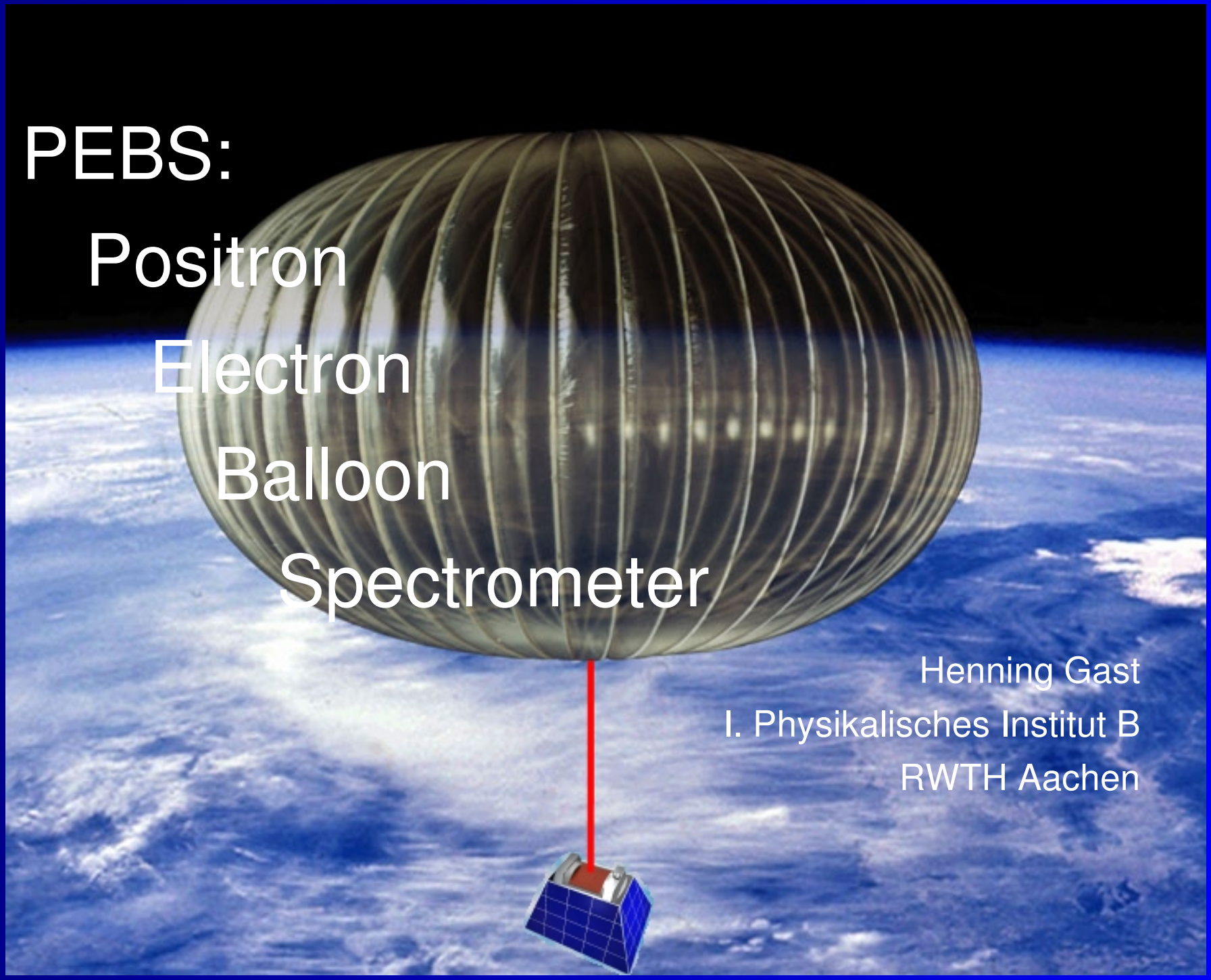
PEBS:
Positron
Electron
Balloon
Spectrometer



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Introduction

Goal:

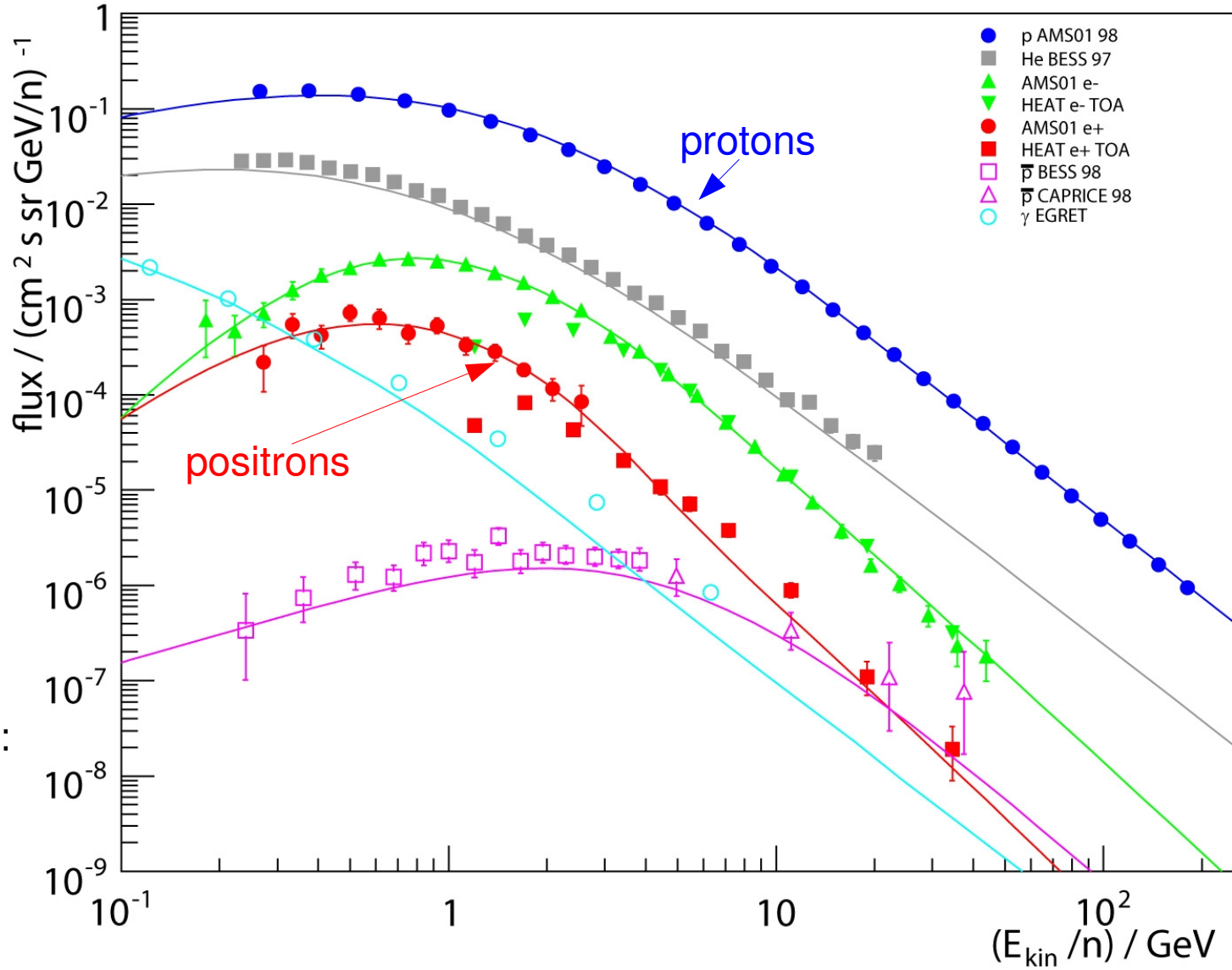
Measure the cosmic-ray positron fraction with a balloon-borne spectrometer.

Motivation:

Indirect search for dark matter.

Requirements:

- Large acceptance:
  > 0.1m^{2}sr for 20-day campaign
- Excellent proton suppression:
  1 in 1 million
- Good charge separation
- Payload weight < 2t
- Power consumption <1000W



Prospective performance of PEBS detector

acceptance @100GeV
and mission duration

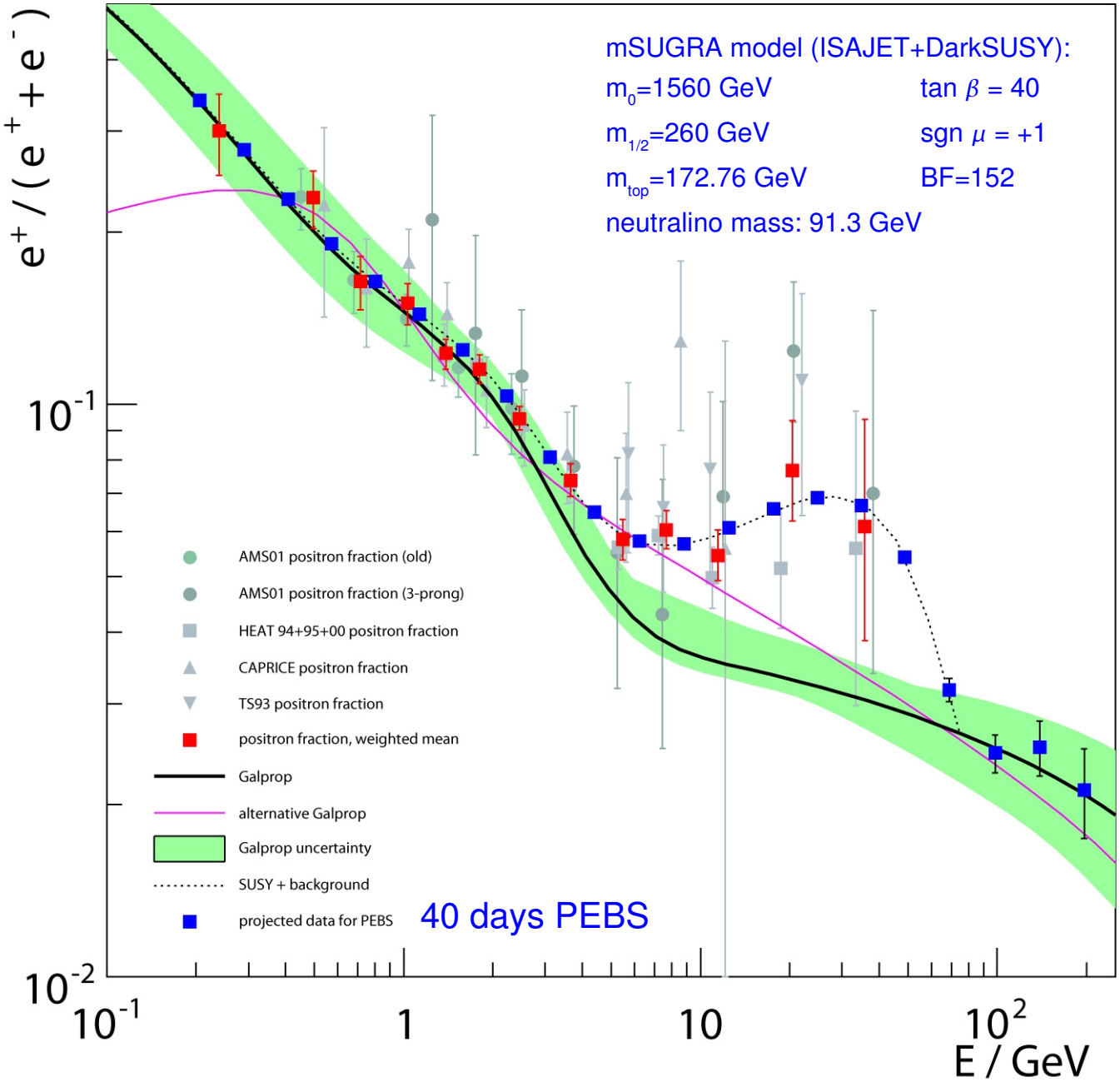
PEBS 0.4 m^2sr
100 days

PAMELA 0.002 m^2sr
1000 days

AMS02 0.08 m^2sr
1000 days

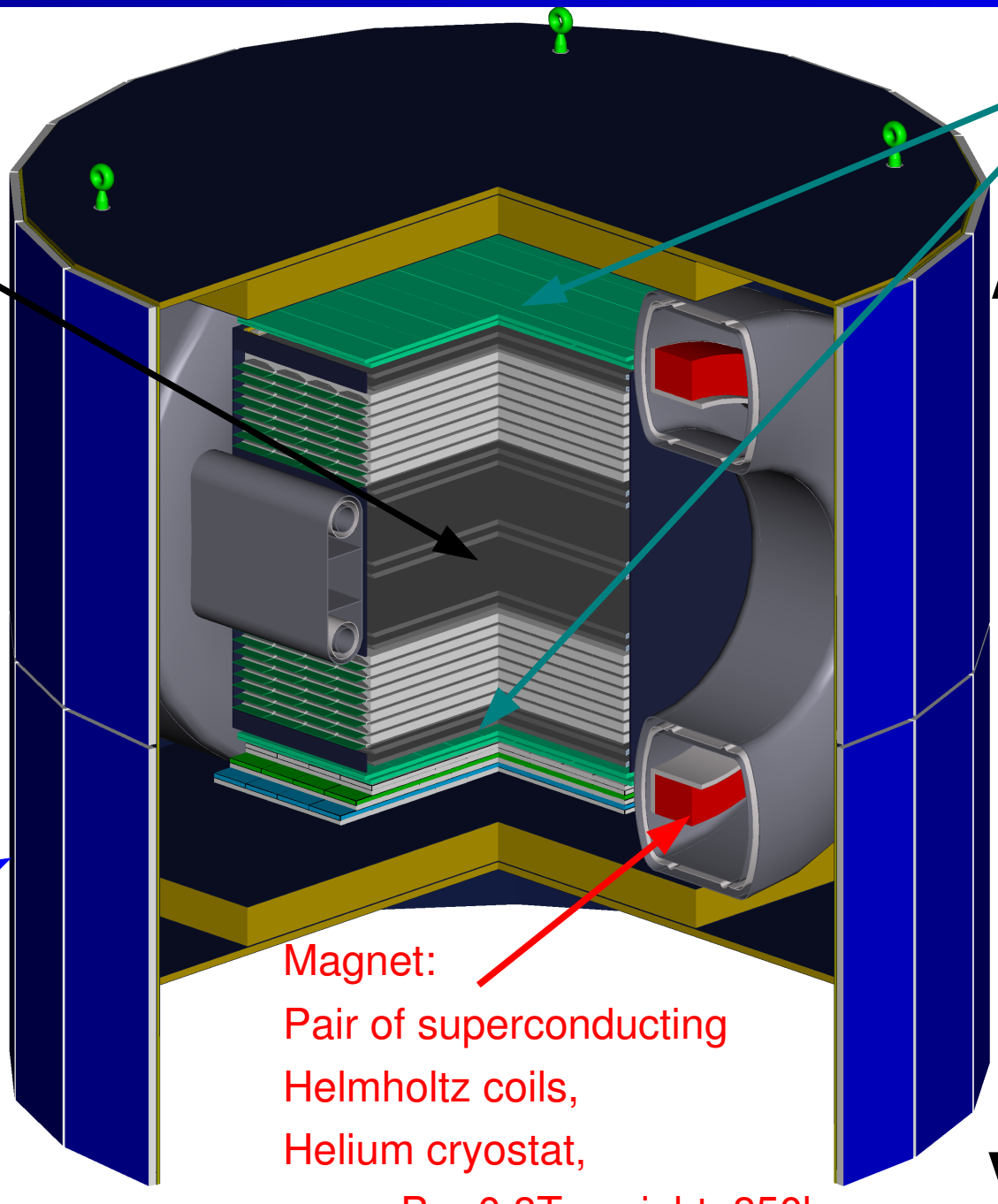
aim for first flight in 2012
accumulate statistics in additional flights

100 days PEBS=
52 years PAMELA
1.3 years AMS02



PEBS design overview

Tracker:
Scintillating fibres
(d=250 μm),
with Silicon
Photo-Multiplier
(SiPM) readout;
power: 260W



Time-of-Flight
system (TOF):
2 x 2 x 5 mm
scintillator, SiPM
readout; trigger
system!

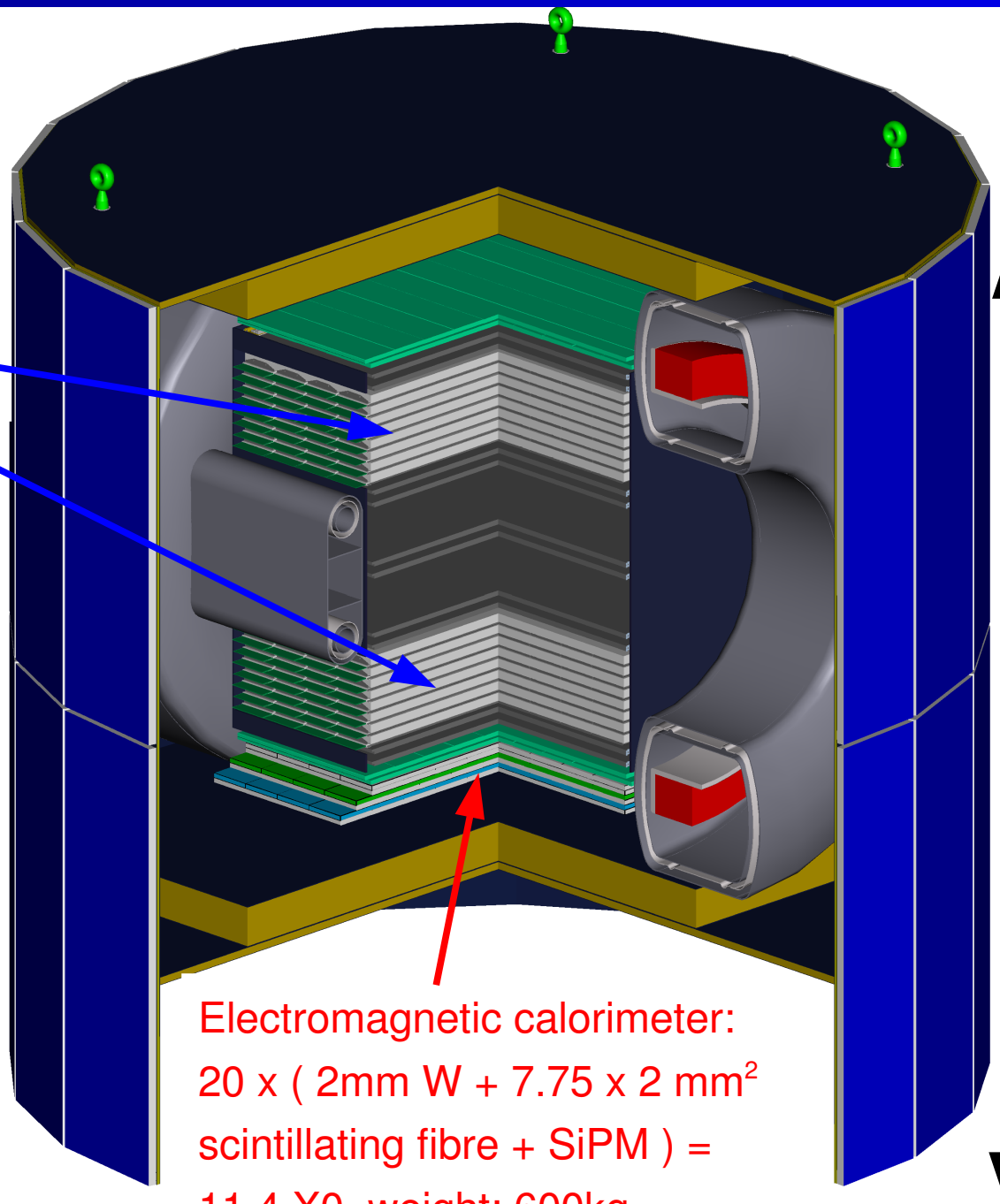
2.2 m

Solar panels:
power for
subdetectors,
communications,
data handling
~600 W

Magnet:
Pair of superconducting
Helmholtz coils,
Helium cryostat,
mean B = 0.8T, weight: 850kg

PEBS design overview

Transition Radiation Detector (TRD):
2 x 8 x
(2cm fleece radiator +
6mm straw tube
Xe/CO_2 80:20)

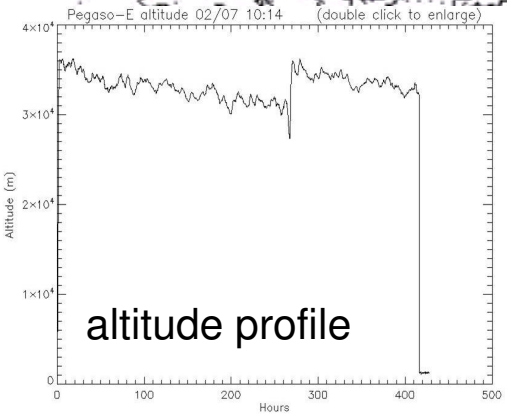


Positron acceptance:
0.4 m^2sr

2.2 m

Electromagnetic calorimeter:
20 x (2mm W + 7.75 x 2 mm^2 scintillating fibre + SiPM) =
11.4 X0, weight: 600kg

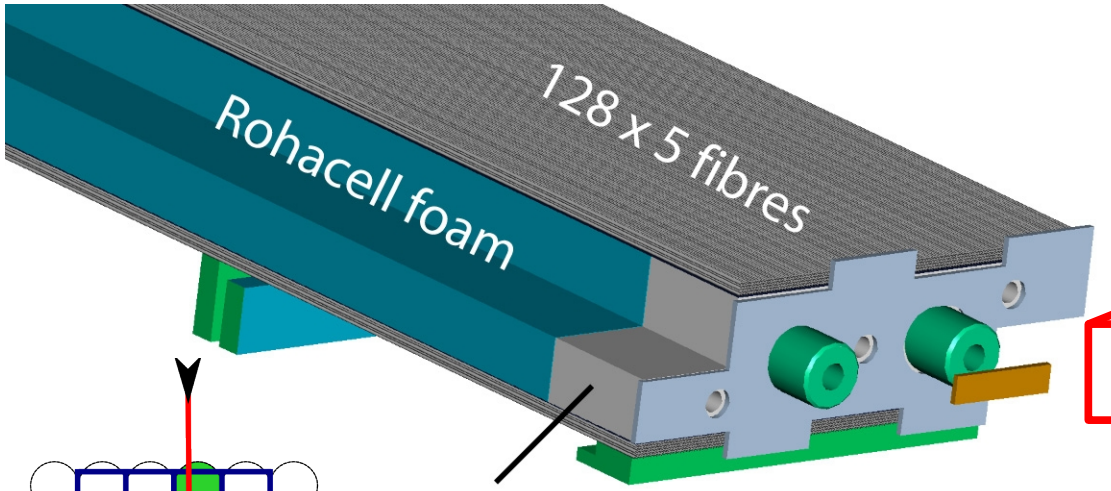
Balloons

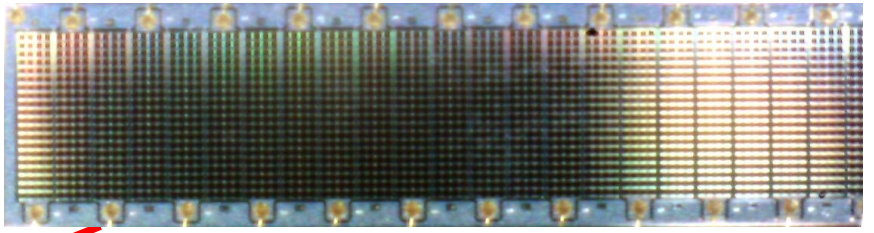


High-altitude (~40km), long-duration (~20 days) balloon flights from Svalbard balloonport (ASI)

Interesting alternative to space, allows recalibration of experiment as well as multiple journeys

Tracker modules

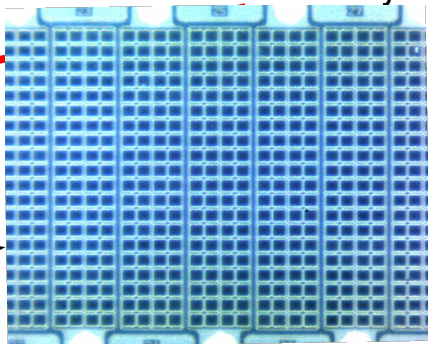


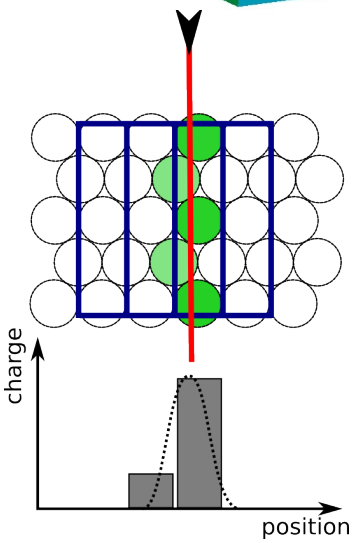


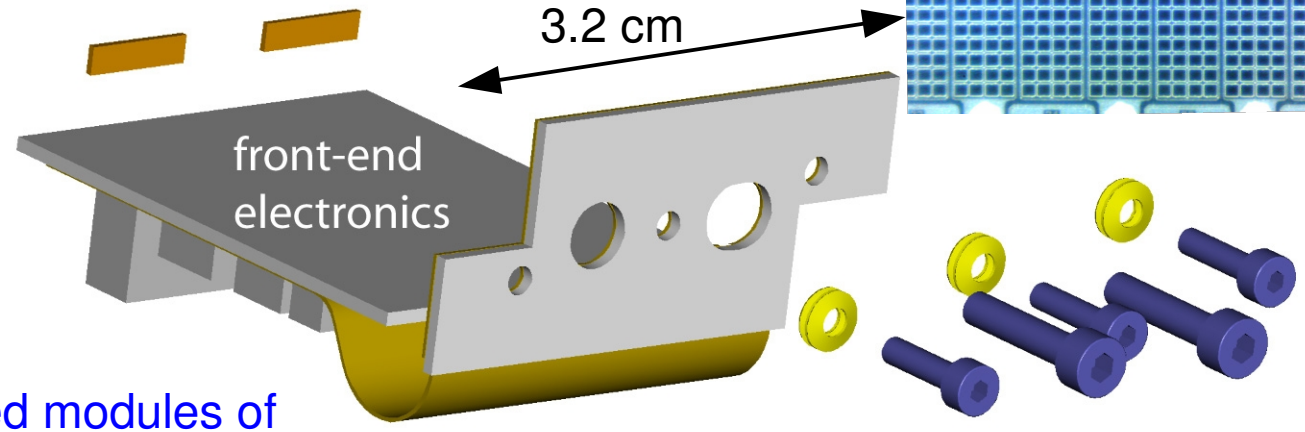
Hamamatsu MPPC array

mirrors

SiPM arrays







8 superlayers of 25 double-layered modules of scintillating fibres, d=250 μm,

stack of fibres accumulates light on SiPM

readout of SiPMs by dedicated chip (VA or SPIROC)

material budget: 12% X0

(6% X0 tracker + 6% X0 TRD)

32x1 silicon photomultiplier

250µm strip width, 80 pixels/SiPM

more on the SiPM-fibre-tracker:
NIM A 581 (2007) 423-426

PEBS fibre module testbeam setup at CERN 06/2008

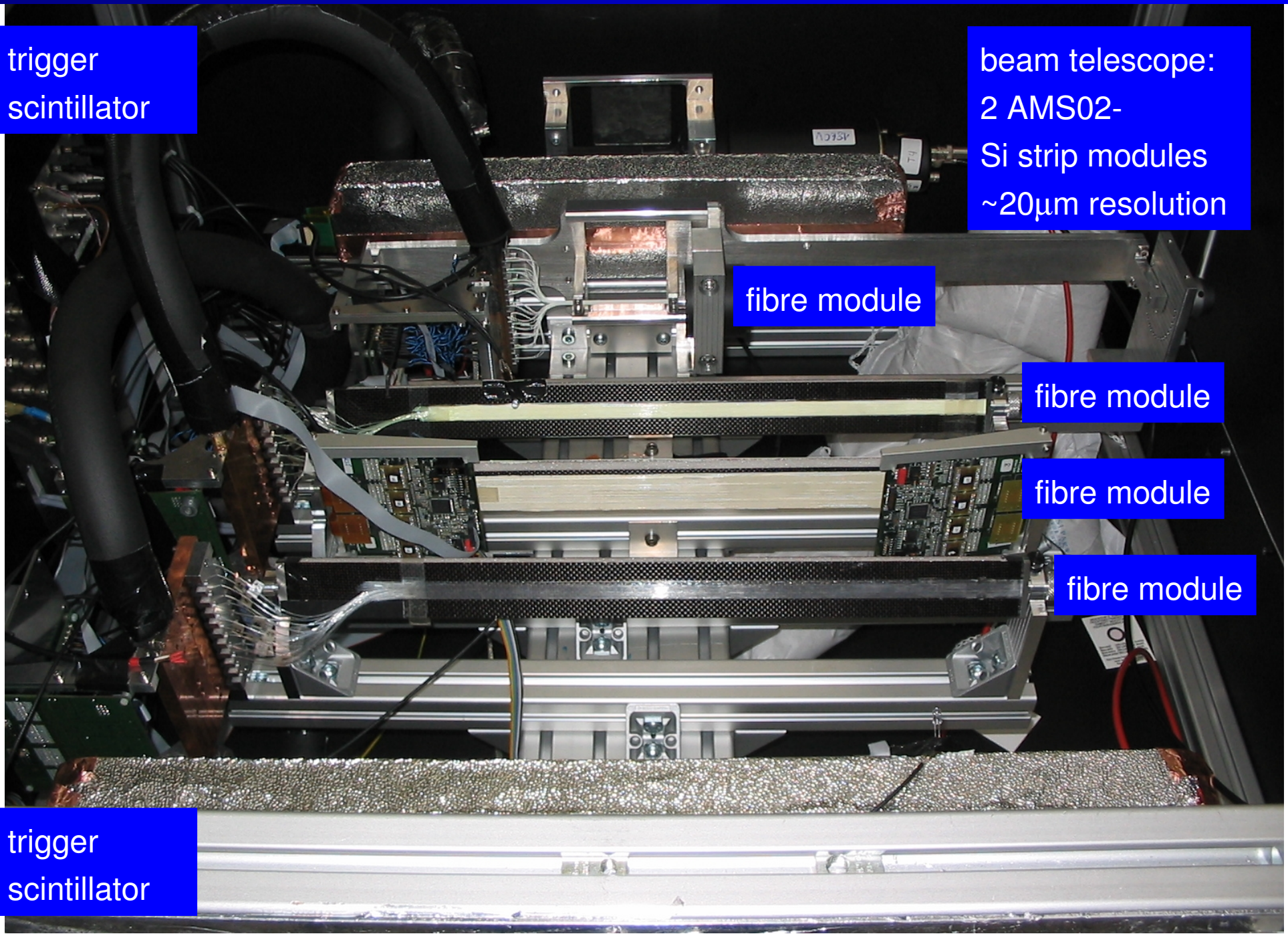
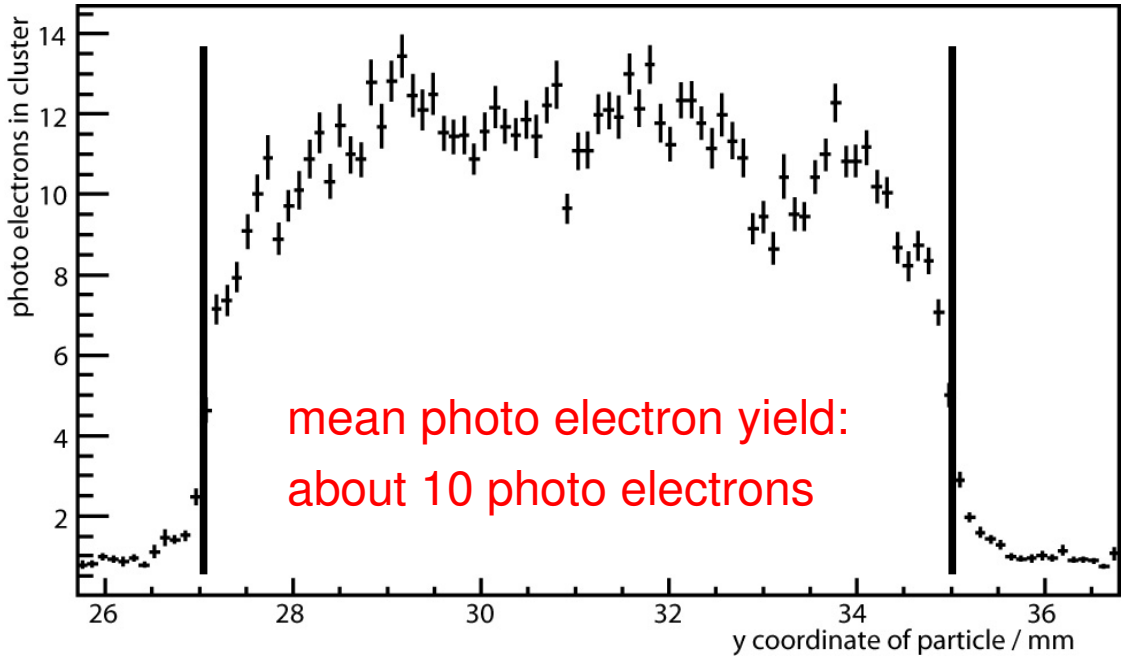
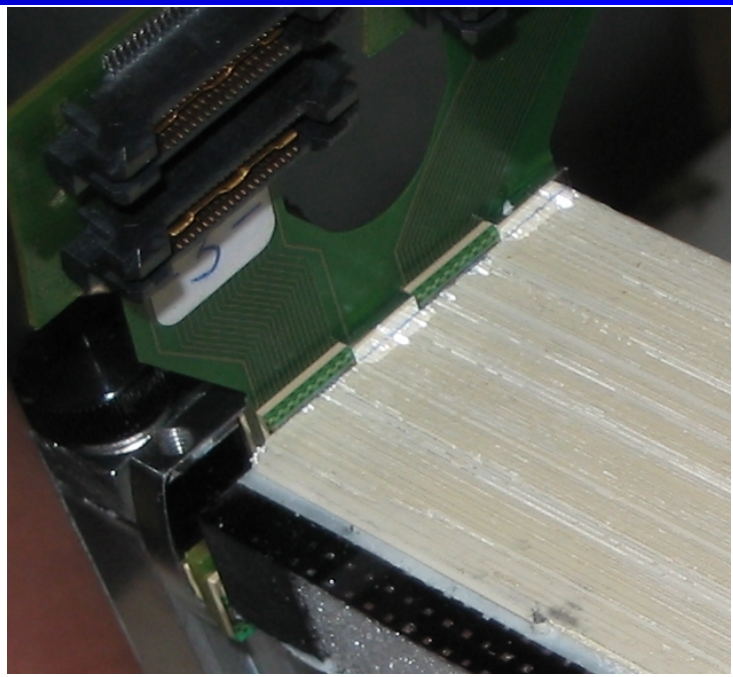
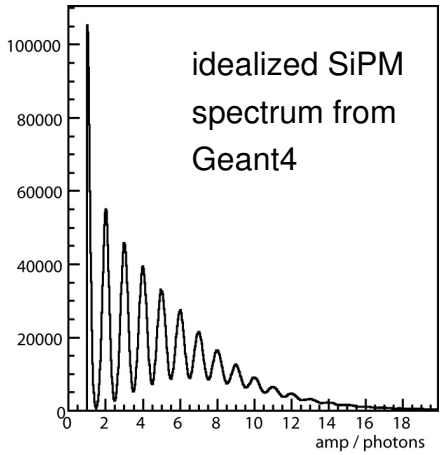
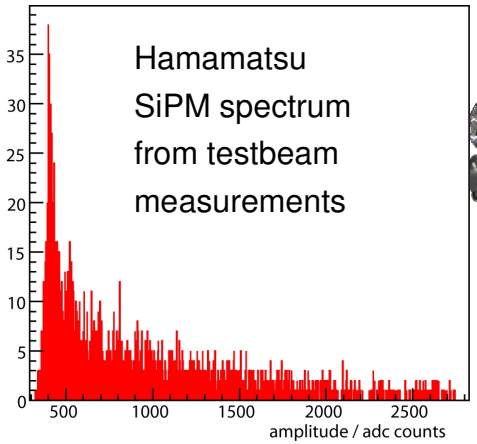


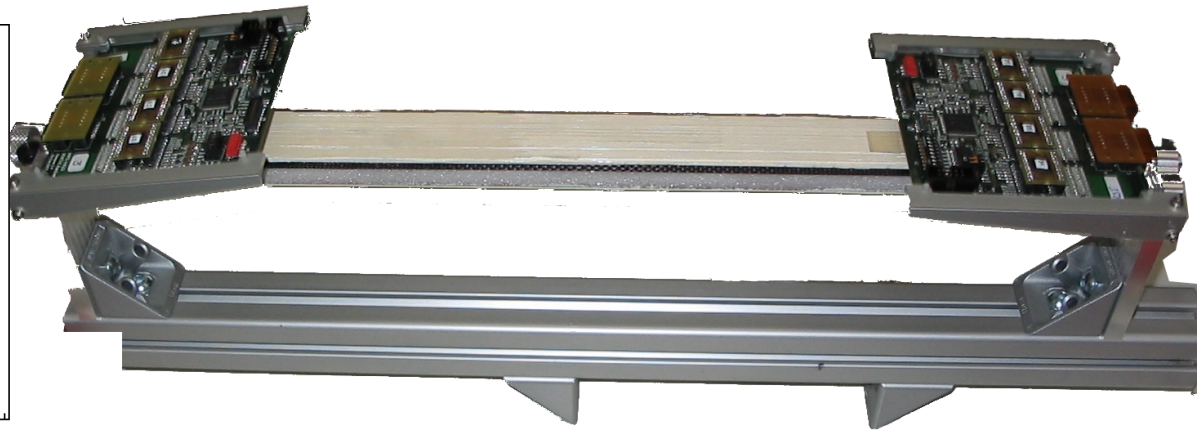
Photo electron yield of tracker module







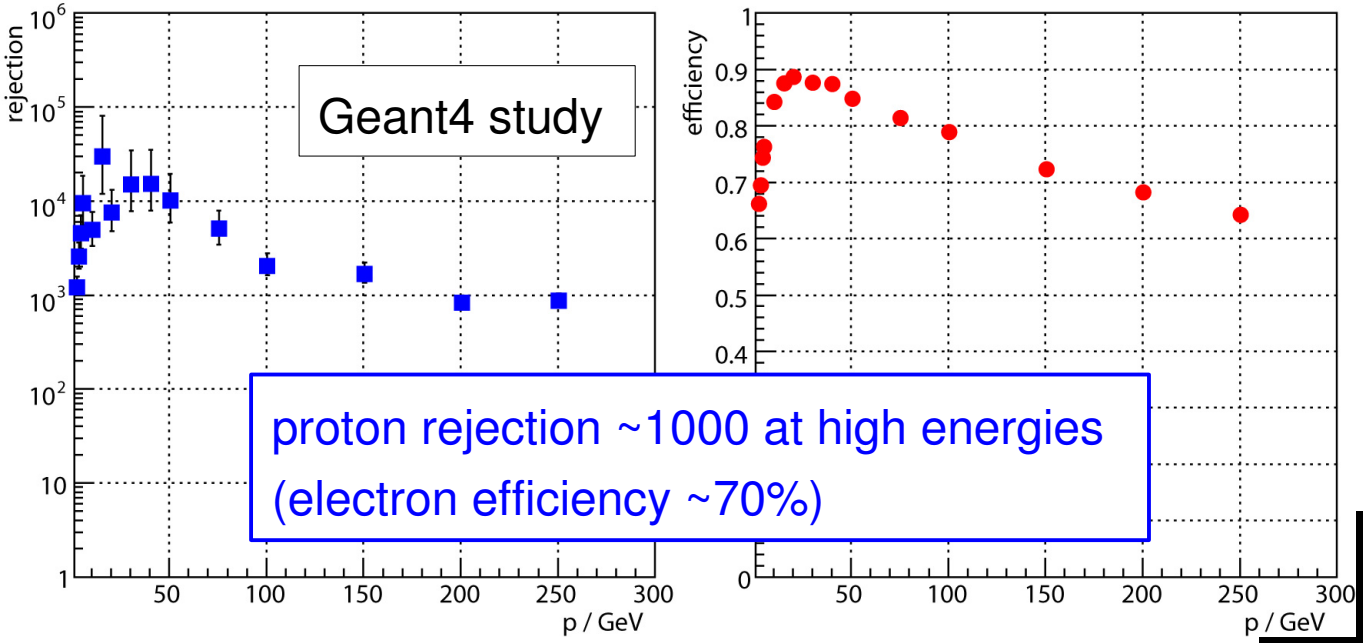




10 p.e. per cluster → PEBS MC simulation → positron momentum resolution: a=3%, b=0.18%/GeV → MDR=550 GV

$$\frac{\sigma_p}{p} = \sqrt{a^2 + (b \cdot p)^2}$$

ECAL proton rejection and energy resolution



proton rejection ~1000 at high energies
(electron efficiency ~70%)

ECAL energy resolution
7% at 100 GeV
determined by
leakage effect and
SiPM dynamic range

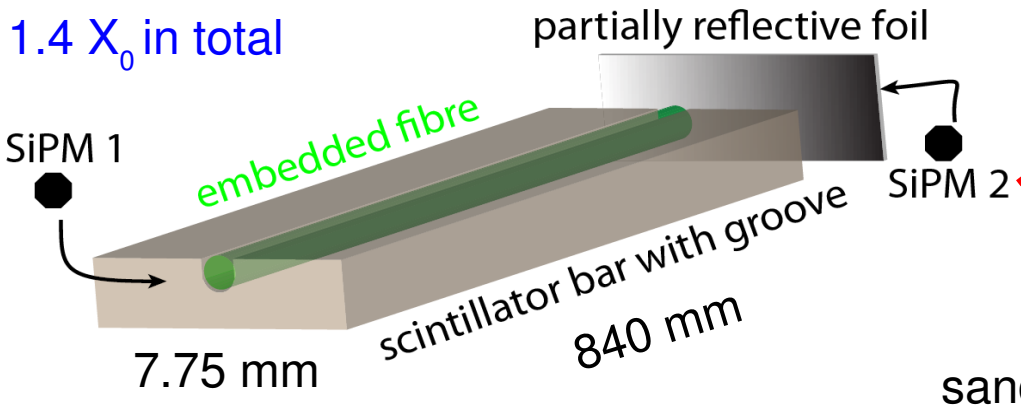
20 layers in total:

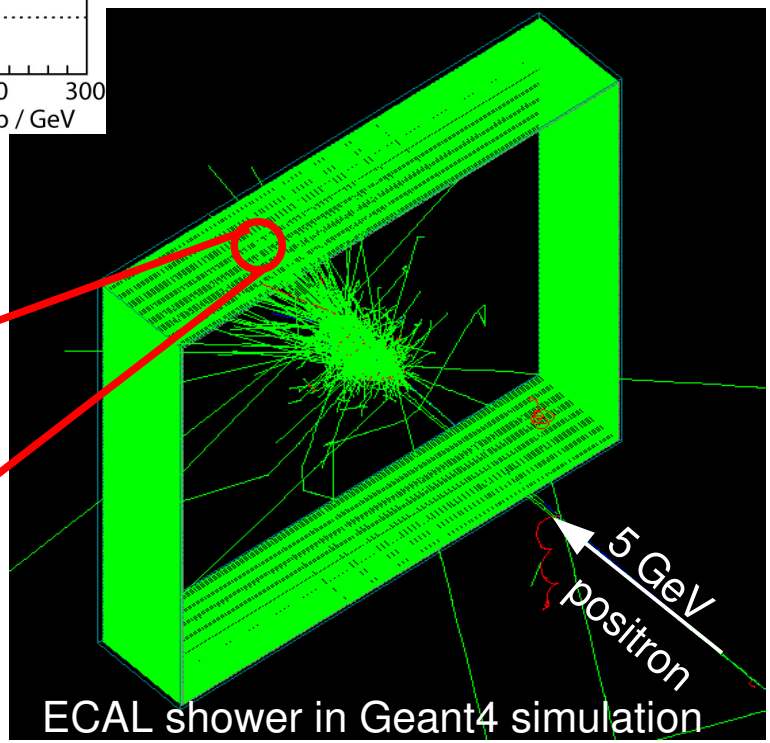
2 mm tungsten +

2 mm scintillator bar +WLS fiber +

2 SiPMs

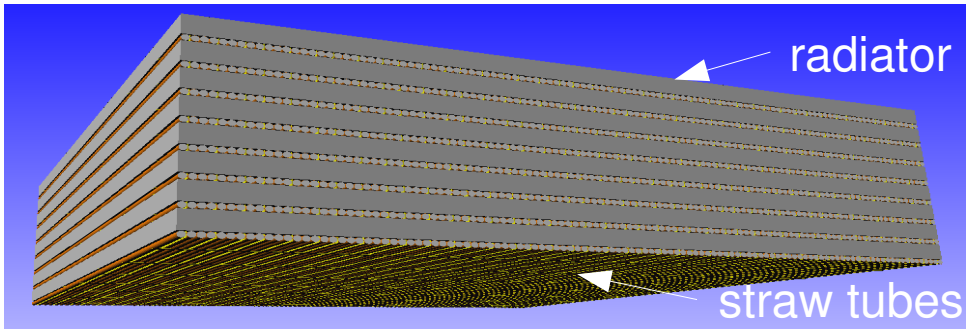
11.4 X_0 in total





sandwich calorimeter for 3D-shower reconstruction

TRD design

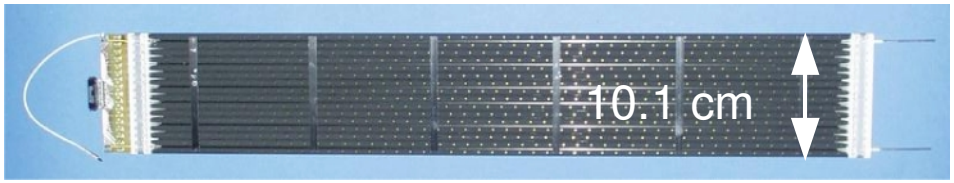


TRD superlayer in G4 simulation

Tasks:

proton suppression and

tracking in non-bending plane



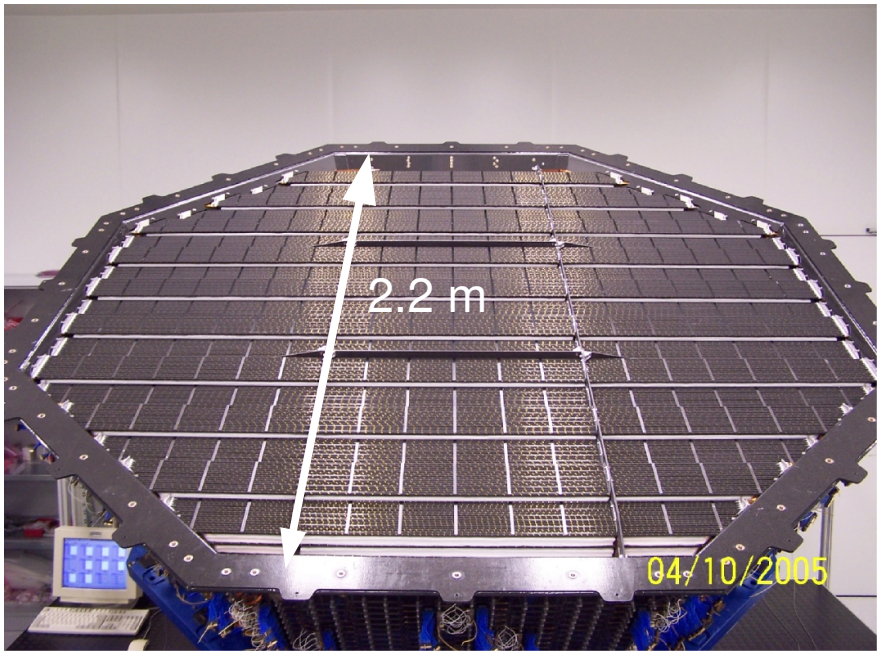
single TRD module

TRD reference:
NIM A 558 (2006) 526-535

2 x 8 layers of fleece radiator,

TR x-ray photons absorbed by Xe/CO2 mixture (80:20), in 6mm straw tubes with 30 μm tungsten wire

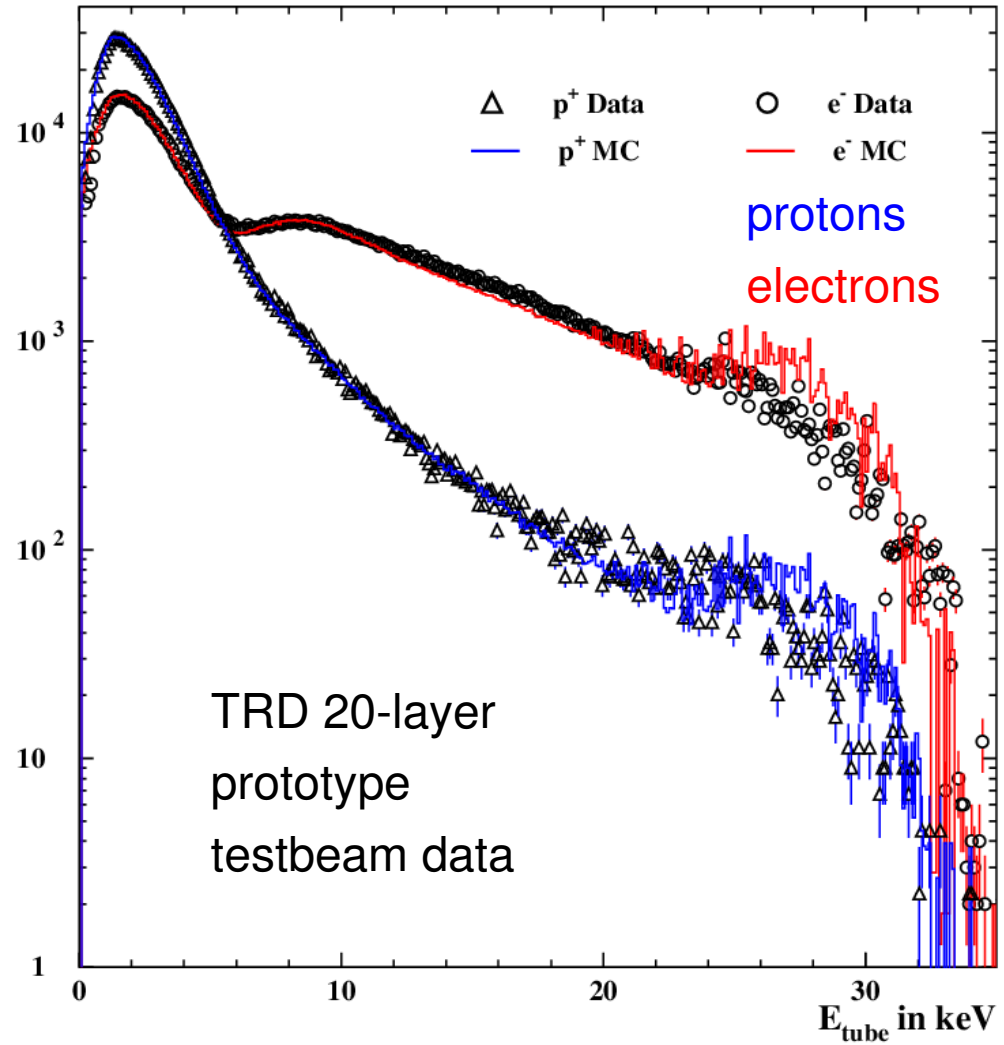
Design equivalent to AMS02 space experiment

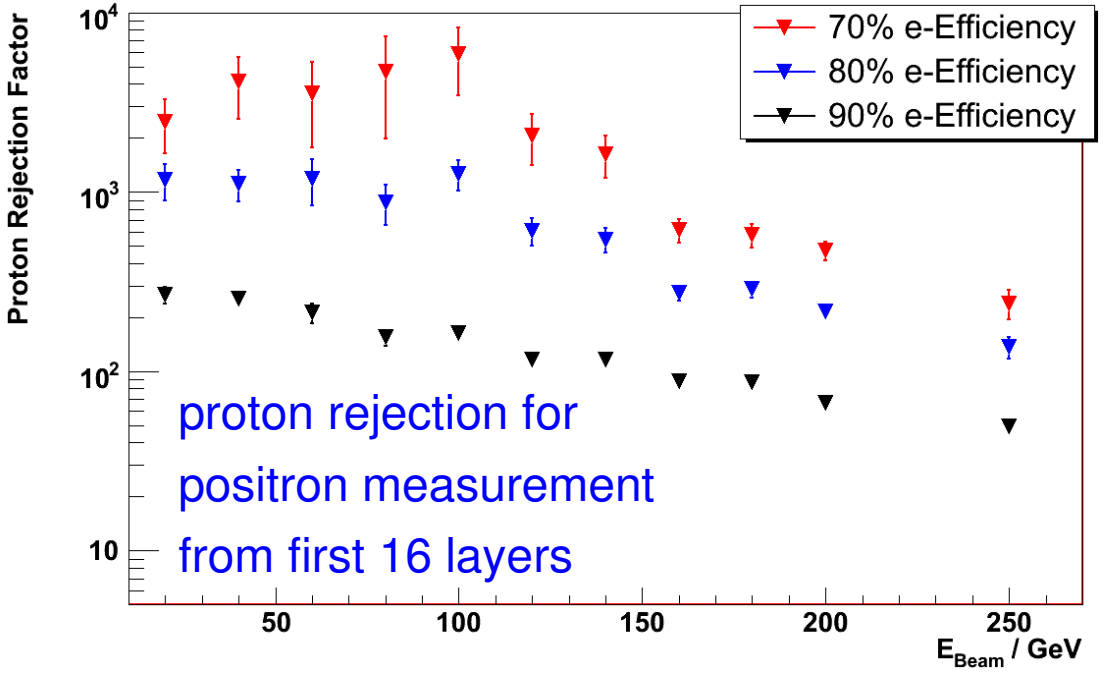


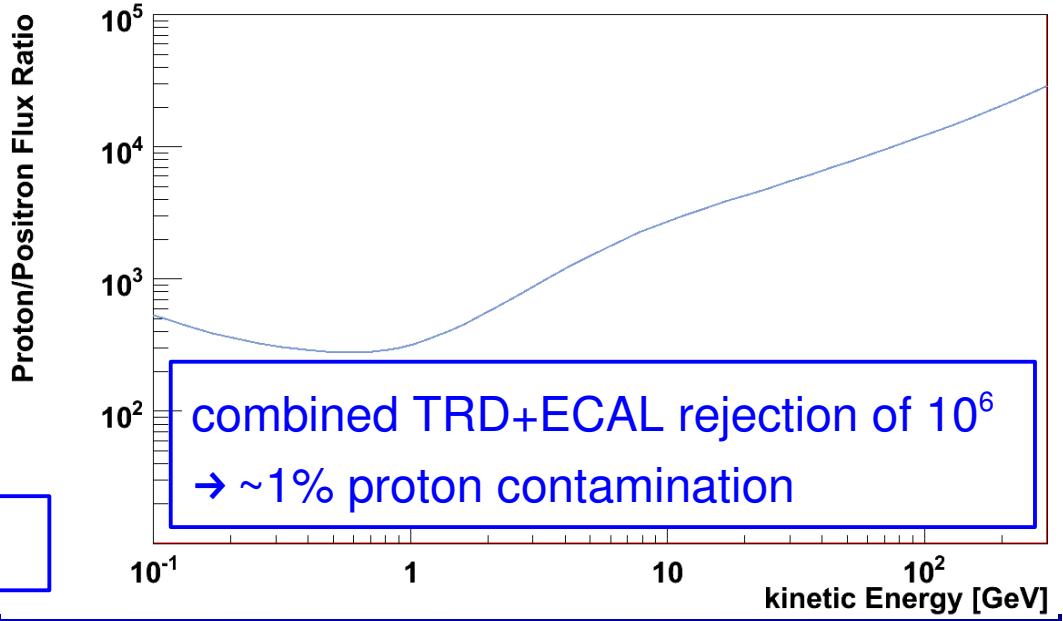
AMS02 TRD octagon integrated at RWTH Aachen workshop

TRD performance: positron/proton separation

Analysis of TRD prototype testbeam data







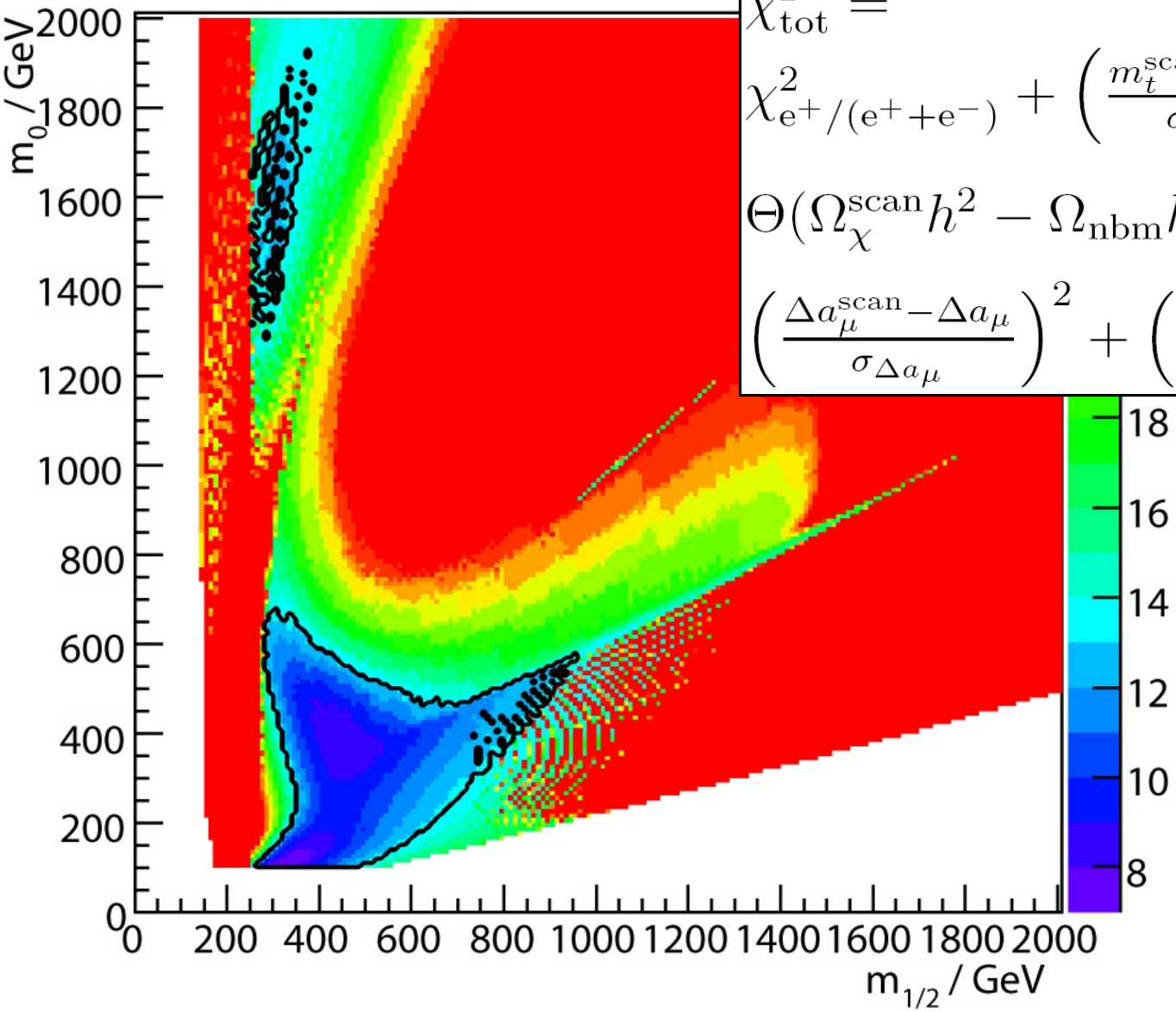
proton rejection ~1000

Projected performance: mSUGRA example

mSUGRA scan: vary m_0, $m_{1/2}$, tan β, m_{top} :

check constraining power of current data, identify benchmark points

$$\chi^2_{\rm tot} = \chi^2_{\rm e^+/(e^+ + e^-)} + \left(\frac{m_t^{\rm scan} - m_t}{\sigma_{m_t}}\right)^2 + \Theta(\Omega_\chi^{\rm scan} h^2 - \Omega_{\rm nbm} h^2) \cdot \left(\frac{\Omega_\chi^{\rm scan} h^2 - \Omega_{\rm nbm} h^2}{\sigma_{\Omega_{\rm nbm} h^2}}\right)^2 + \left(\frac{\Delta a_\mu^{\rm scan} - \Delta a_\mu}{\sigma_{\Delta a_\mu}}\right)^2 + \left(\frac{BR_{b\to s\gamma}^{\rm scan} - BR_{b\to s\gamma}}{\sigma_{BR(b\to s\gamma)}}\right)^2$$



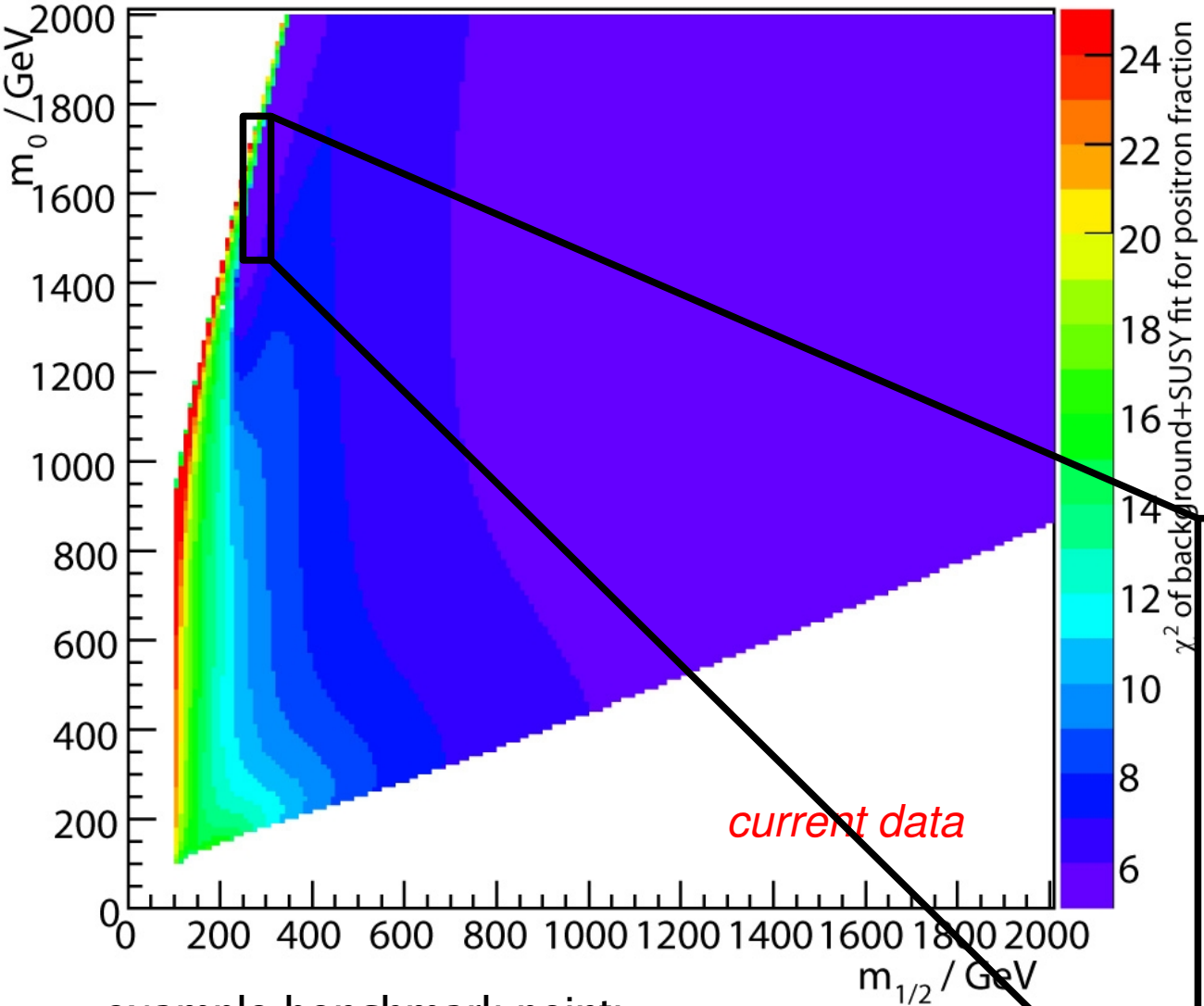
Ingredients

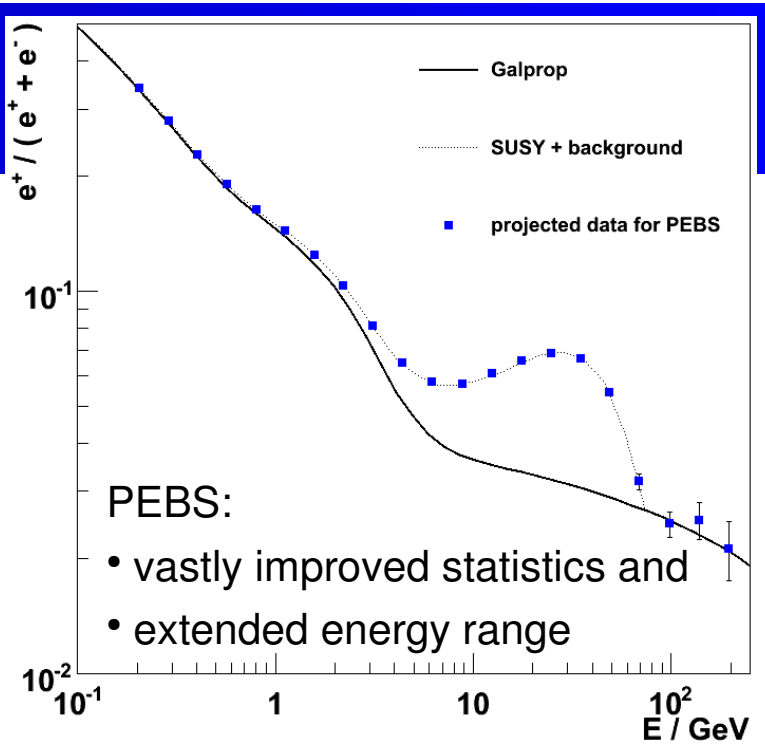
(using ISAJET+DarkSUSY+Galprop):

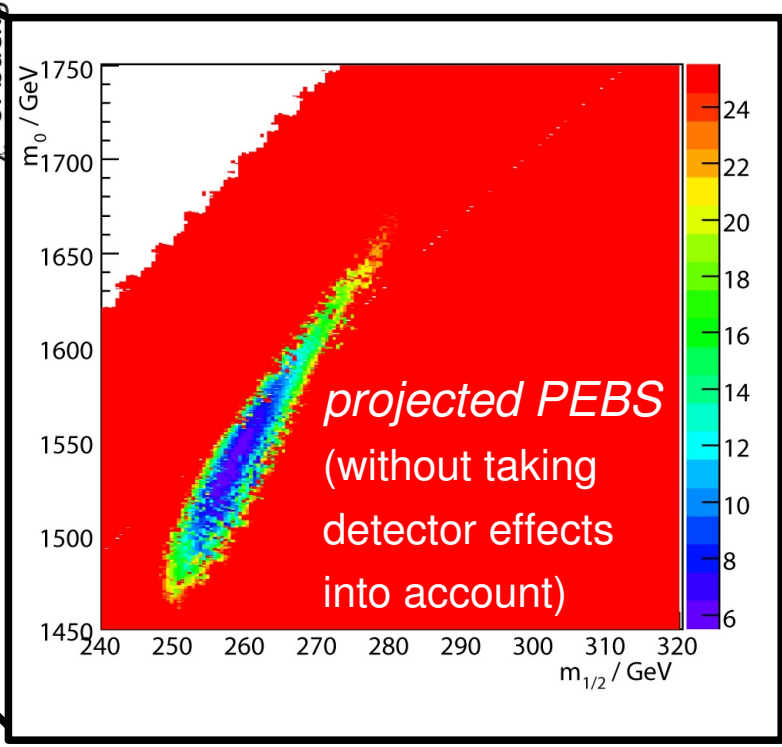
- top quark mass
- relic density of dark matter
- anomalous magnetic moment of the muon
- b→s γ branching ratio
- CR positron fraction using free boost factor

+ direct search and mass limits

Positron fraction χ^2







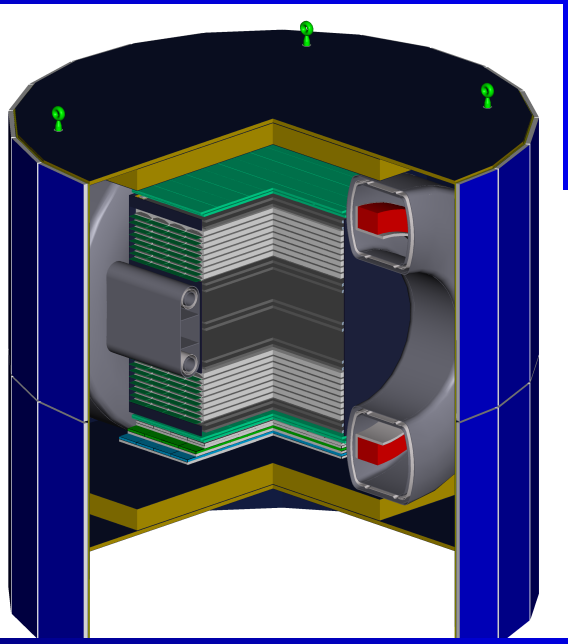
example benchmark point:

m_0= 1560 GeV, $m_{1/2}$= 260 GeV

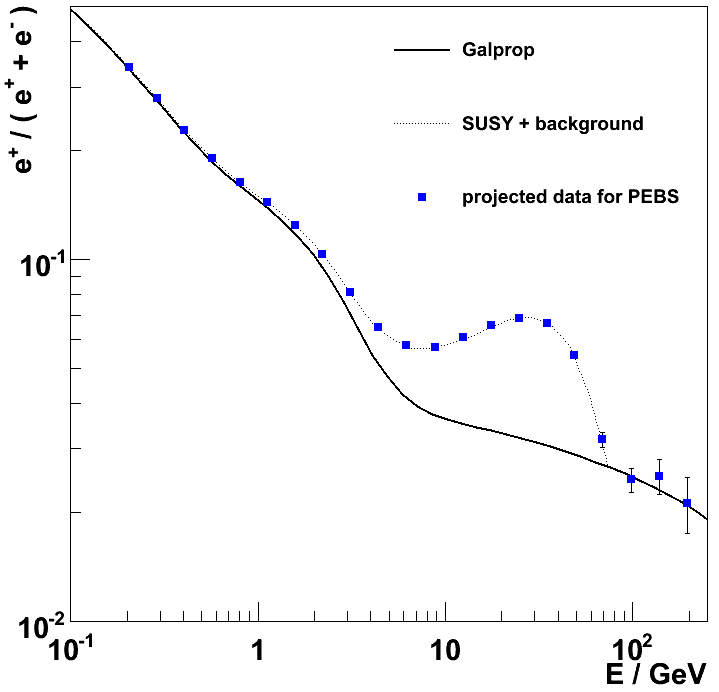
tan β = 40, m_{top} = 172.76 GeV, sgn μ = +1, A_0 = 0

Conclusion

- Design study to build a balloon-borne spectrometer to measure the cosmic-ray positron fraction, in the context of indirect search for dark matter
- Scintillating fibres with SiPM readout as key components, proof of principle established in testbeams at CERN in 2006-08
- Proton rejection of O(1,000,000) could be achieved with ECAL and TRD
- Study of physics program ongoing (antiprotons, B/C, ...)



Anomaly in the positron spectrum?
PEBS could answer the question!



Acknowledgments

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