Proposed modification for Gamma-400 to widen its science objectives. Current status in US and perspectives for contribution to the collaboration

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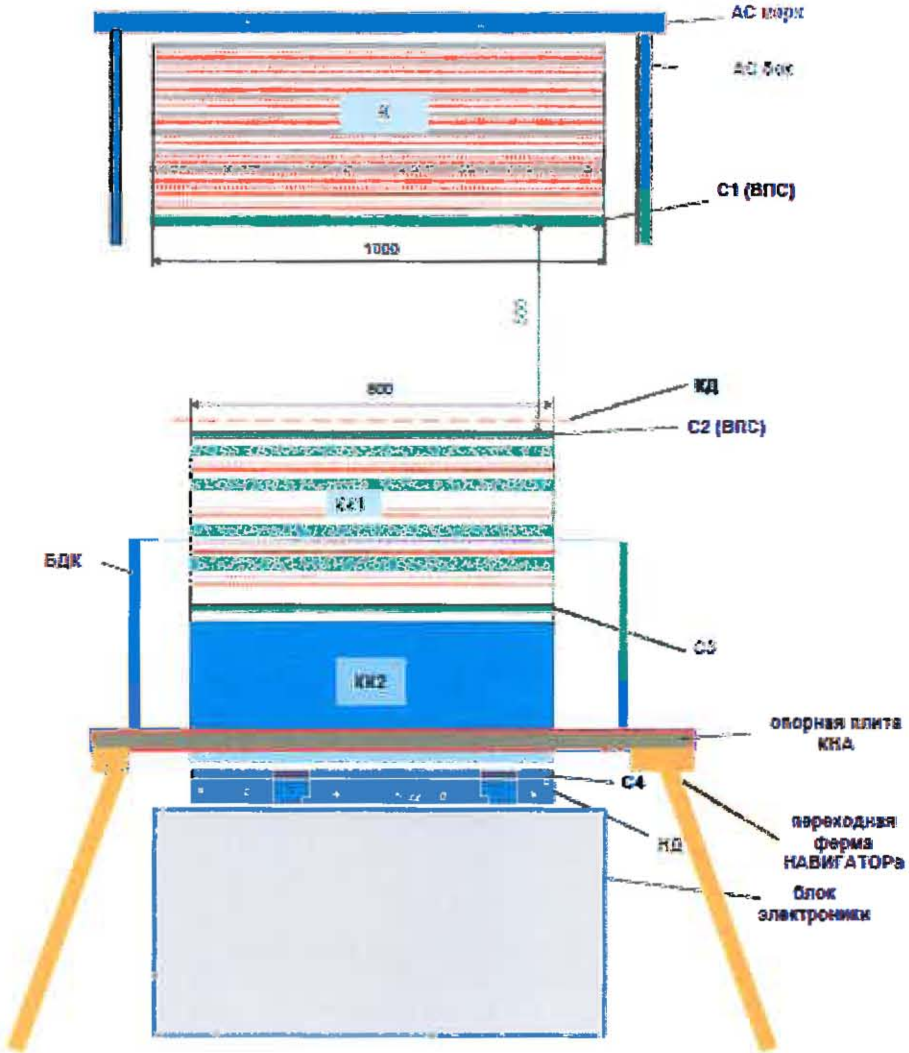
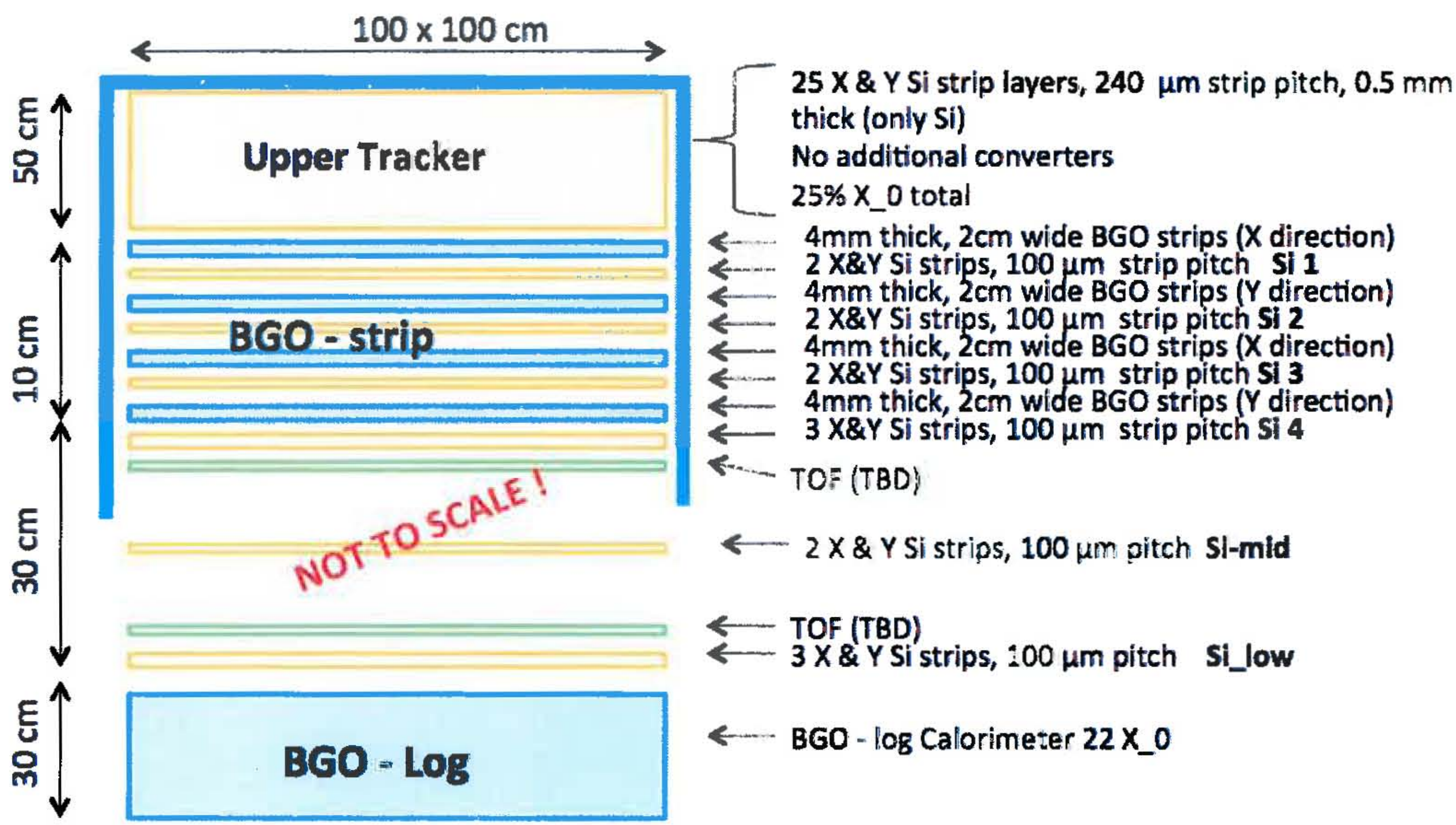
Gamma-400 conceptual design (as of April 9, 2012)



Proposed Concept:

1. **Science focus:** two energy ranges. The first is from a few GeV down to as low as possible (achieved by the upper part of the instrument), hereafter LE. The second range of interest is above ~ 50 GeV, achieved by the bottom part, hereafter HE. The range between these two ranges is assumed to be best explored by Fermi LAT
2. **Fully active instrument for LE**, with energy measurement in all layers. No passive material. This maximizes the performance for low energy. BGO-strip calorimeter provides energy measurement for LE photons, and acts as a converter for HE. BGO-log calorimeter provides energy measurement for HE



Difference with current "baseline" design:

- No tungsten converters (lowest multiple scattering for LE). All photon conversions occur in active elements (no "missed" energy in converters).
- "Thick" active converter (BGO-strip) serves to measure energy for LE, and serves as a converter for HE. Segmented onto "strips", it has some coordinate measurement capability, allowing to assign the energy deposition to the track (addressing the "ghost" problem)
- As a result, majority of converted LE photons will be detected, "fully seen", and their energy will be measured with most possible accuracy

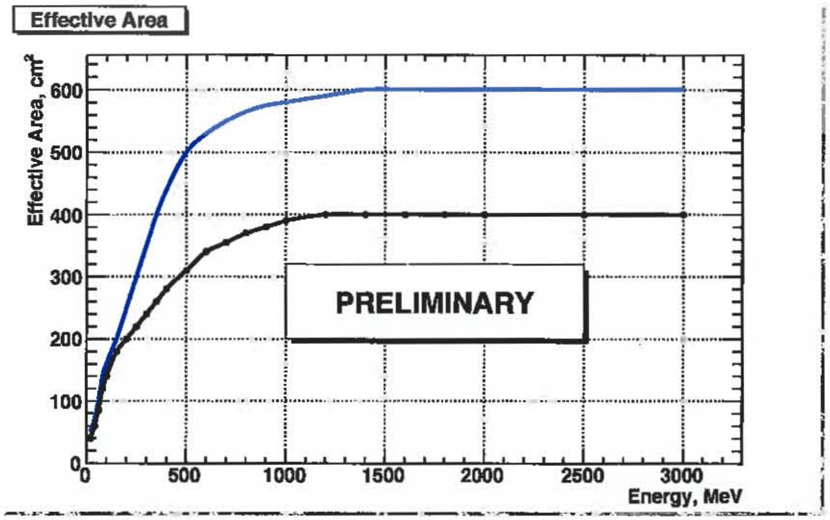
Totals:

- Total thickness of converter for LE: ~ 0.25 X_0
- Total thickness of converter for HE (BGO-strip): ~ 1.7 X_0
- Total thickness of BGO-log (HE) calorimeter : 22 X_0
- Number of X & Y Si strip planes : 39
- Number of Si-strip channels (assumed each other strip read out) : 2.4×10^5
- Number of BGO strips : 200
- Number of BGO-strips channels : 400 (strips are read out from both ends)

Expected parameters (very crude estimates):

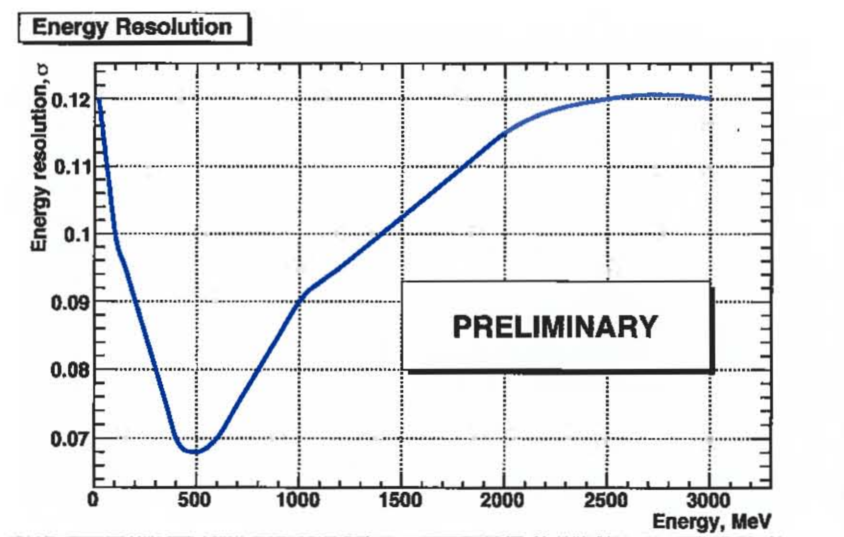
- Effective area for LE (at 100 MeV) : ~700 cm^2
- Angular resolution (PSF) at 100 MeV : 1 degree
- Effective area for HE (above a few GeV) : ~3,000 cm^2
- Angular resolution at 10 GeV / 100 GeV : 0.1 / 0.01 degree
- Energy resolution at 100 MeV / >10 GeV : TBD / 2-3%

Simulated performance for Low Energy range



Effective Area

Energy Resolution



Principe of operation:

Triggering: TBD. Requires detailed consideration because the instrument has to be capable to detect cosmic rays too. However the LE trigger can be borrowed from Fermi LAT and be built as "3-in-a-row & ROI". The condition can include a requirement for one of hit layers to have an energy deposition to be above given threshold (say 5 MeV) which would indicate an end of the event track. Most likely this trigger will require the on-board filtering (challenging)

LE energy photon (below a few GeV) converts into a pair in one of Si strips and follows downward. The energy of components is measured in Si strips and in following BGO-strip calorimeter. The stripping structure of this calorimeter and presence of Si strip plane in between allow to assign the energy deposition to the track. Energy resolution is determined by energy resolution of Si strips and BGO-strip calorimeter. Angular resolution is determined by the multiple scattering of the pair components in Si strips (0.01 X_0 in both X & Y planes)

HE energy photon can convert in BGO-strip (~ 22% of HE photons) and also converts in one of four BGO-strip layers (35% X_0 each, or 1.7 X_0 in total, with ~ 80% of conversion efficiency in total for HE photons). The conversion point will be determined by the followed Si strip plane with accuracy better than 0.1 mm. The photon direction will be reconstructed by means by means of Si strip layer Si 1 (or Si 2, or Si 3, or Si 4, depending where the conversion occurred), Si_mid and Si_low. Angular resolution will be limited by the Si strip pitch (0.1 mm) and distance between first point of the track and Si_low, approaching 0.01 degree for > 100 GeV. Energy resolution will be determined by the BGO-Log calorimeter (22 X_0 thick) and can approach 2-3 %, taking into account non-uniformity in individual crystal and FEE characteristics

Possible de-scoping:

- Reduced number of Si planes in the Upper Tracker (effective area will be reduced accordingly)
- Reduced number of BGO-strip layers (reduced effective area for HE). In a case of corresponding increase of the thickness of each BGO-strip layer the angular resolution for HE will get worse
- Reduction of the number of Si planes in Si 1, Si 2, etc – event recognition, and correspondingly the background removal can suffer

Issues / questions:

- viability of making 1 m long, 2 cm wide and 4 mm thick BGO strips. Since the maximum length of the BGO crystal is 30-40 cm, needed strip should be made of 3 of them with bonding by an optical cement with matching index. How will it work? Assuming ~ 1m of the light attenuation length, will there be enough signal from lowest signal in detector (~ 6 MeV for the mip) to provide adequate energy resolution? Another option is to have each of 3 segments read out independently – see below "moduling" for the tracker.
- do we need TOF? Can we recognize backward-upward moving photons by the image in BGO-Log calorimeter? The requirement for the backward-upward selection efficiency is rather modest: 1-2 %.
- Moduling (towering) of the Si planes. This can be an issue for LE pattern recognition and event selection. Needs careful consideration

The main issue : will be there any volunteers to provide enough Si strip planes? The modest cost estimate is ~ \$1M per X & Y plane, so it totals to ~ \$40M. The Russian side does not have these resources