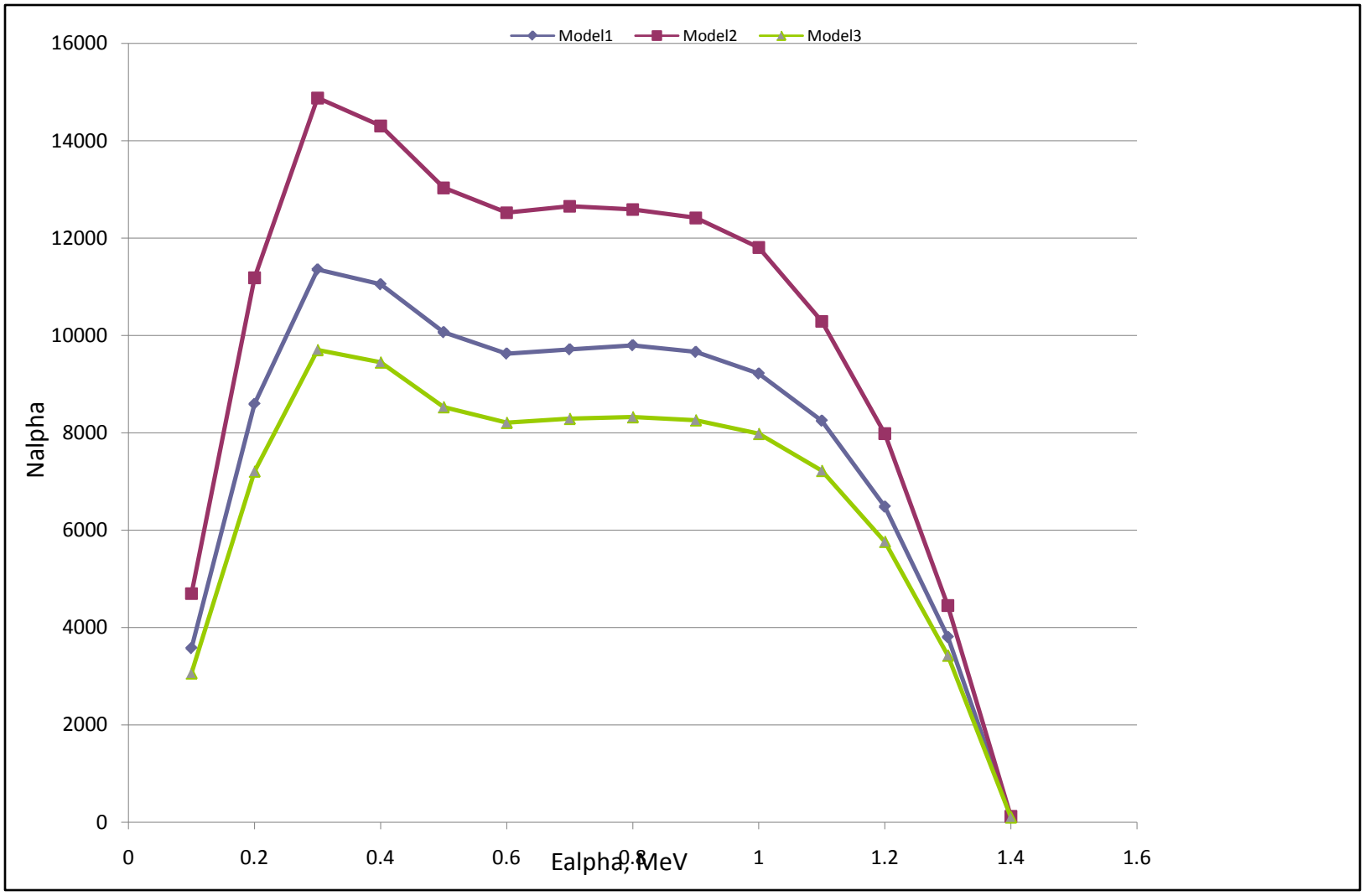

Model1
Model2
Model3
Nalpha
Ealpha, MeV
0
1
2
3
4
5
6
7
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

Ebeam=8.5 MeV

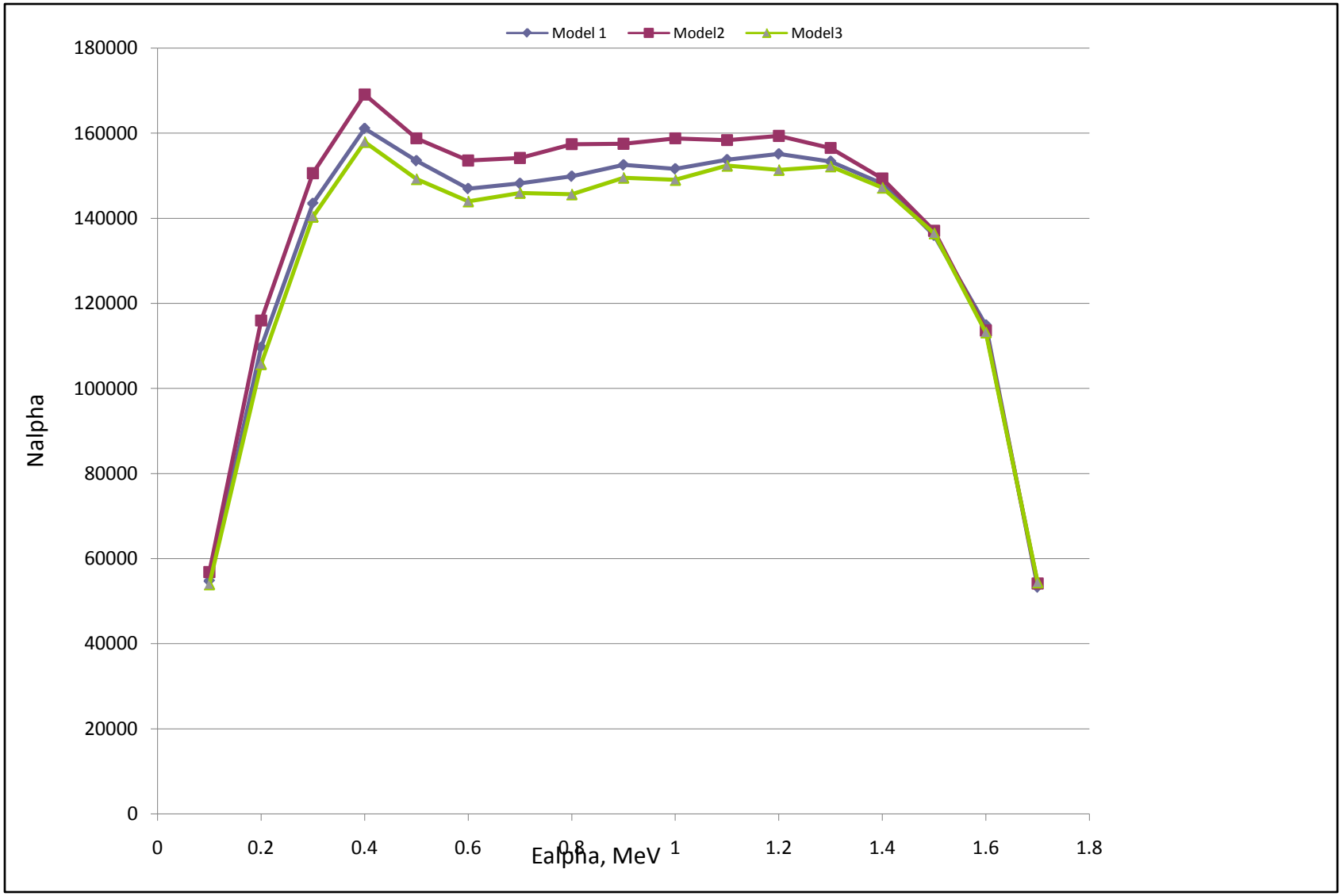


~ 80% of the events are generated by top 200 keV of the photon spectrum! (corresponds to Ecm=1.1÷1.3 MeV)

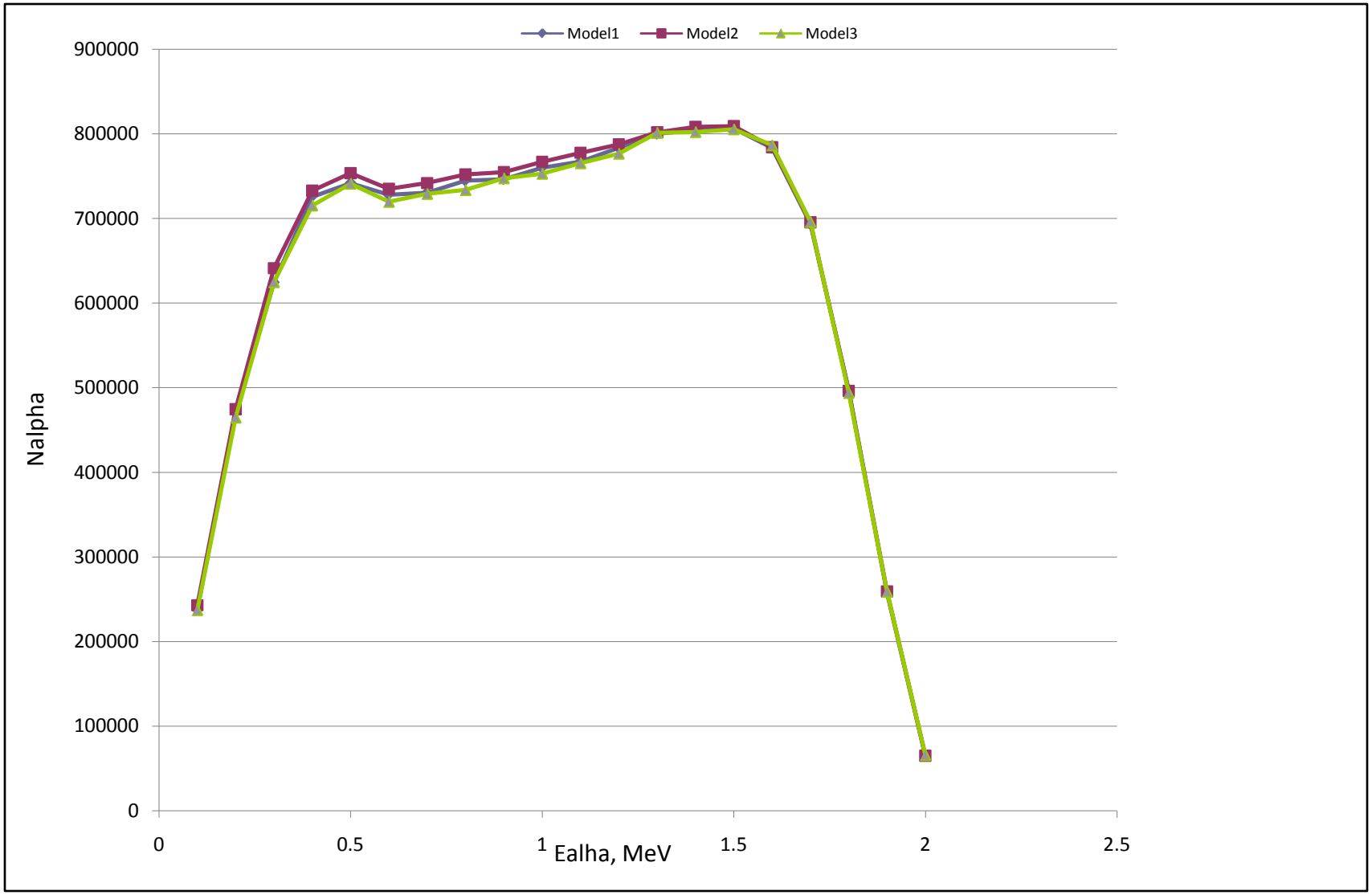
Ebeam=9 MeV


Model1
Model2
Model3
16000
14000
12000
10000
8000
6000
4000
2000
0
Nalpha
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Ealpha, MeV

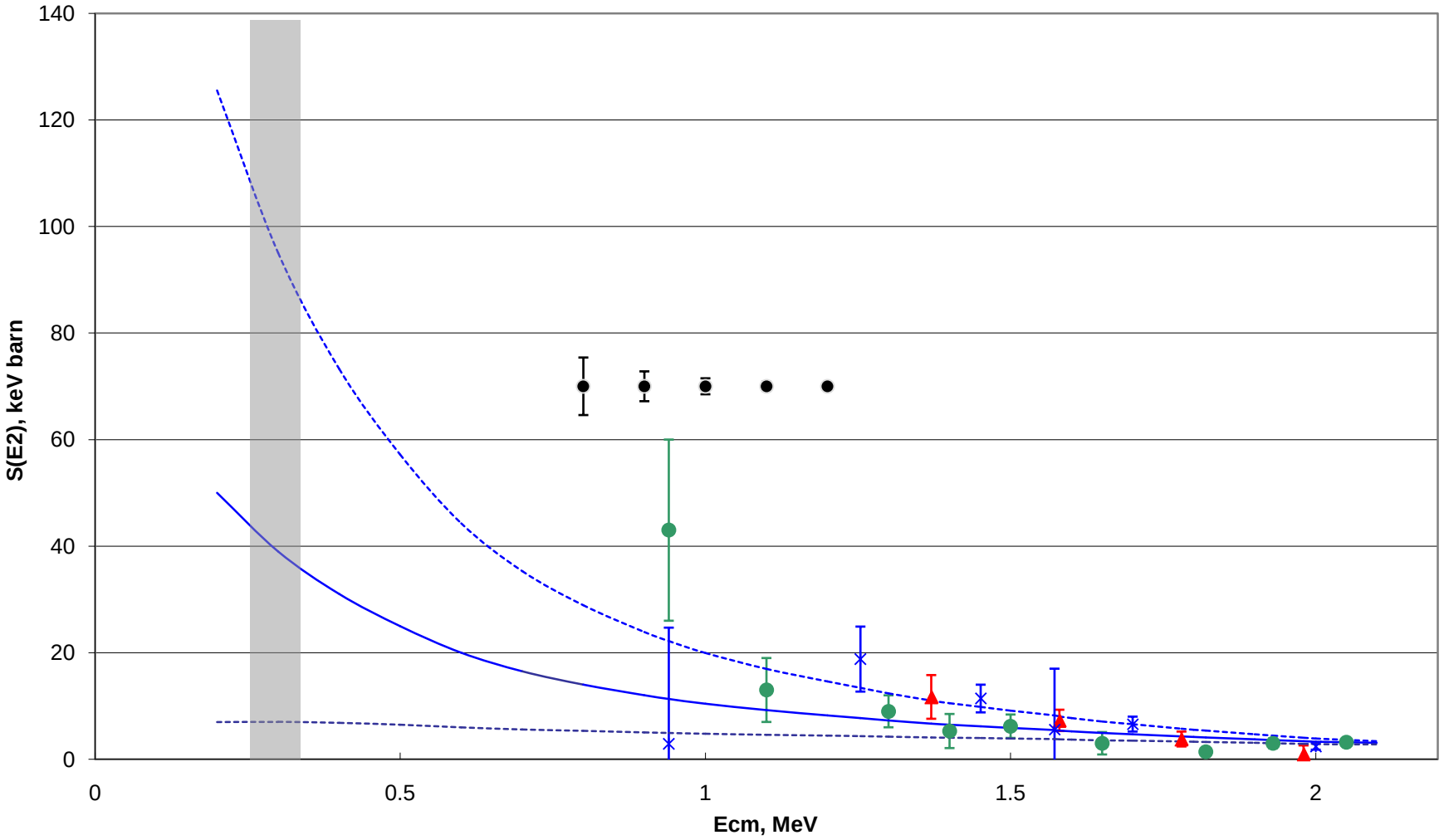
Ebeam=9.5 MeV


Model 1
Model2
Model3
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Nalpha
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Ealpha, MeV

Ebeam=10 MeV

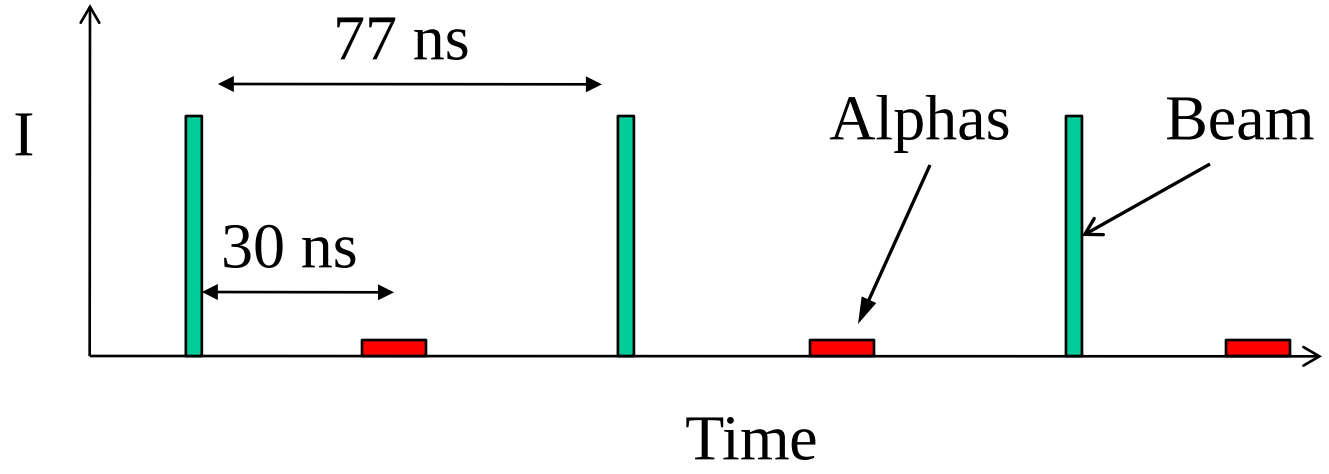

Model1
Model2
Model3
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
Nalpha
0
0.5
1
1.5
2
2.5
Ealha, MeV

Expected statistical errors



Experimental site

FZD (Drezden – Rossendorf)
Radiation Source ELBE.
Superconductive RF gun, superconducting linac.
Average current up to 1 mA, pulses 2 ps, 77 ns between pulses.
TOF of α is about 30 ns – solves the background problem.



Issues - background

1. Proton threshold in ^{16}O is higher than α threshold, no protons expected. However, there will be plenty of electrons and positrons from pair production. Detectors must have very thin sensitive layer (of the order of 10μm) in order to minimize the sensitivity to fast particles.
2. The ice layer must be thick enough to stop protons coming from the cooling plate.
3. Most likely, isotope enriched water must be used to remove the background from ^{18}O .

Oxygen isotopes

$$\sigma = \sigma_{nuclear} \cdot T_{coulomb} = \sigma_{nuclear} \cdot \exp(-\sqrt{\frac{E_{coulomb}}{E_{c.m.}}}) = \sigma_{nuclear} \cdot \exp(-\sqrt{\frac{E_{coulomb}}{E_{\gamma} - T}})$$

$E_{coulumb}$ - height of the Coulumb barrier, T – alpha threshold. E_{γ} =8 MeV.

Isotope	Abundance (A)	T	Tcoulumb	A*Tcoulumb
O16	99.76 %	7.16 MeV	$1.9 \cdot 10^{-10}$	$1.9 \cdot 10^{-10}$
O17	.038%	6.36 MeV	$1.0 \cdot 10^{-7}$	$3.8 \cdot 10^{-11}$
O18	.2%	6.23 MeV	$2.0 \cdot 10^{-7}$	$4.0 \cdot 10^{-10}$

Detectors

Silicon detectors are a major issue. They must be very thin (10÷100μm), have very thin dead layer (<1μm) and have very good time resolution (10 ns). Such detectors exist, but they are very expensive (~10 K per cm^2), and we need to cover at least 100 cm^2. The electronics could be even more expensive.

Ideally, we want to find collaborators who already have such detectors. There are some silicon detectors at ELBE, but it is unclear if they match our requirements, and how many detectors they have.