CALORIMETERS AND SPECTROMETERS: WHAT'S NEXT?

What's Next Raggi Cosmici

Padova, 3 Dicembre 2014

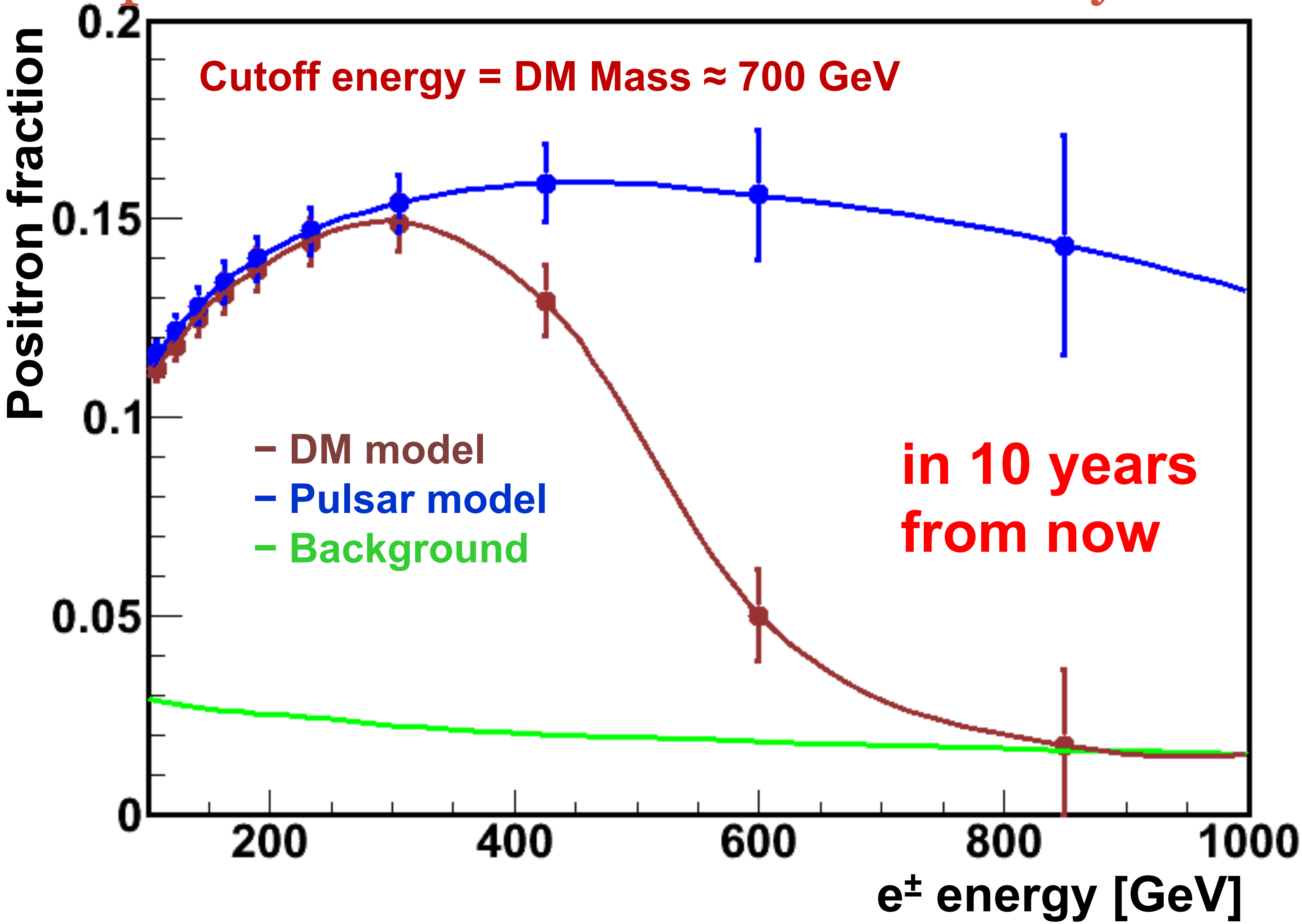
Oscar Adriani - Firenze

HIGH ENERGY CHARGED COSMIC RAYS: PRESENT AND NEAR FUTURE STATUS

1: Measurements requiring the identification of the charge sign

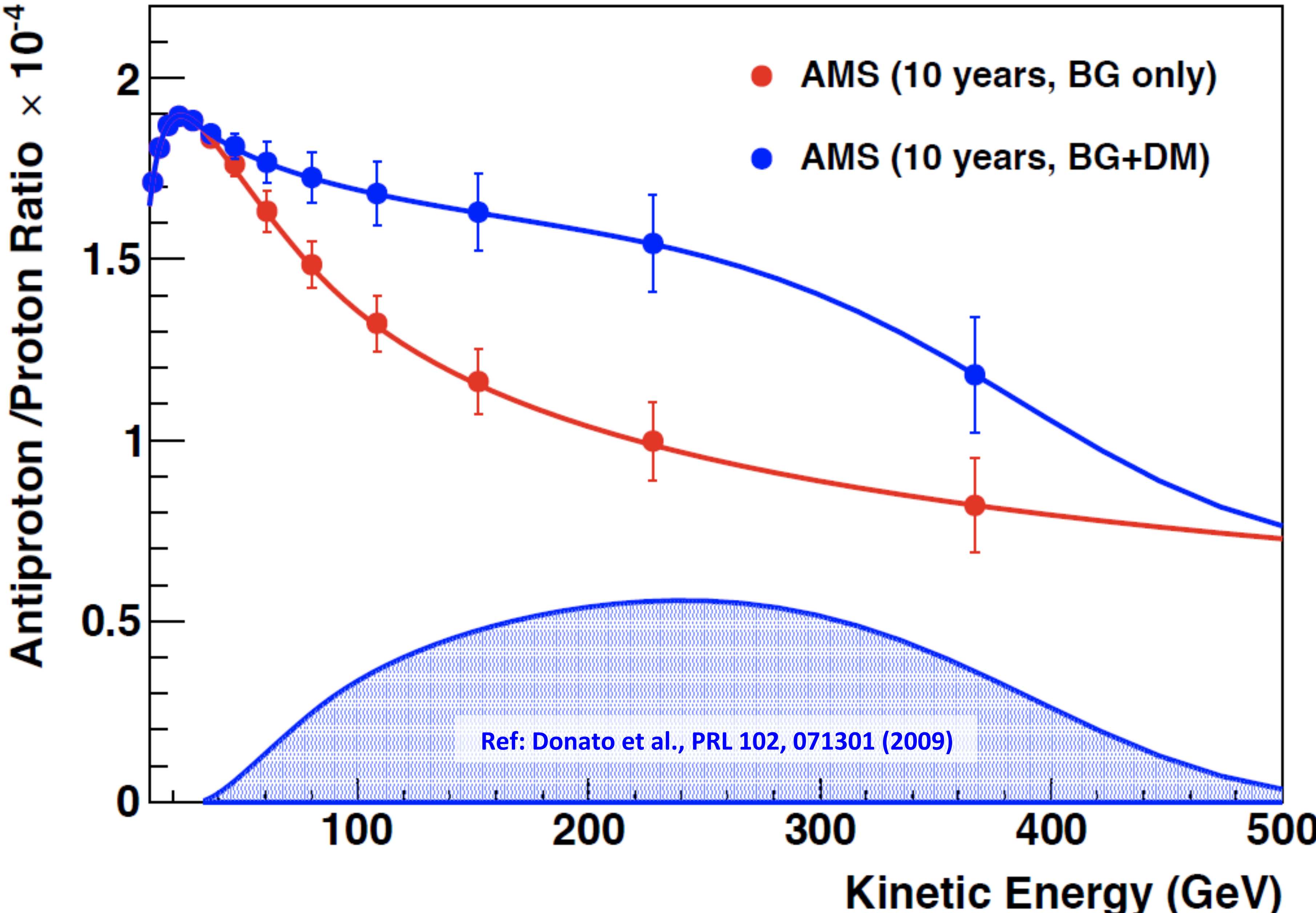
- Antiprotons
- Positrons
- Antideuterons
- Magnetic spectrometers are necessary
  - Pamela/AMS/(Fermi)
- Current limits:
  - Positrons
    - Pamela (up to 300 GeV)
    - AMS (up to 500 GeV)
    - Fermi (up to 200 GeV)
  - Antiprotons
    - Pamela (up to 350 GeV)
- Near future limits
  - Positrons
    - AMS in 10 years (up to 1 TeV)
  - Antiprotons
    - AMS in 10 years (up to 500 GeV)

Expected AMS-02 reach in 10 more years



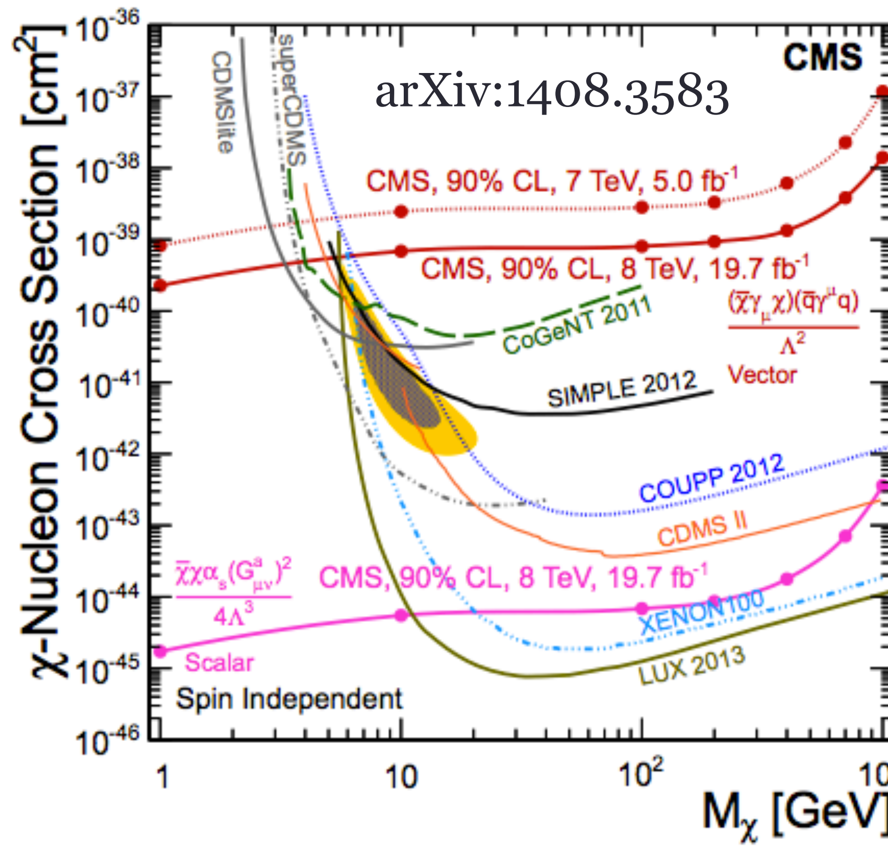
What will the Positron Fraction look like at high energy?

Expected AMS-02 reach in 10 more years

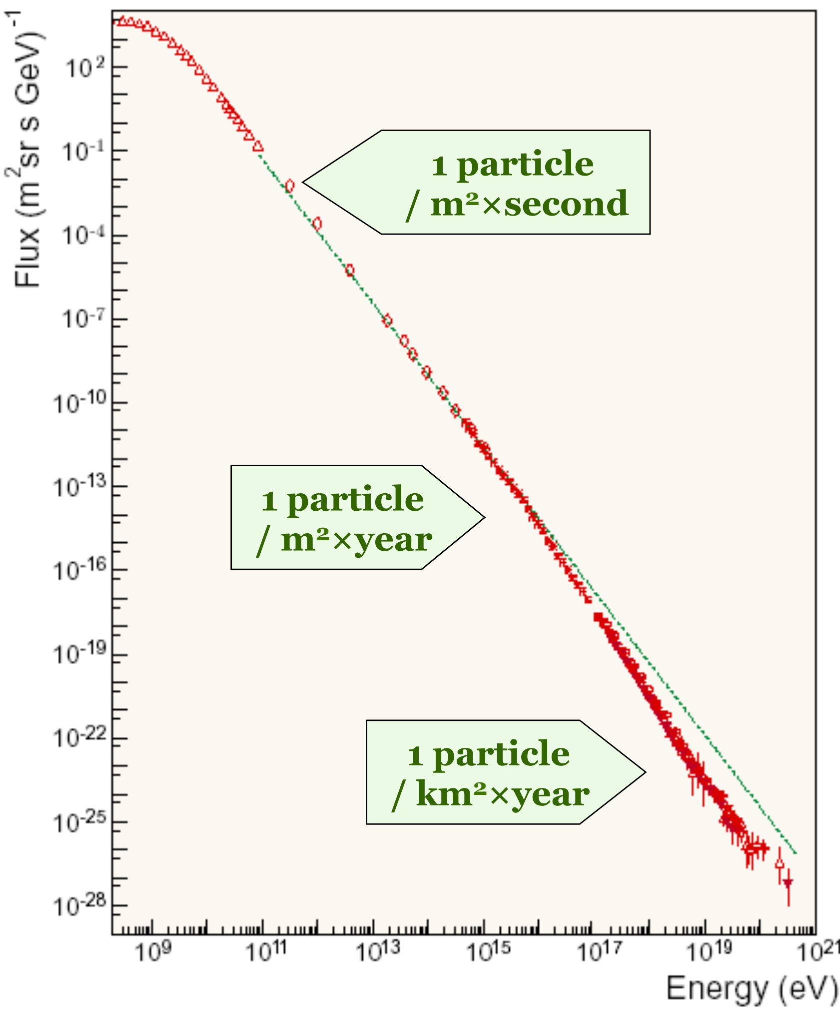


The far future challenges: Dark Matter searches

- LHC will be able to probe in an optimal way neutralino masses up to $m_\chi < O(100)$GeV
- Direct search detection in the underground laboratories will paly an essential role
- From the cosmic ray physics we have to measure:
  - Positrons at the 1-10 TeV scale
  - Antiprotons at the 1 TeV scale
  - Gamma rays at the TeV scale
  - Antideuterons at the GeV scale



2: Measurements NOT requiring the identification of the charge sign



High energy nuclei

- **"Knee" structure around ~ PeV**
  - Upper energy of galactic accelerators (?)
  - Energy-dependent composition
- **Structures in the GeV – TeV region recently discovered for p and He**
  - Composition at the knee may differ substantially from that at TeV
- **Spectral measurements in the knee region up to now are only indirect**
  - Ground-based atmospheric shower detectors
  - High uncertainties

A direct spectral measurement in the PeV region requires great acceptance (many m^2sr), good charge measurement and good energy resolution for hadrons (much better than 40%)

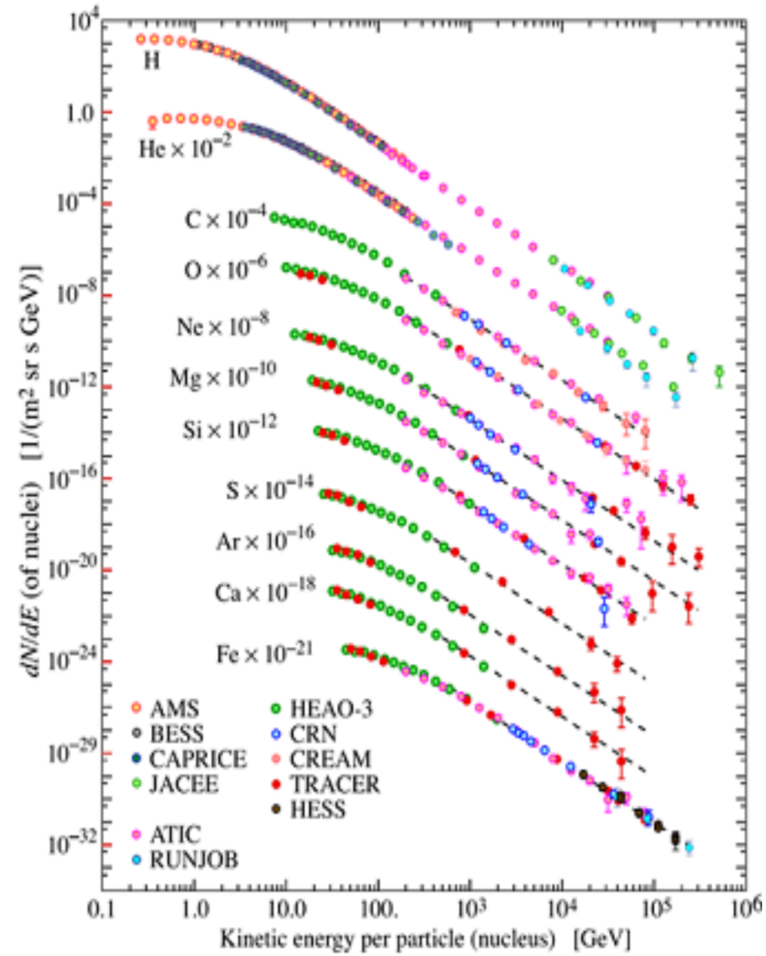
High energy Electrons+Positrons

- **Currently available measurements show some degree of disagreement in the 100 GeV – 1 TeV region**
- **Cutoff in the TeV region?**

Direct measurements require excellent energy resolution (~%), a high e/p rejection power (> 10^5) and large acceptance above 1 TeV

2: Measurements NOT requiring the identification of the charge sign

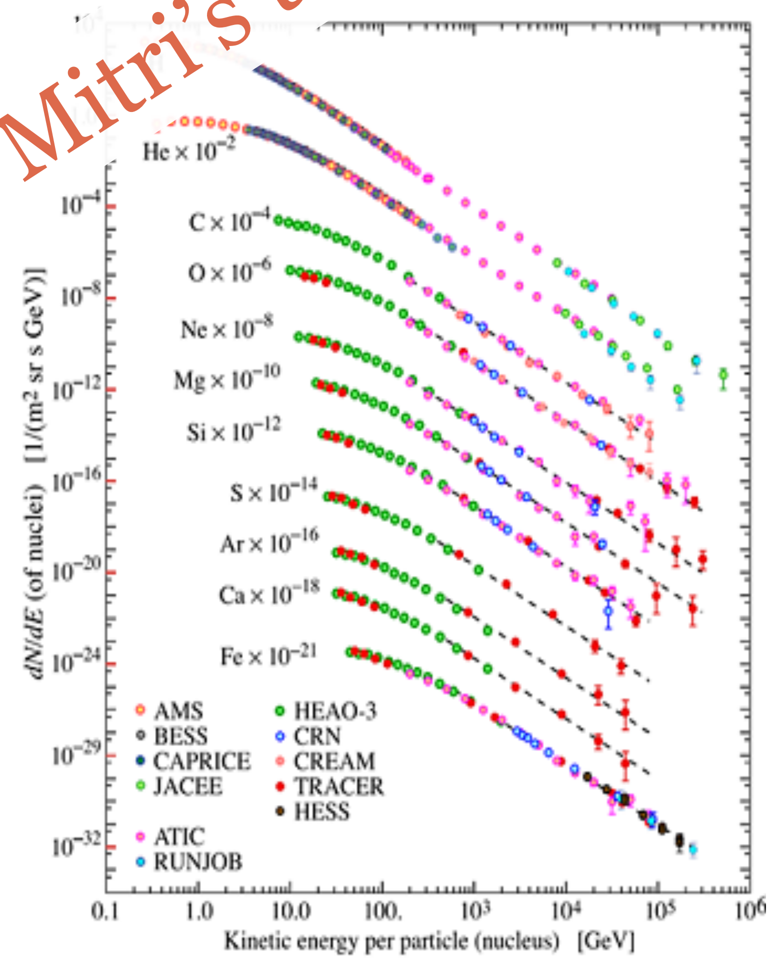
- Spectral features at the knee scale
  - Protons at the PeV scale
  - Helium Nuclei at the PV scale
  - Heavier Ions at the 100 TeV/PeV scale
- Up to now no measurements in orbit for E>few TeV
- Near future
  - Calet (2015 on ISS)
  - ISS-Cream (~2015 on ISS)
  - Dampe (~2016 on Chinese Satellite)
- Far future
  - Direct probe of the >knee region



2: Measurements NOT requiring the identification of the charge sign

- Spectral features at the knee scale
  - Protons at the PeV scale
  - Helium Nuclei at the PV scale
  - Heavier Ions at the 100 TeV/PeV scale
- Up to now no measurements in orbit for a few TeV
- Near future
  - Calet (2015 on ISS)
  - ISS-Cream (~2015 on ISS)
  - Dampe (~2016 on Chinese Satellite)
- Far future
  - Direct probe of the >knee region

Clear message from Ivan De Mitri's talk!

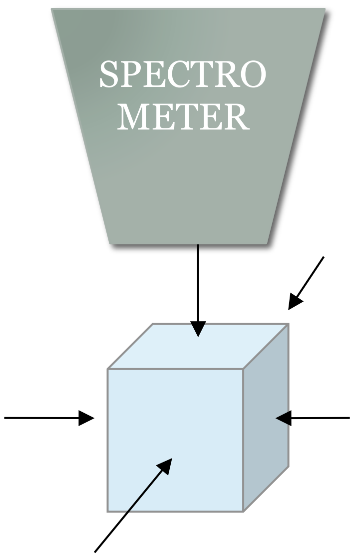


SOME BASIC IDEAS FOR THE DETECTORS

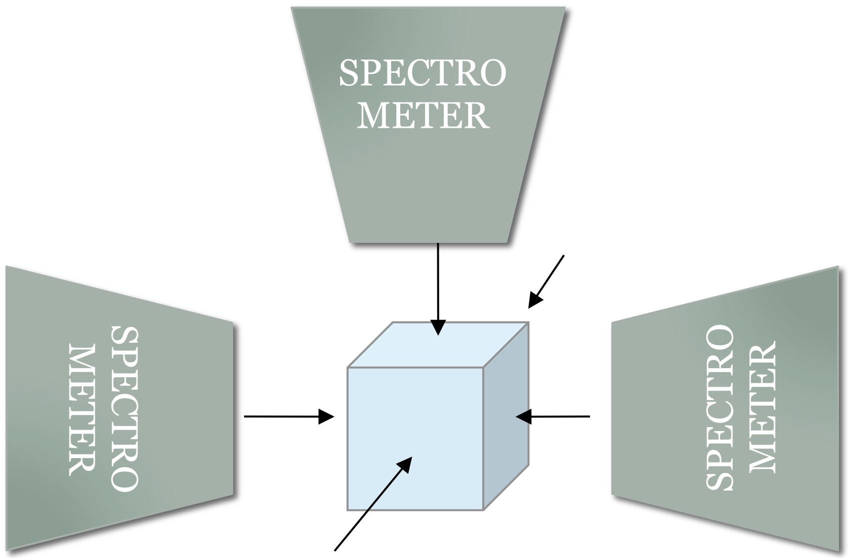
A possible proposal for an 'optimal' CR detector in the What's Next framework

- **A core consisting of a 3-D, deep, homogeneous and isotropic calorimeter:**
  - depth and homogeneity to achieve energy resolution (but please remember that anyway a full containment HCAL is impossible in space!!!!)
  - Possibility to measure the Z of the nucleus
  - isotropy (3-D) to accept particles from all directions and increase GF
- **An high performance spectrometric system located above/around the calorimeter**
  - Very large magnetic deflection
    - Large lever arm
    - Intense B field
  - Excellent position resolution
  - To achieve both goals of:
    - Very High MDR (~10 TV/c)
    - Very High Geometric Factor (~10 m^2 sr)
- **Ancillary detectors to optimize overall performances**

A ‘Traditional’ Approach



A ‘More exotic’ Approach

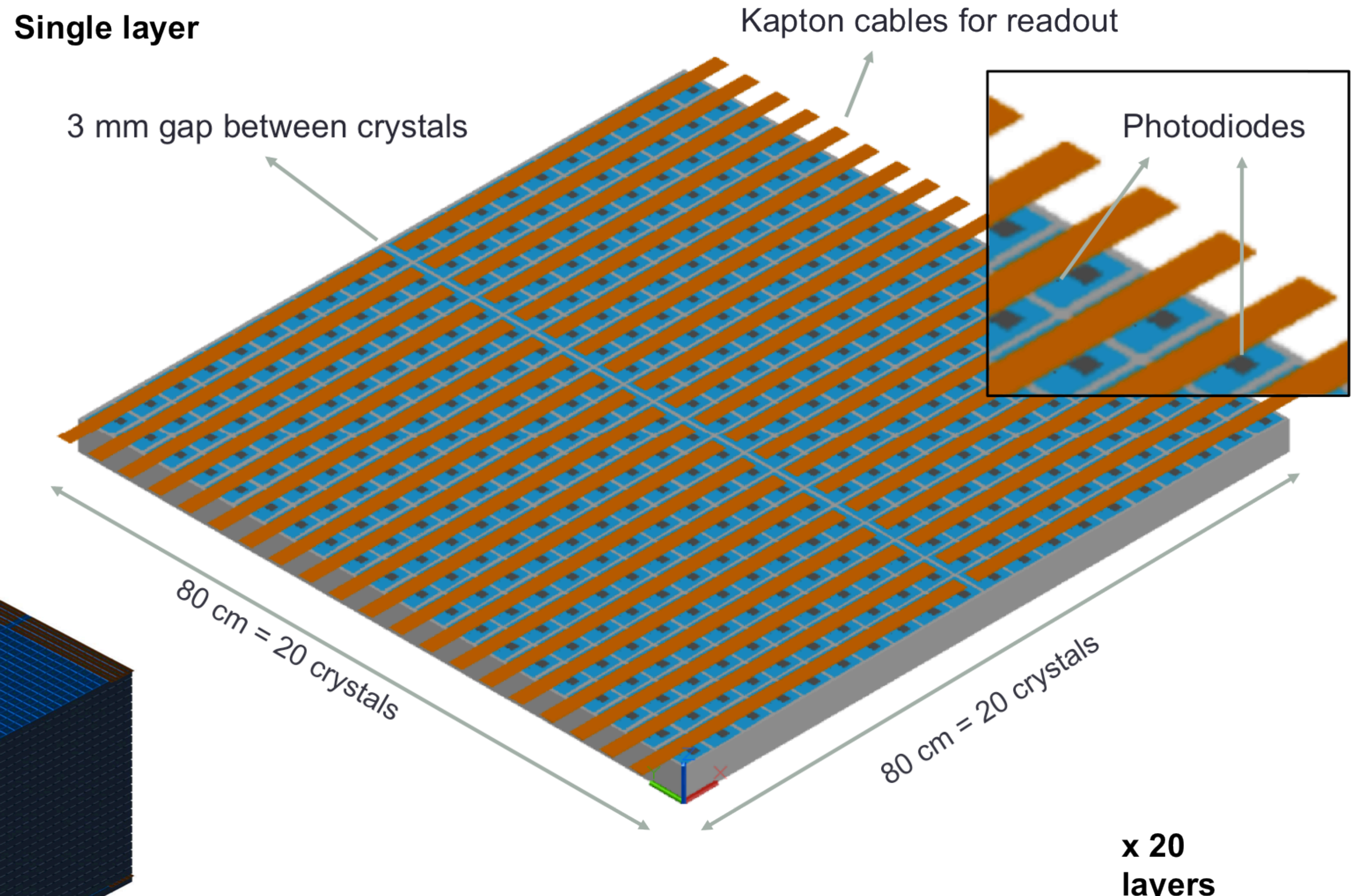


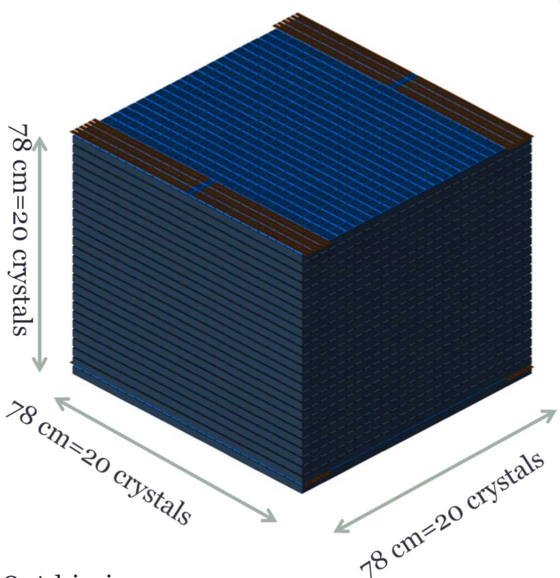
THE CALORIMETRIC PART

Highlight of the calorimetric part

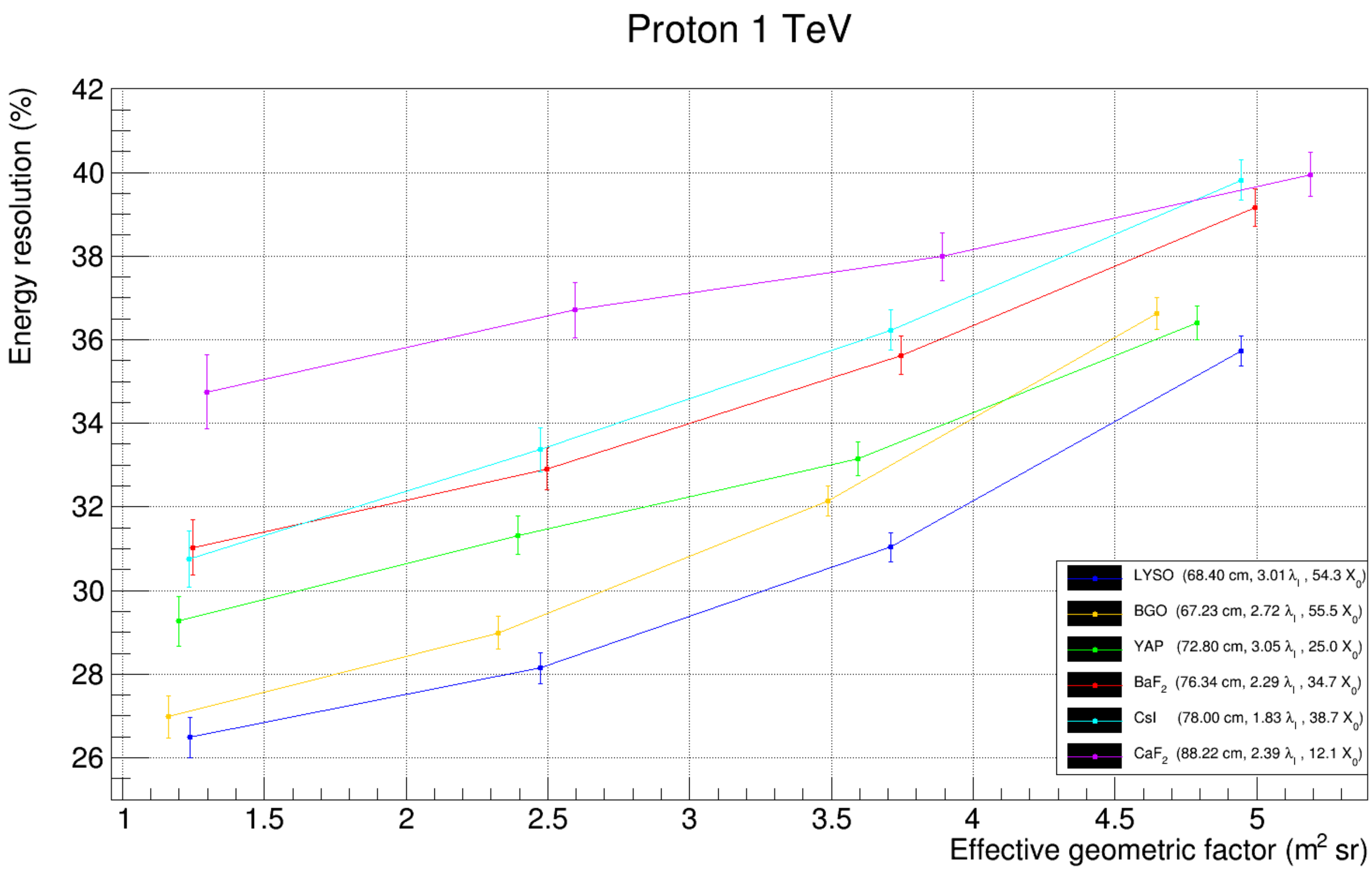
- **An homogeneus, deep, isotropic calorimeter**
  - can accept events from all sides (mechanical support on bottom side) → ~GF * 5
  - segmentation in every direction gives e/p rejection power by means of topological shower analysis
  - small size (~Molière radius) scintillating crystals for homogeneity
  - gaps between crystals increase GF and can be used for signal readout
    - small degradation of energy resolution
  - must fulfill mass&power budget of a space experiment
  - modularity allows for easy resizing of the detector design depending on the available mass&power
  - dual/multiple readout
    - Improve the hadronic energy resolution
    - Improve the p/e rejection
- A weight of few tons is feasible
- Assumption for the next few slides: 2000 kg of active material

The simplest solution: a large cube made by small scintillating cubes



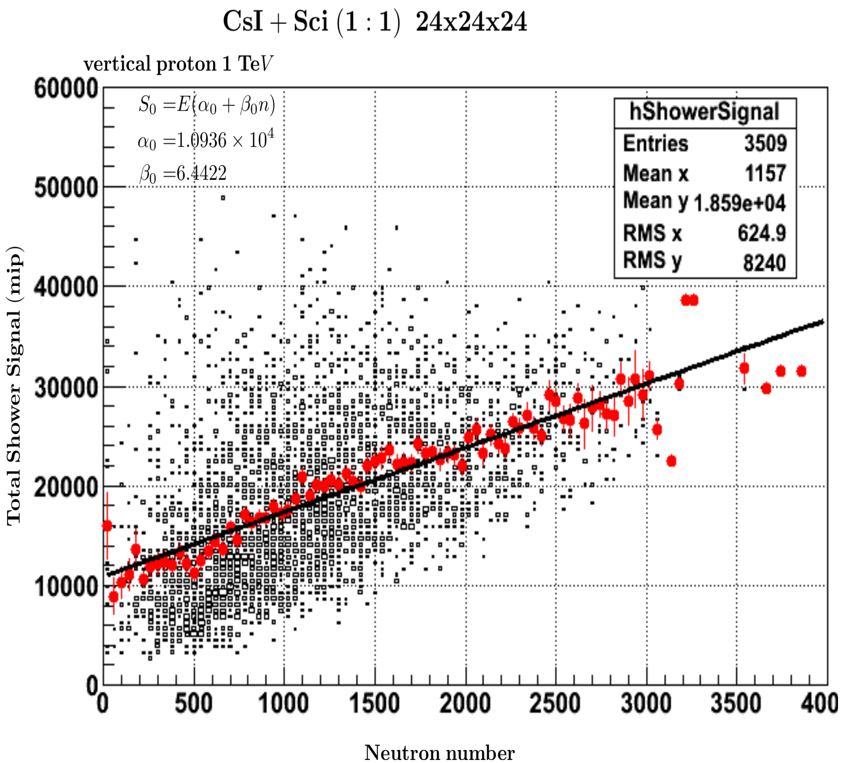


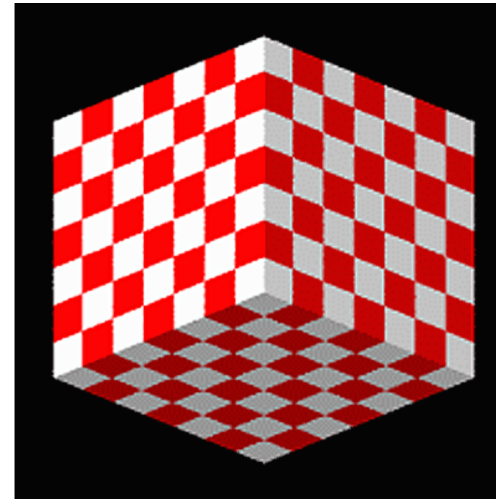
Effective geometrical factor for a 2 tons calorimeter

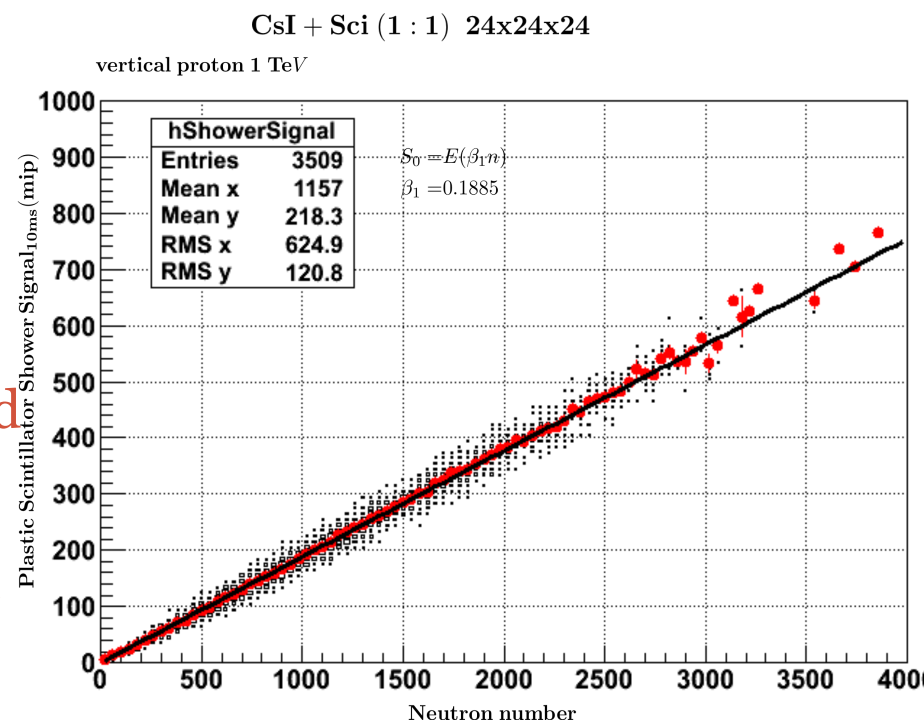


We can obtain different GF by applying different selection criteria

The Dual Readout option





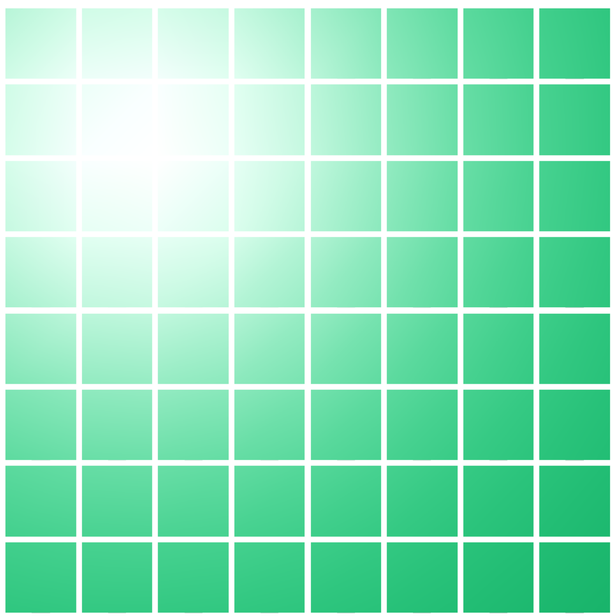


The number of neutrons N_n is correlated to the energy release

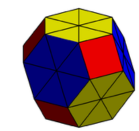
And delayed signal in plastic scintillator is a good tool to estimate N_n!

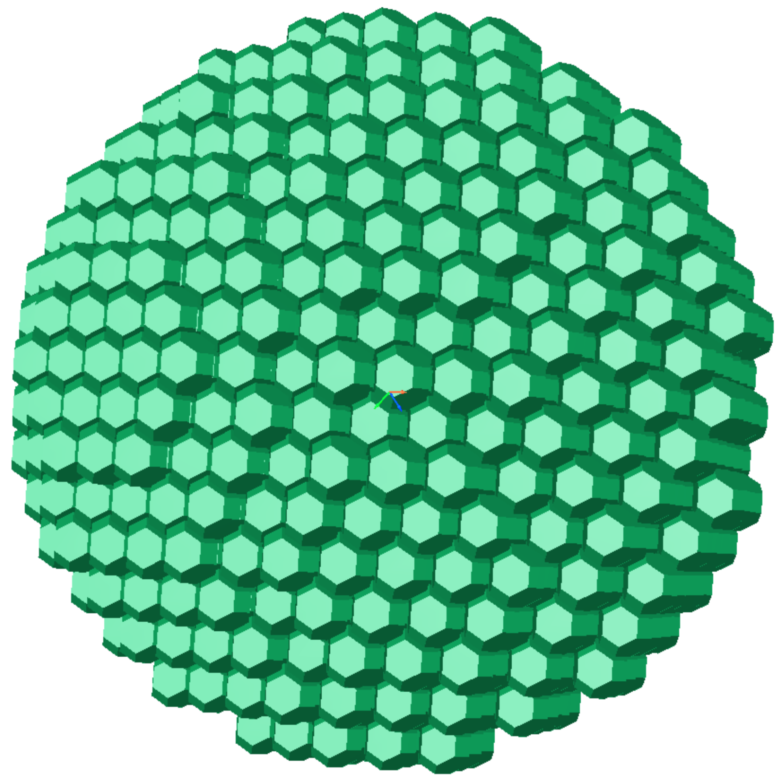
A more exotic solution

Cubic configuration with small size cubic crystal
Simpler from the mechanical point of view



Spherical configuration with small crystals with truncated octahedron shape
More complex from the mechanical point of view



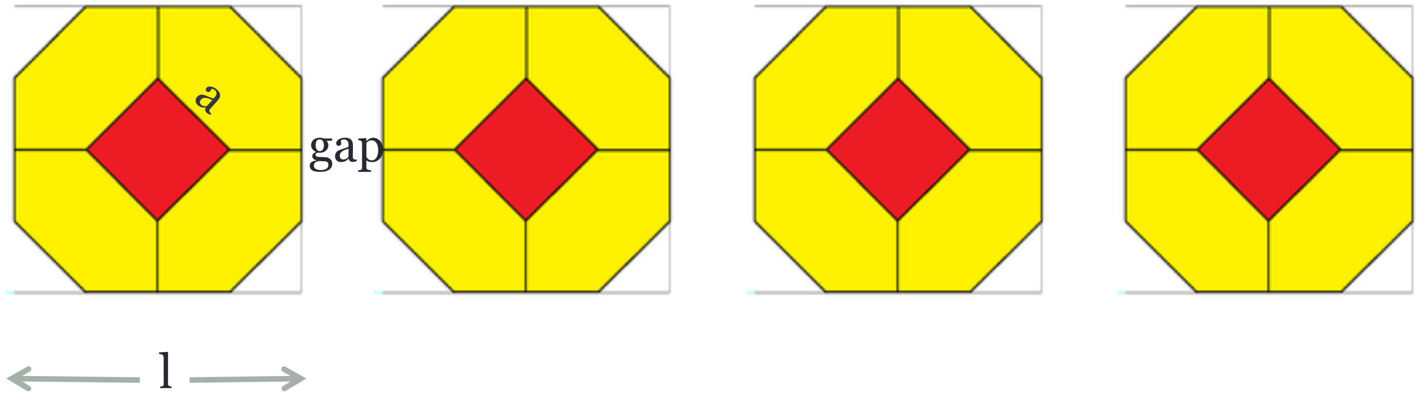


Basic ideas:

- Reduce as much as possible the leakages by avoiding possible escape planes
- Spherical geometry to increase the acceptance (maximize the surface, and hence the GF, once the weight is fixed)

Optimization criteria:

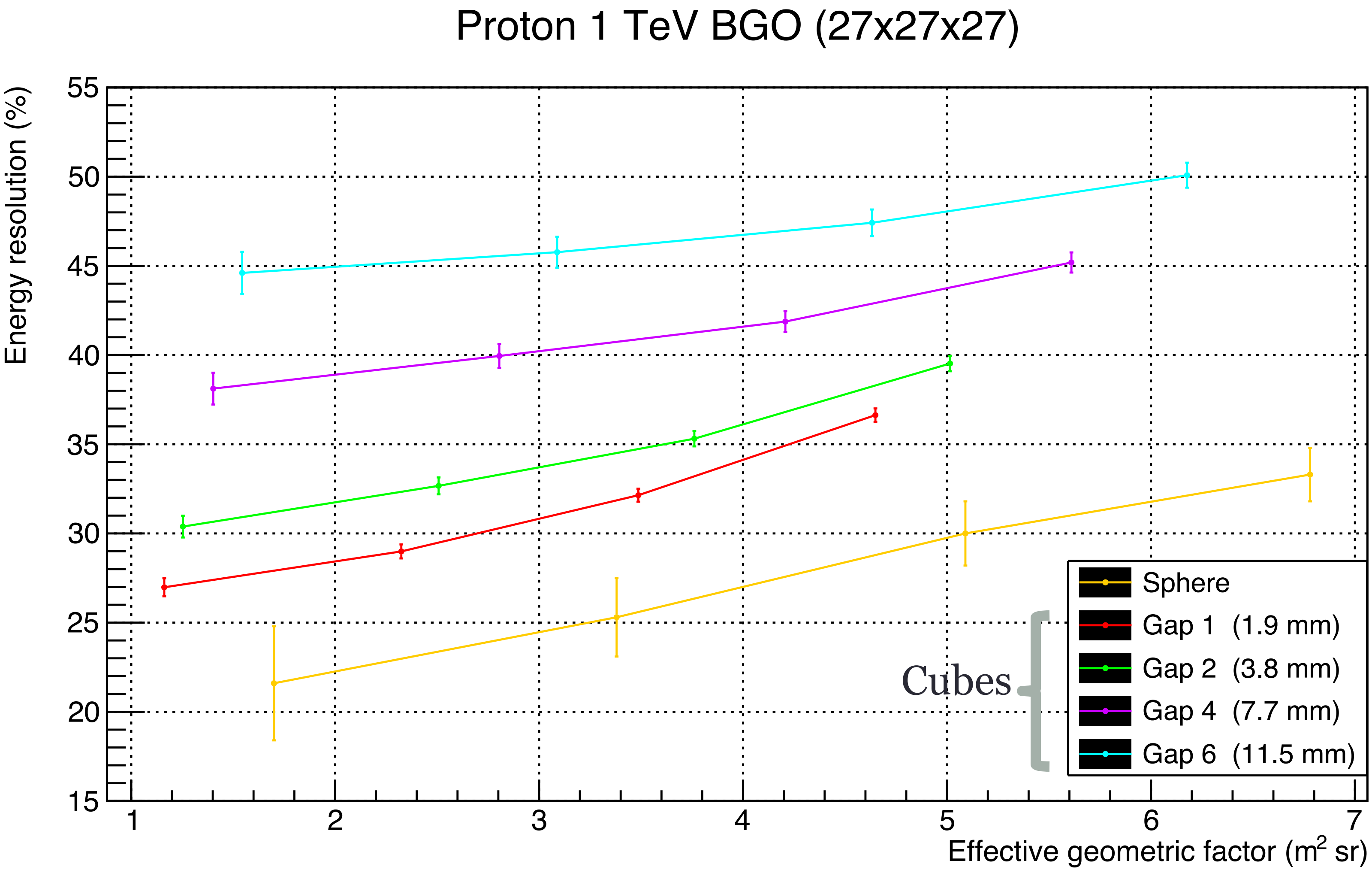
- Crystals dimensions
- Gap btw crystals to increase the acceptance



Size of the red square	a = *1.2 cm*	Single crystal
Size of the yellow cubic envelope	$l = \sqrt{2} \times 2 \times a = 3.4$ cm	
Gap	gap = *0.8 cm*	
Volume	$V = 8 \times \sqrt{2} \times a^3 = 19.55$ cm^3	
Weight	W = *139.4 g*	

Number of crystals along the diameter	*25*	
Total number of crystals	*14361*	Spherical calorimetric
External Diameter	*103.6 cm*	
Total weight	*2002 kg*	
Depth on the diameter	$3.75\ \lambda_I$	
Geometrical factor	*10.6 m^2 sr*	

The Spherical Calorimeter



Expected number of high energy charged cosmic rays events with a GF_{eff}=10 m² sr

Some assumptions:

- 10 years exposure
- e/p rejection factor ~ 10^5

Protons and Helium (Polygonato model)											
Effective GF (m² sr)	σ(E)/E	E>0.1 PeV		E>0.5 PeV		E>1 PeV		E>2 PeV		E>4 PeV	
		p	He	p	He	p	He	p	He	p	He
~10.0	35%	20.10^3	19.10^3	$1.1.10^3$	$1.3.10^3$	$3.0.10^2$	$3.7.10^2$	70	110	12	25

Electrons (no nearby sources)					
Effective GF (m² sr)	σ(E)/E	E>0.5 TeV	E>1 TeV	E>2 TeV	E>4 TeV
10	~1%	550.10^3	105.10^3	15.10^3	18.10^2

THE MAGNETIC SPECTROMETER

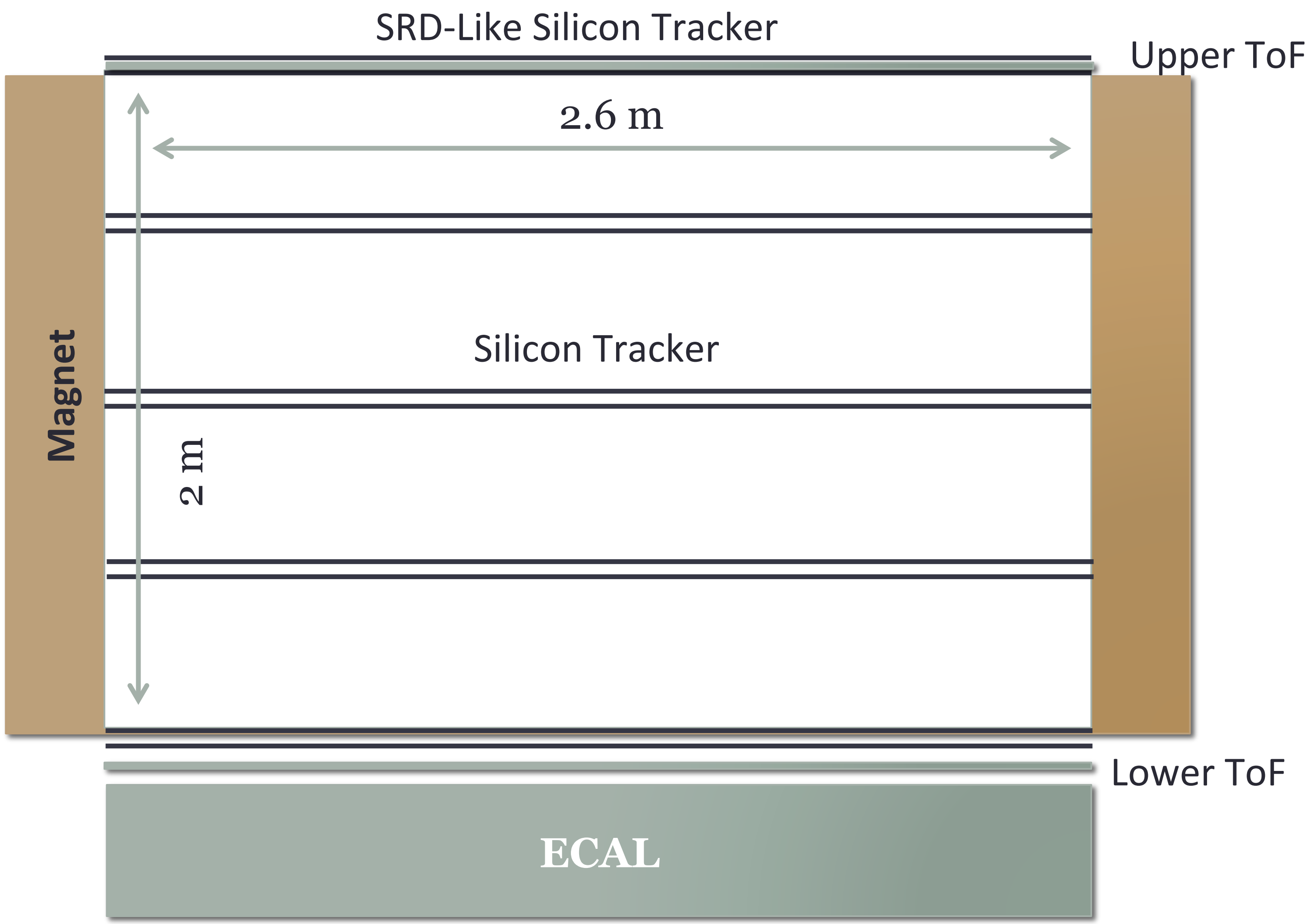
How to reach the O (10 TeV) scale with a ‘traditional’ approach?

- Let’s take AMS-02 as a reference
- Exposure : increase by a factor O(100) for e^+

From 0.05 m^2 sr to 5 m^2sr

- Detector : capable to deal with 10 TeV particles
  - Tracker + Magnet → MDR > 20 TV
  - ECAL → ECAL+HCAL

IMPROVED AMS-Permanent Magnet



A possible design: ToF + Tracker + Ecal/HCAL + SRD-like

SRD-like: 2D X-ray detector to be installed on the top of the magnet on the space station

Permanent Magnet:

Inner radius 130 cm, Height 200 cm,
B-field 0.10 Tesla
Weight: ~13 Tons , MDR 22 TV/c,
Acceptance 6 times AMS-02-Magnet

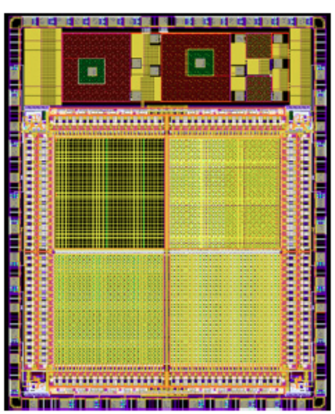
Calorimeter: Radius 130cm, tungsten absorber,
Scintillating fibers with SiPM readout,
Thickness 32 cm, 37 Radiation Length,
Weight ~15 Tons Acceptance 50 times AMS-02 ECAL

Tracker: 5 carbon fiber disks in a carbon fiber support structure with a top and bottom silicon layer on each disk.
Single Point resolution < 0.002 mm.
Technology : CMOS camera arrays being developed for LHC during the last 10 years (record resolution 600 nanometers)

Expected Acceptance: ~5 m^2 sr **MDR: 22 TV/c**

How to get to micron tracking accuracy

- 1) AMS experience show us that through suitable cooling micron level stability can be achieved over O(1) m^3 using stiff CR as alignement tool
- 2) Space seems to be the right place to implement O(1) um resolution tracking which is considered for LHC upgrades and has been developed for at least 10 years → CMOS monolithic pixel sensors



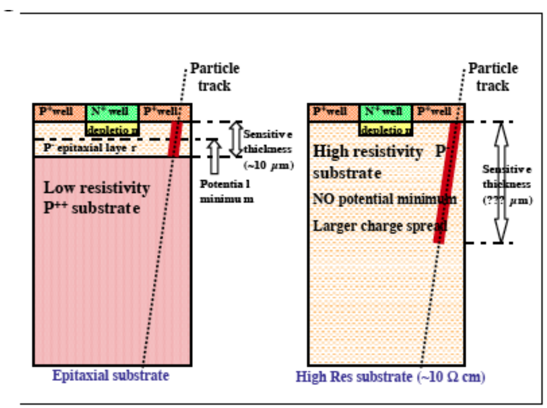


Fig. 1. Cross section of silicon wafers used for the fabrication of CMOS monolithic pixel sensors. On the left, the structure of epitaxial type wafer is shown. On the right the non-epitaxial, high resistivity wafer is presented.

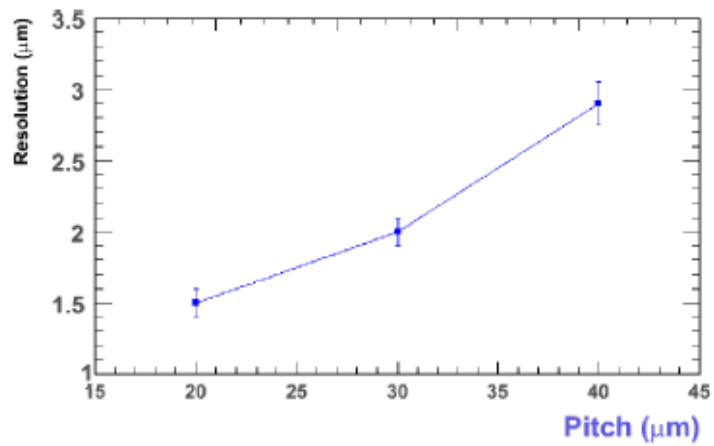
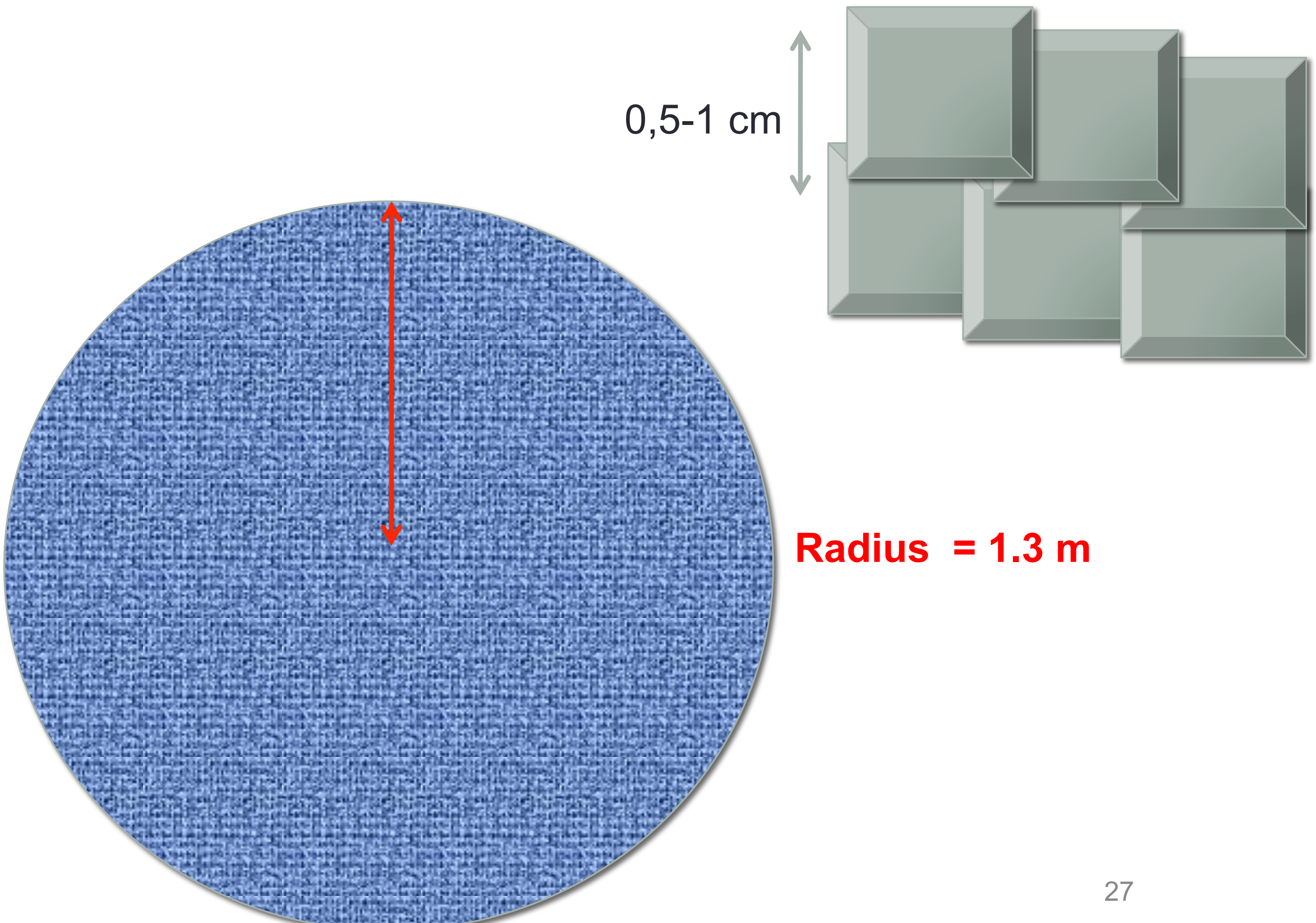
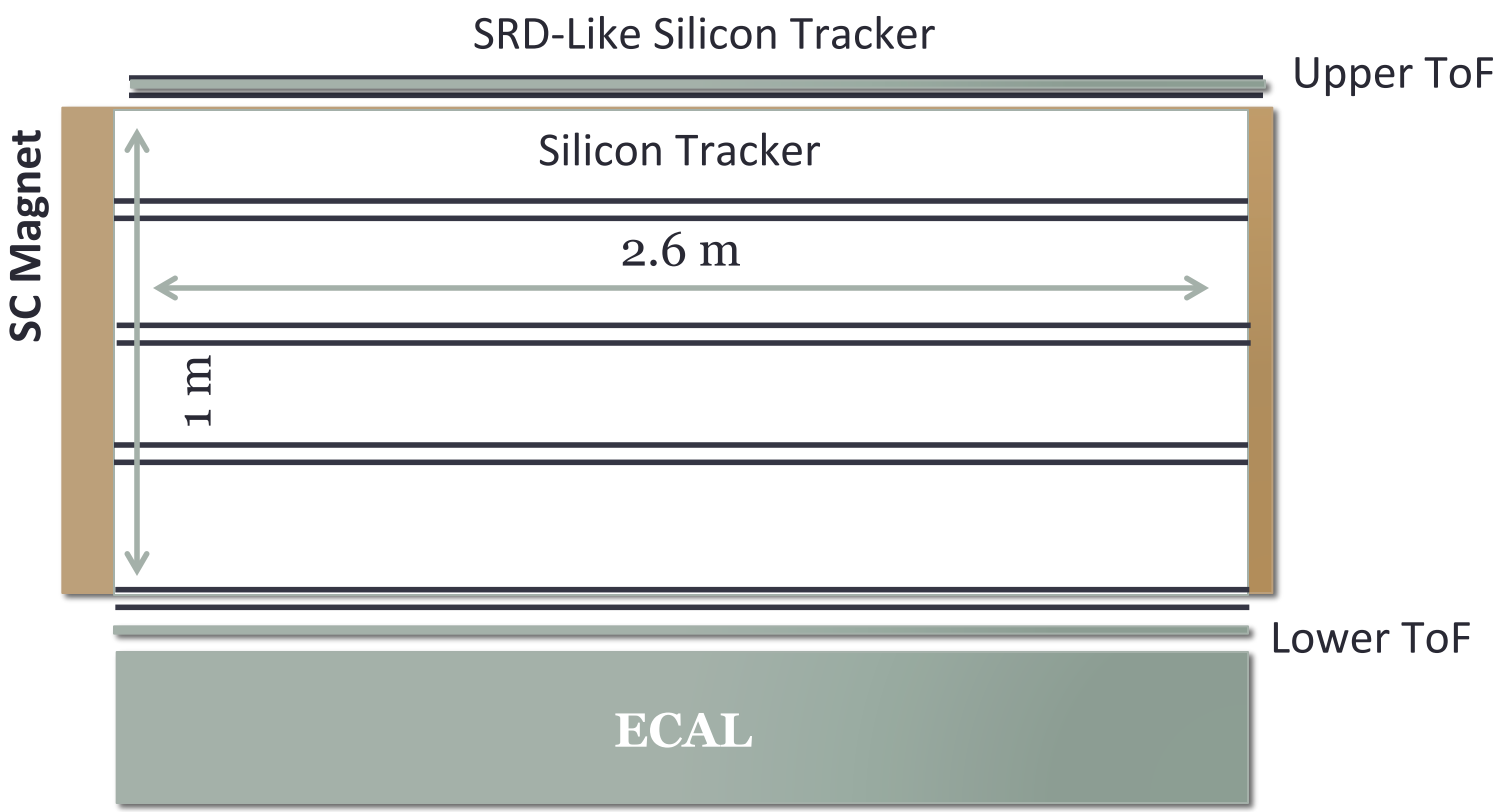


Fig. 8. Spatial resolution for minimum ionizing particles as a function of pixel pitch, measured with Mimosa9 prototype.

Micron accuracy, tiles tracker



IMPROVED-AMS- Super Conducting Magnet



A possible design: ToF + Tracker + Ecal/HCAL + SRD-like

SRD-like: 2D X-ray detector to be installed on the top of the magnet on the space station

Magnet: MgB2 double helix (perfect dipole) :
Inner radius 130 cm, Height 100 cm,
B-field 1 Tesla
Weight: << 1 Ton , MDR 56 TV,

ECAL: Radius 130cm,
tungsten absorber, scintillating fibers with SiPM readout,
Thickness 32 cm, 37 Radiation Length,
Weight ~15 Tons Acceptance 75 times AMS-02 ECAL

Tracker: 5 carbon fiber disks in a carbon fiber support structure with
a top and bottom silicon layer on each disk.
Single Point resolution < 0.002 mm.
Technology : CMOS camera arrays being developed for LHC during the last 10 years (record resolution 600 nanometers)

Expected Acceptance: 9 m^2 sr **MDR: 56 TV/c**

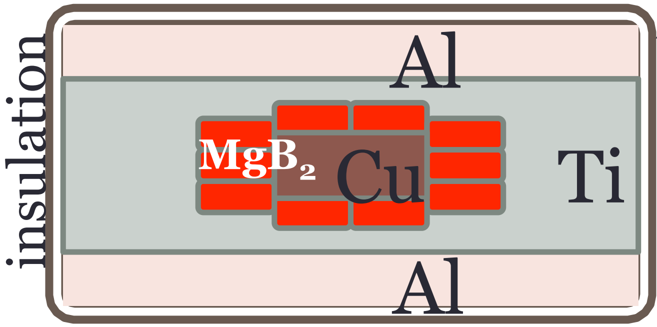
R&D on High Temperature Superconductors

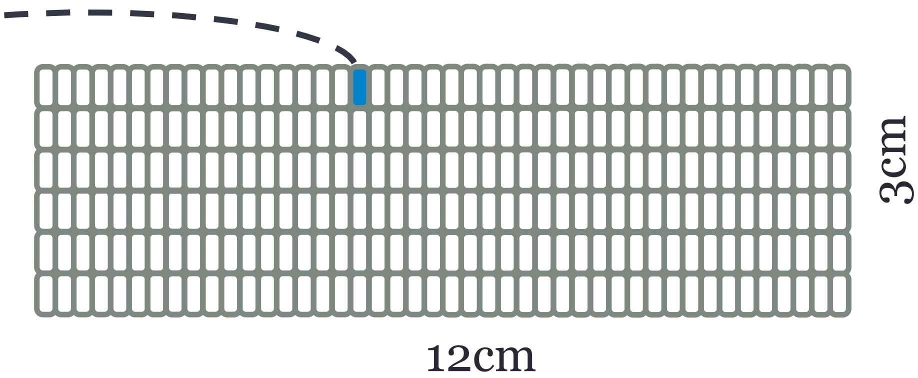
Superconducting Compound	T_c in Kelvin	Hc_2 at 4.2 K in Tesla	ξ (nm)	Mass Density (g/cm^3)
Nb-Ti	9	10	5	6.0
Nb_3Sn	18	28	5	7.8
MgB_2	39	up to 70	5	2.5
YBCO-123	90	> 50	<< 1 *	5.4
BSCCO-2223	108	> 50	<< 1 *	6.3

SRS2 FP7 program is developing a **MgB2 –Ti cable** which could match the needs of such a spectrometer

Magnet operation temperature 10K, cryogenics based on recirculating fluid → **no endurance limit**

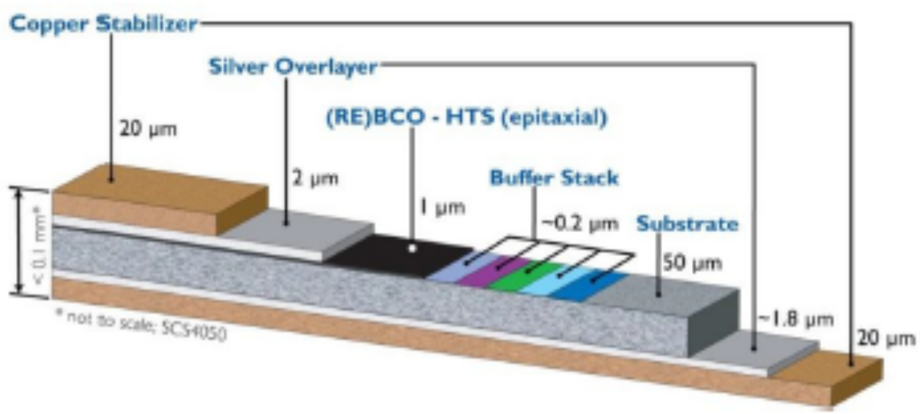
MgB_2 @ ≥10K [δ=600A/mm², d=3.64g/cm³]





Cross section: 2.5x5mm²

YBCO @ 40K [δ=870/mm² (for Rad protection in space - project), d>6.4g/cm³]



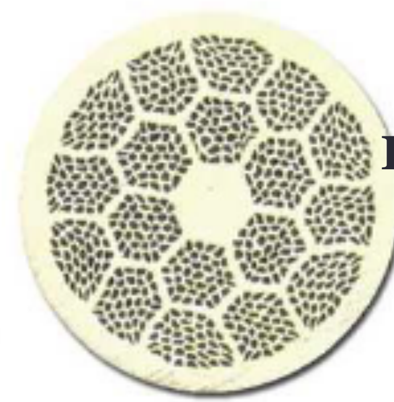
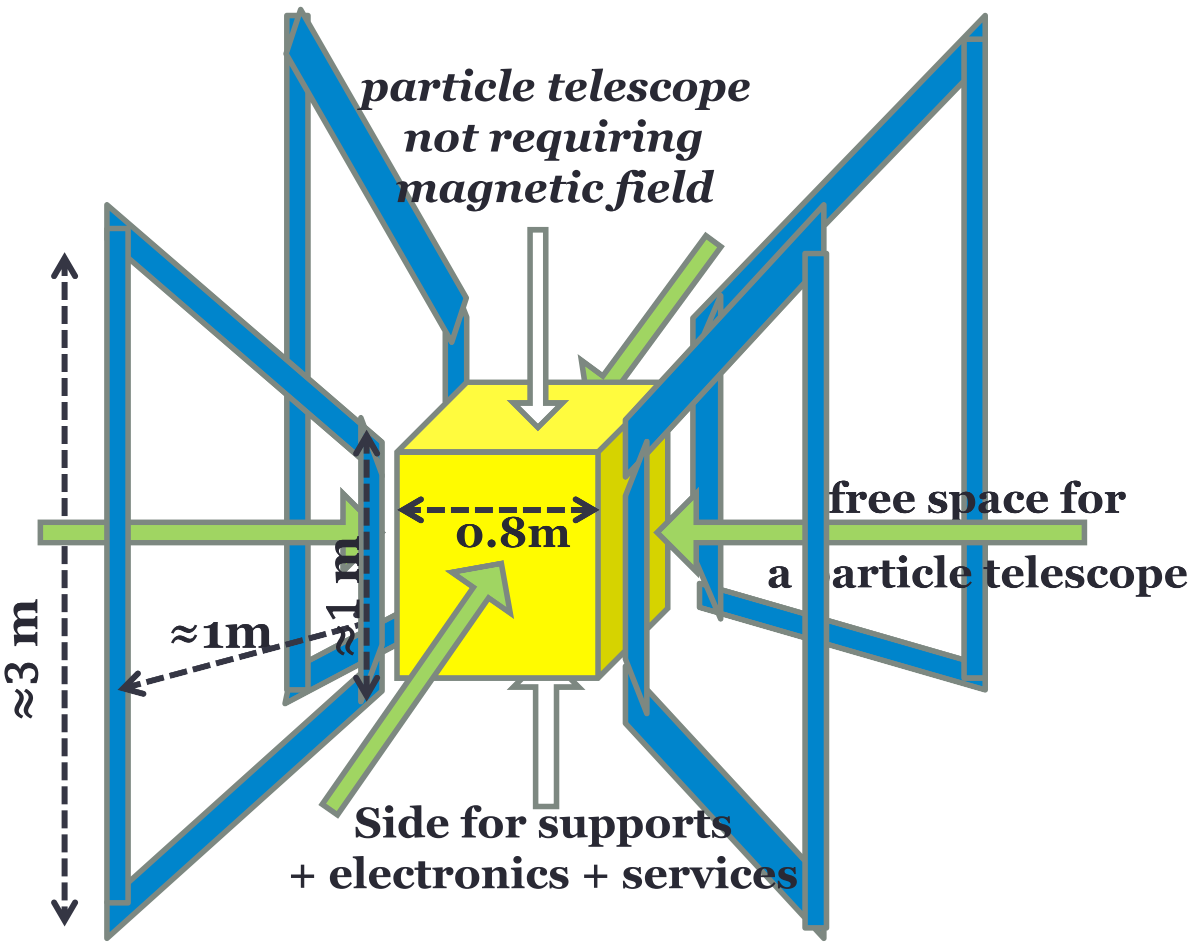


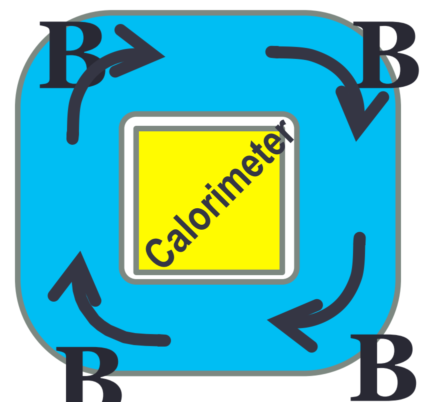
Figure 3 Example YBCO tape (graphic provided courtesy of SuperPower Inc.), left; and example BSSCO multifilament round wire in Ag stabilizer (graphic provided courtesy of Oxford Instruments), right

A more 'exotic' approach for the spectrometer

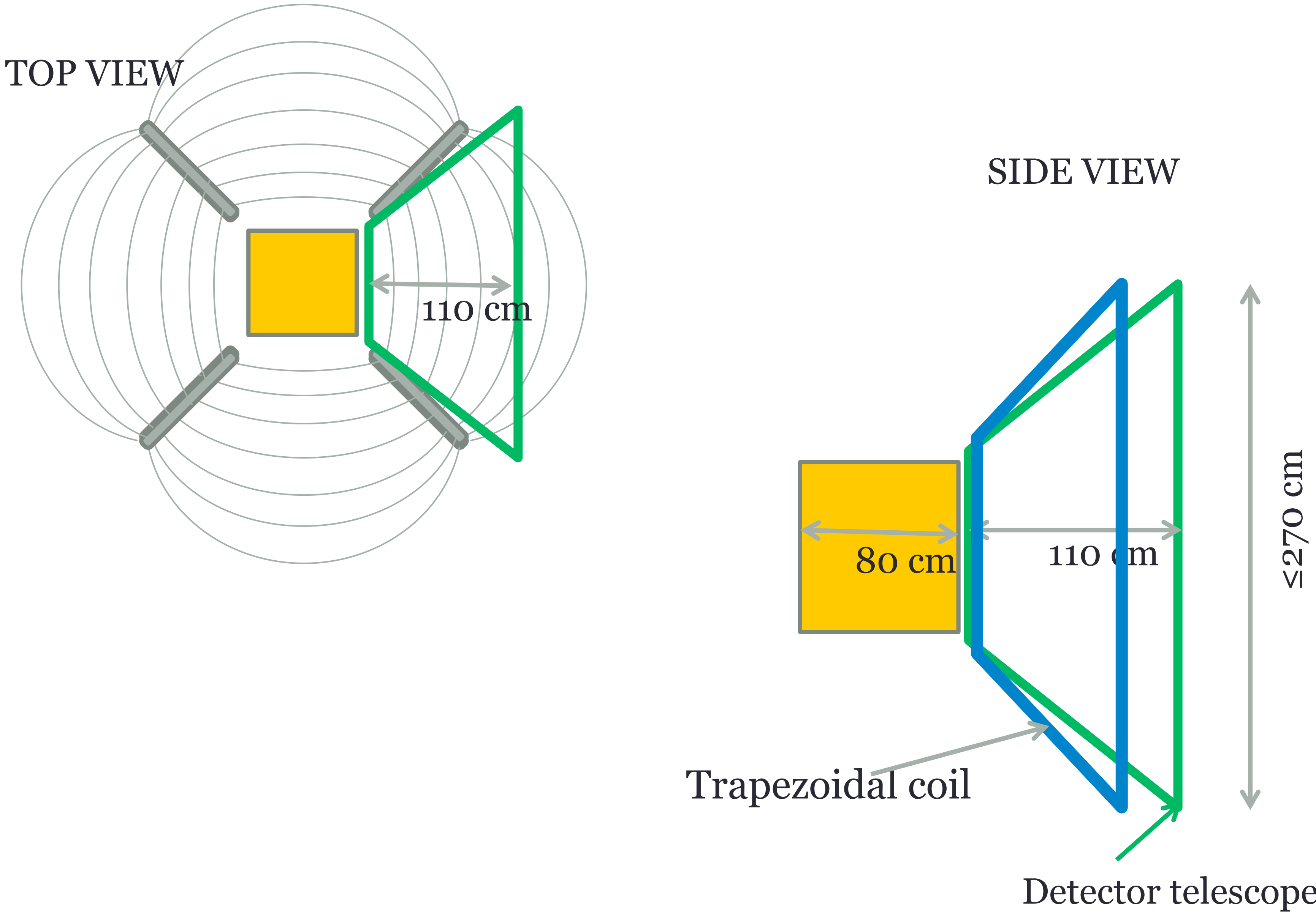


Spectrometer
$GF_1 \leq 1.28 m^2 sr$
x4
$GF \leq 5.12 m^2 sr$

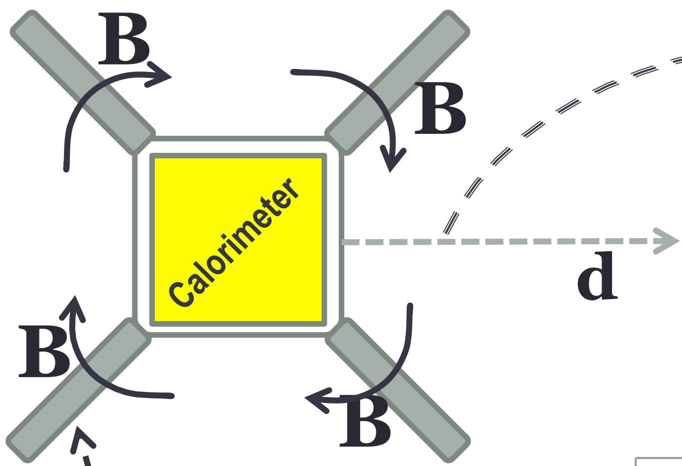
The 'torus' concept, **B** running around four faces of the calorimeter
magnetic dipole = null
suitable for CR experiments in space

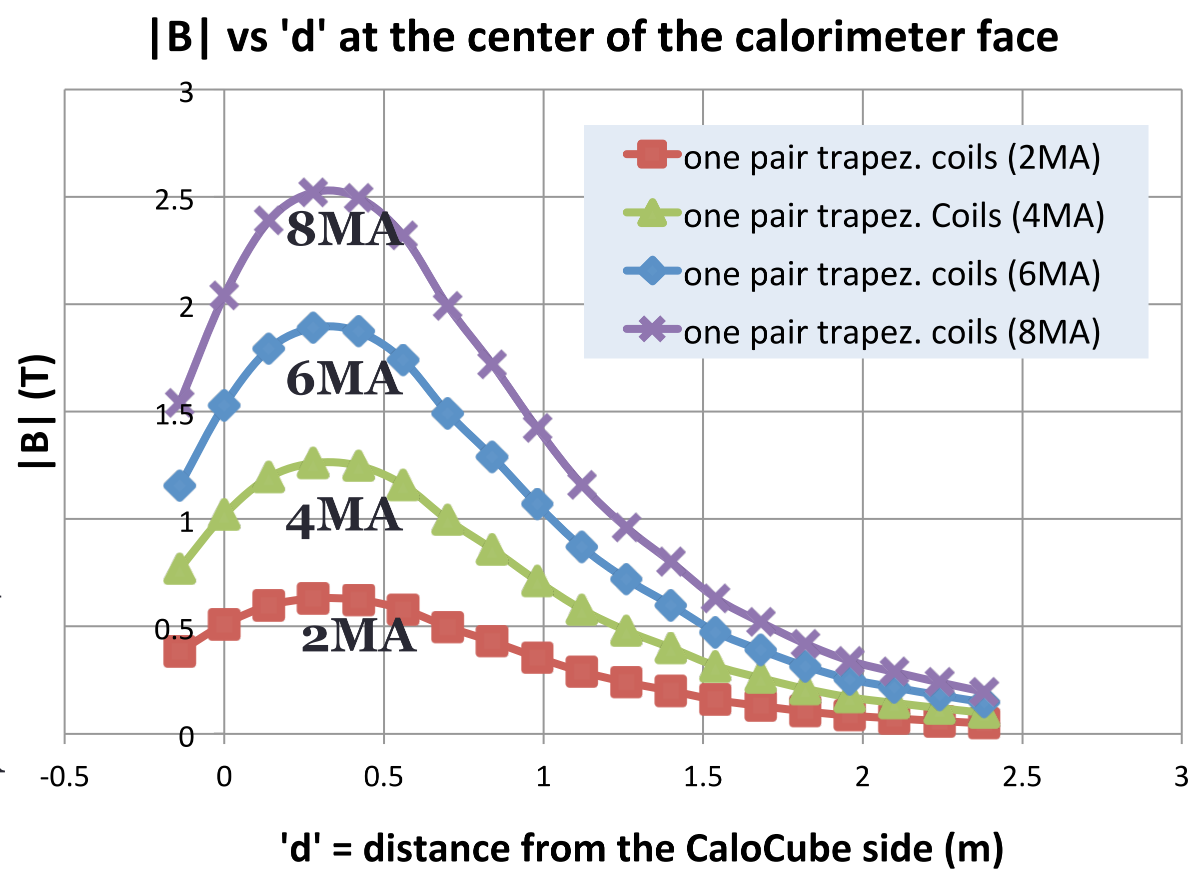


Next few slides from P. Spillantini


TOP VIEW
110 cm
SIDE VIEW
80 cm
110 cm
≤270 cm
Trapezoidal coil
Detector telescope

Bending power





$\int Bdl \approx 0.5Tm$ @ 2MA
$\int Bdl \approx 1.0Tm$ @ 4MA
$\int Bdl \approx 1.5Tm$ @ 6MA
$\int Bdl \approx 2.0Tm$ @ 8MA

Parameters of s.c. cable (for trapezoidal coils, length≈7m)

MgB_2 (drawn in Ti, stabilized in Al) @ T =10K @ few tesla (B≤4T)

with **δ = 600A/mm²** (short samples, engineering in next years)

for 1MA cable section = 17cm² (r=2.3cm), Bmax=8.7T
cable mass = 6.7kg/m→ coil = 47kg

for 2MA cable section = 35cm² (r=3.3cm), Bmax=12.1T
cable mass = 13kg/m → coil = 90kg

for 4MA cable section = 70cm² (r=4.6cm), Bmax=17.4T
cable mass = 26kg/m → coil = 180kg

for 6MA cable section = 105cm² (r=6.6cm), Bmax=18.2T
cable mass = 36kg/m → coil = 255kg

With HTS (e.g. YBCO) the masses could be 1.5 times lower,

Conclusions for the magnetic bubble instrument

	PAMELA	AMS-2	magn. bubble (4 telescopes) cal. side 0.8m	magn. bubble (4 telescopes) cal. side 0.8m	Magn. bubble (4 telescopes) cal. side 0.8m
bending power (Tm)	0.22	0.10	0.5 (2MA)	1.0 (4MA)	2.0 (8MA)
GF for e+ (m^2sr)	0.0025	0.031	≤5.2*	≤5.2*	≤5.2*
MDR (TV/c)	1.2	2.1	≈4**	≈8**	≈16**

*for largest possible telescopes 2.9x2.9m², h=1.2m
**depending from the precision of the tracker (assumed 5μm for the sagitta)

Conclusions

- To have a full coverage of some of the still unresolved items in the charged cosmic ray physics a double approach is clearly preferred
  - Wide aperture, very deep, isotropic homogeneous calorimeter looks to be the best choice
    - Few tons
    - Gf_{eff}~10 m^2sr
    - Direct investigation of the knee region with ~30% hadronic energy resolution
    - Excellent all electron spectrum up to ~10 TeV with ~% e.m. energy resolution
  - Huge acceptance magnetic spectrometer is a must
    - Gf_{eff}~10 m^2sr
    - MDR~10 TV/c
    - 'Traditional' scheme or more exotica solutions can be envisaged

  - Certainly a very exciting field, stay tuned (and collaborate!!!!!!)

BACKUPS

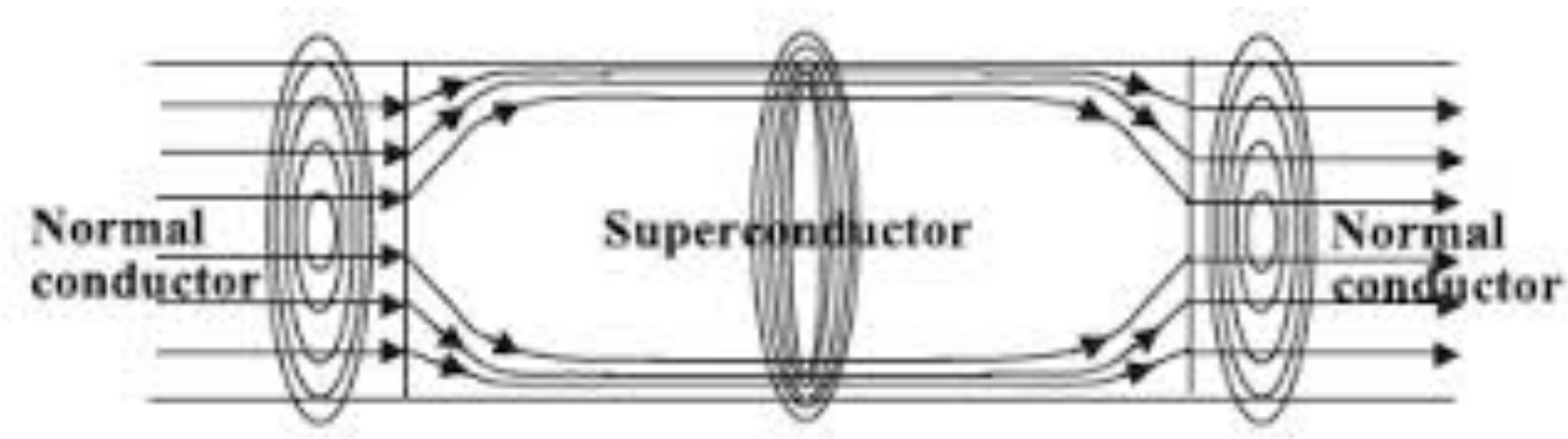
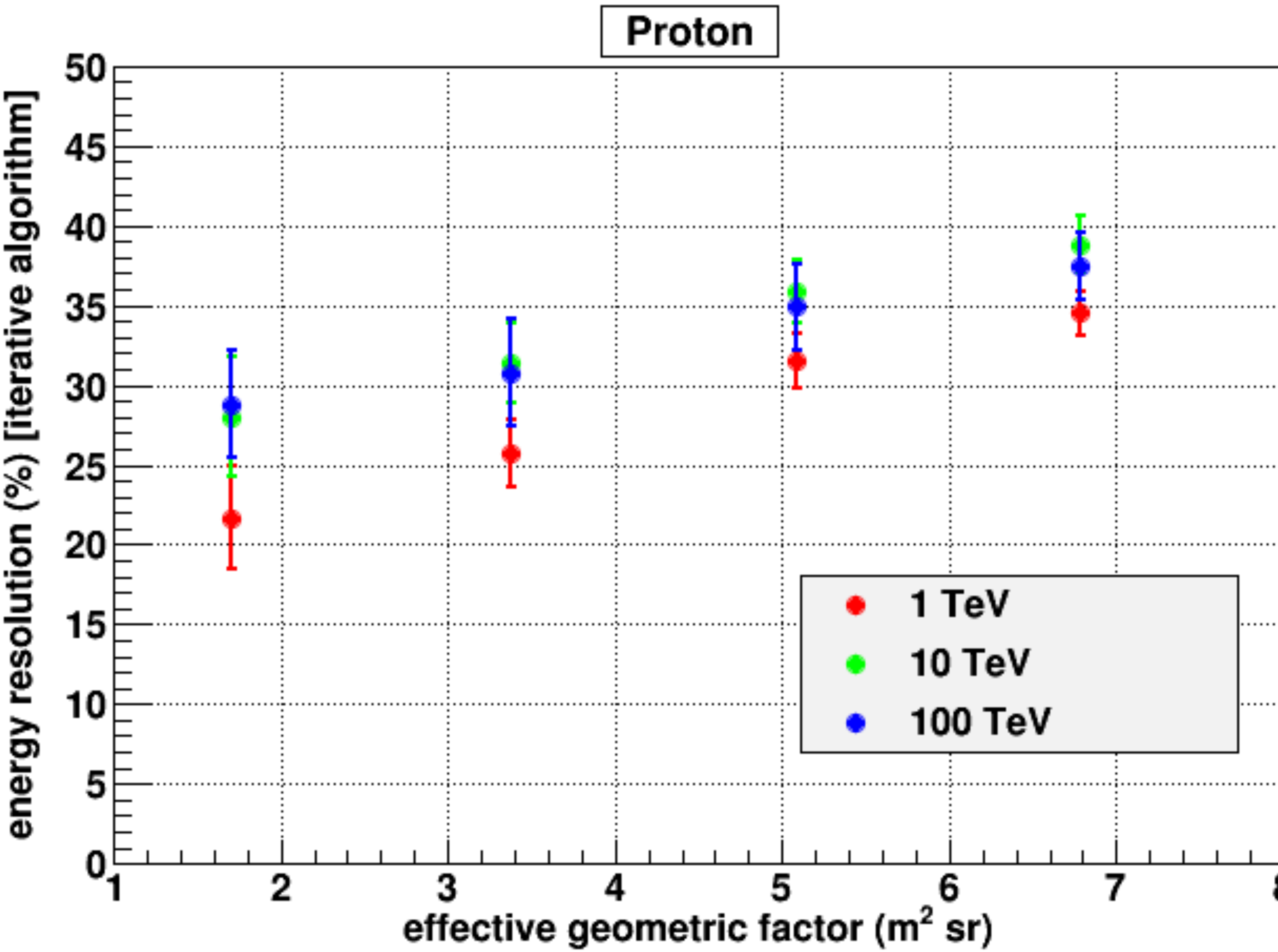
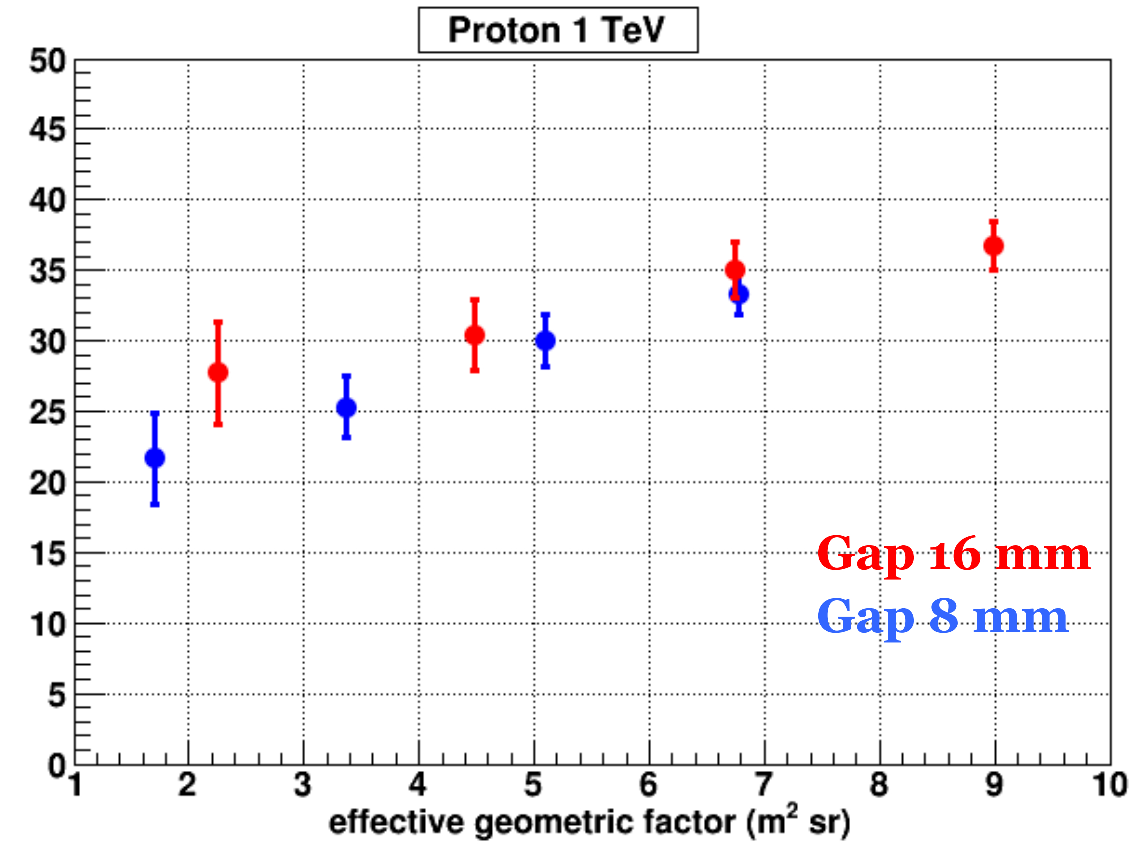


Figure 3. Current distribution in a superconducting wire fed by normal conducting leads. As electrons enter the superconducting region their velocities acquire a radial component and charge moves towards the surfaces together with magnetic field lines (circles).


Proton
energy resolution (%) [iterative algorithm]
effective geometric factor (m² sr)
1 TeV
10 TeV
100 TeV
0
5
10
15
20
25
30
35
40
45
50
1
2
3
4
5
6
7
8

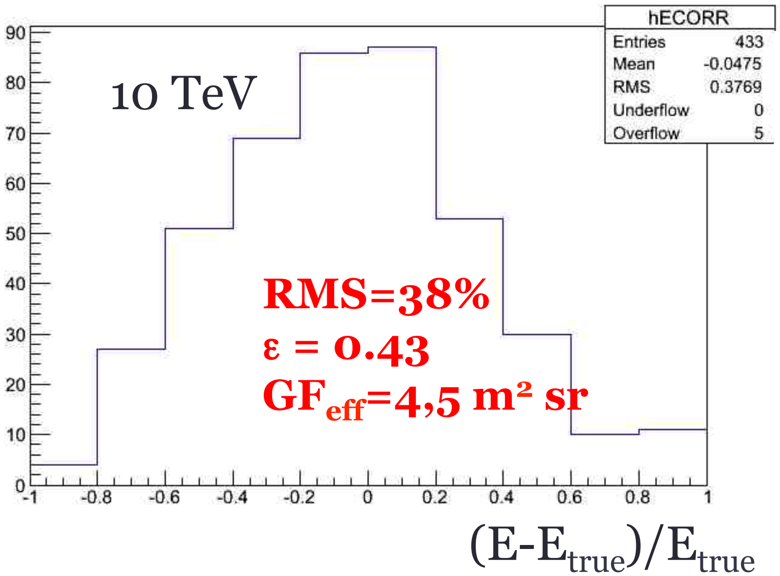
Comparison between different geometric configurations

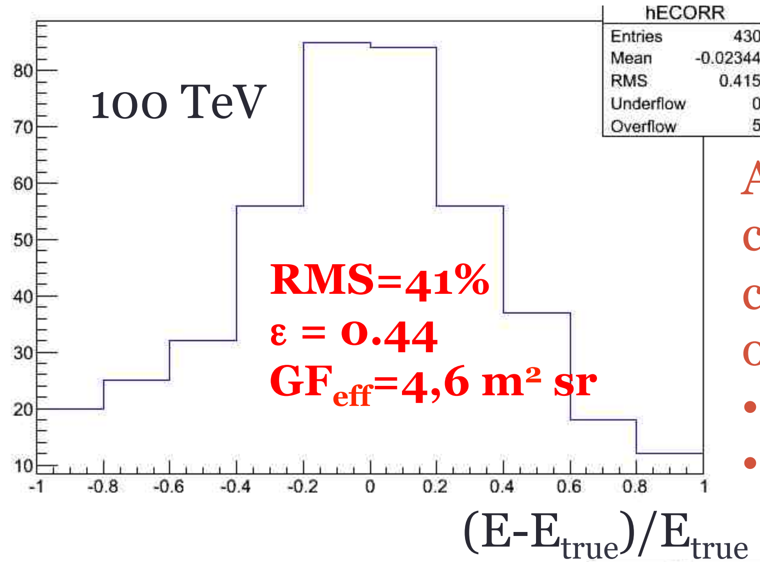


Gap 16 mm

efficienza (%)	ΔE/E (%)	G.F. efficace (m^2 sr)
100	36.7 ± 1.7	8.99
75	35.0± 2.0	6.74
50	30.4 ± 2.5	4.49
25	27.7± 3.6	2.25

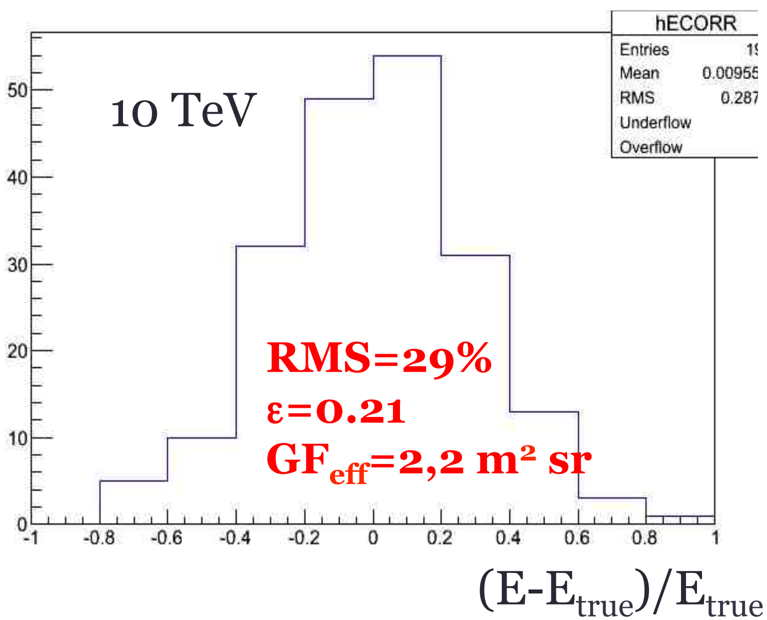
Protons: energy resolution

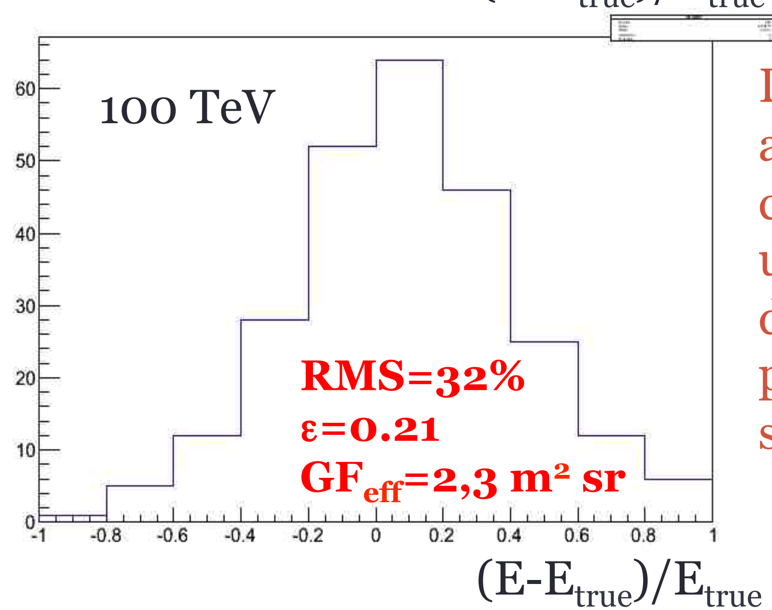




Analysis criteria can be changed to optimize:

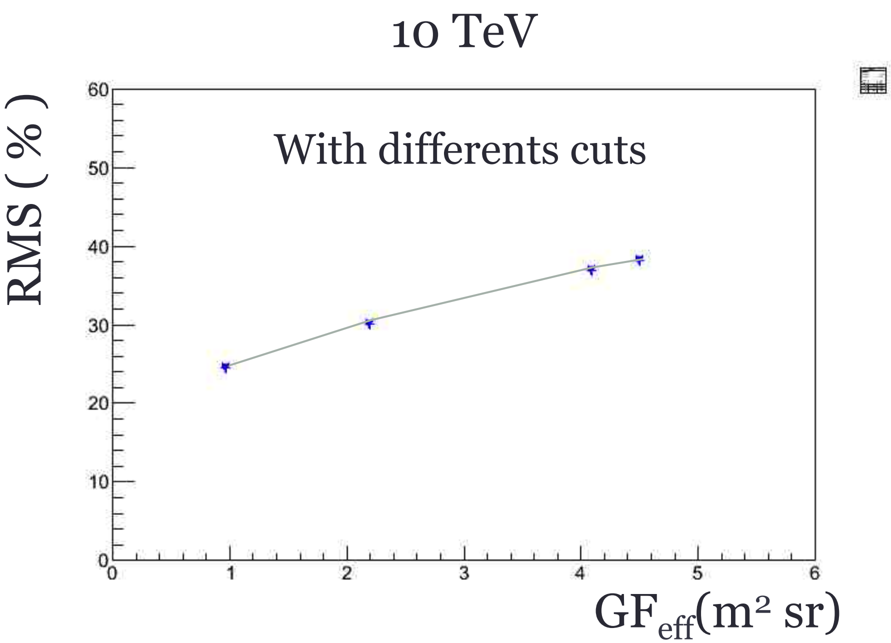
- Acceptance
- Energy resolution

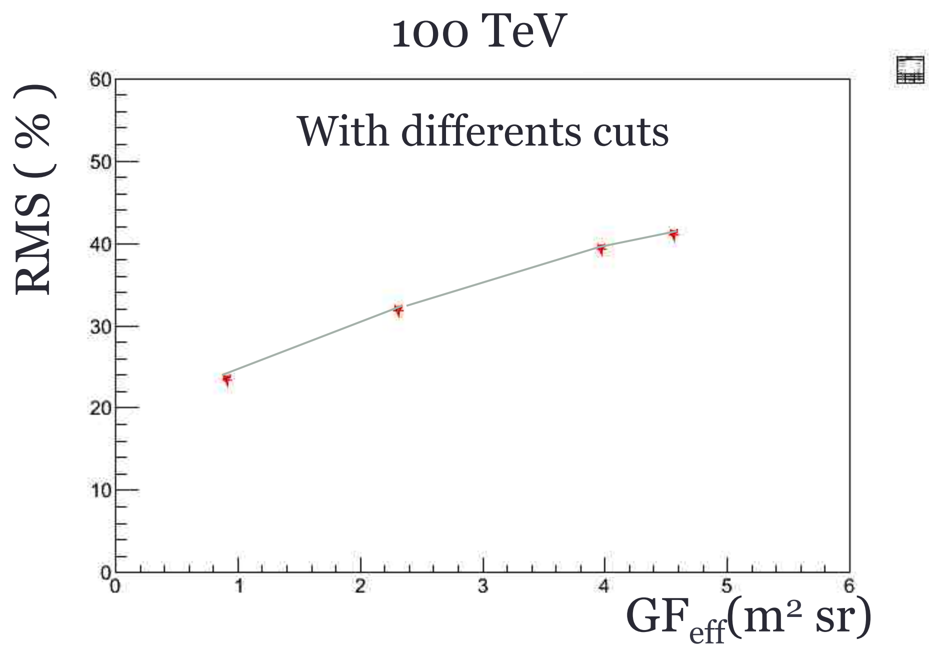




Different analysis criteria can be used for different portions of the spectrum

Protons: energy resolution





		Density (g/cm3)	λ (cm)	X_0 (cm)	λ/X_0	R_M (cm)	Cube side (cm) @ 2t	Total n.int.lengths @ 2t	Total n.rad.lengths @ 2t	W.L. max. emission (nm)	D.time (ns)	L.Y. (%) @300K	Price (EUR/cm^3)	S	C	n	Notes
Li-glass		2,5	?	?	?	?	93	?	?	?	?	?		✓	?	✓	
CaF2:Eu		3,18	34	3,1	11	3,7	86	2,5	28	435	940	50		✓			
LGB:Ce	Li6GdB3O9	3,5	?	?	?	?	?	?	?	390	200	26		✓	?	✓	
NaI:Tl		3,67	43	2,6	17	4,1	82	1,9	32	410	230	100		✓			
LiI:Eu		4,08	45	2,6	18	4,4	79	1,7	31	470	1400	30		✓		✓	
YSO:Ce	Y2SiO5	4,5	27	3,0	9	2,9	76	2,8	25	420	35	26		✓	?		
CsI		4,5	40	1,9	21	3,6	76	1,9	41	310	10	5	8	✓	T		
CsI:Na		4,5	40	1,9	21	3,6	76	1,9	41	420	630	88	6,5	✓	T		
CsI:Tl		4,5	40	1,9	21	3,6	76	1,9	41	550	1250	165	6	✓	✓		prototype 4,5 EUR/cm3
YAG:Ce	Y3Al5O12	4,57	25	3,5	7	2,8	76	3,0	22	550	70	40	94	✓	T		
YAG:Yb	Y3Al5O12	4,57	25	3,5	7	2,8	76	3,0	22	335	20	9	?	✓	T		
BaF2		4,89	31	2,0	15	3,1	74	2,4	37	300	630	36	11	✓	T		good UV properties
YAP:Yb	YAlO3	5,5	22	2,7	8	2,4	71	3,3	26	362				✓	T		
YAP:Ce	YAlO3	5,5	22	2,7	8	2,4	71	3,3	26	370	27	47	170	✓			
GSO:Ce	Gd2SiO5	6,7	22	1,4	16	2,2	67	3,0	48	440	56	24		✓	?		
LuAG:Yb	Lu3Al5O12	6,73	21	1,5	14	2,2	67	3,3	46	346			?	✓	?		
LuAG:Ce	Lu3Al5O12	6,73	21	1,5	14	2,2	67	3,3	46	535	70	20	290	✓	?		
BSO	Bi4Si3O12	6,8	22	1,1	20	2,2	67	3,0	60	480	100	6		✓	✓		
BGO	Bi4Ge3O12	7,13	23	1,1	20	2,2	65	2,9	58	480	300	21		✓	✓		
NBWO	NaBi(WO4)2	7,5	?	?	?	?	64	?	?	0	0	0			✓		
LYSO:Ce	Lu2Y2Ce2x(SiO4)O	7,4	21	1,1	19	2,1	65	3,1	59	402	40	85		✓			
LSO:Ce	Lu2Ce2x(SiO4)O	7,4	21	1,1	19	2,1	65	3,1	59	402	40	85		✓			
PbF2		7,7	?	0,9	?	2,2	64	?	69	0	0	0			✓		
CWO	CdWO4	7,9	19	1,1	18	2,0	63	3,3	58	470	14500	39		✓			
PWO	PbWO4	8,3	21	0,9	23	2,0	62	3,0	70	425	5	0,3		✓			

AMS-02 : expected rates and detection tools/limitations

ELECTRON AND POSITRON PHYSICS @ AMS-02

	0,05 m2 sr		3,14E+07 s/y			EXCLUDED	EXCLUDED	EXCLUDED
eV	**10^8**	**10^9**	**10^10**	**10^11**	**10^12**	**10^13**	**10^14**	**10^15**
scale	**100MeV**	**GV**			**TV**			**PV**
Integral . 1/y	**.@ 0,1-1**	**.@ 1-10**	**.@ 10-100**	**.@ 100-1000**	**.@ 1.000 ->**	**.@ 10.000 ->**	**.@ 100.000 ->**	**.@ 1.000.000 ->**
e-	4,99E+08	3,11E+07	1,56E+06	9,33E+03	7,78E+01	7,78E-01	7,78E-03	7,78E-05
e+	4,99E+07	3,11E+06	2,33E+05	1,40E+03	1,17E+01	1,17E-01	1,17E-03	1,17E-05
Detectors	tracker, TOF, TRD, ECAL	tracker, TOF, TRD, ECAL	Tracker, TRD, ECAL	Tracker, TRD, ECAL	Tracke,TRD,ECAL			
Variables	R, beta, gamma, energy	R, beta, gamma, energy	R, gamma, energy	R, gamma, energy	R, gamma, energy	R, Energy, Synchroton Radiation	R, Energy, Synchroton Radiation	R, Energy, Synchroton Radiation
Physics	Van Allen, solar, subcutoff	solar, geomagnetic, galactic	DM, galactic, asymmetries	DM, galactic, asymmetries	DM, galactic	DM, galactic, moon shadow, sun shadow	DM, galactic	DM, extragalactic, knee
Tools	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, TRD calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, TRD calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, TRD calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner/outer tracker, TRD, alignement, backtracing (Earth-Moon, Earth- Sun)	acceptance vs R, live time, efficiency, MC, outer tracker, alignement, SRD calibration, ECAL calibration, backtracing Earth-Moon, Earth-Sun	acceptance vs R, live time, efficiency, MC, outer tracker, alignement, SRD calibration, ECAL calibration, backtracing Earth-Moon, Earth-Sun	acceptance vs R, live time, efficiency, MC, outer tracker, alignement, SRD calibration, ECAL calibration, backtracing Earth-Moon, Earth-Sun	acceptance vs R, live time, efficiency, MC, outer tracker, alignement, SRD calibration, ECAL calibration, backtracing Earth-Moon, Earth-Sun
Background e-	-	-	-	p	p	p	p	p
Background e+	p	p	p	p	p	p	p	p
Limitations	multiple, scattering, acceptance,AMS02 magnetic field		-	TRD loses, ECAL must be in acceptance	momentum resolution runs out, TRD loses, ECAL must be in accceptance	no statistics	no statistics	no statistics

AMS-02 : expected rates and detection tools/limitations

PROTON and HELIUM PHYSICS @ AMS-02

0,3 m2 sr		3,14E+07 s/y				EXCLUDED	EXCLUDED	EXCLUDED
	10^8 100MeV	10^9 GV	10^10	10^11	10^12 TV	10^13	10^14	10^15 PV
Integral . 1/y	**.@ 0,1-1**	**.@ 1-10**	**.@ 10-100**	**.@ 100-1000**	**.@ 1.000 ->**	**.@ 10.000 ->**	**.@ 100.000 ->**	**.@ 1.000.000 ->**
p	3,00E+09	5,98E+09	1,19E+09	2,38E+07	4,32E+05	8,61E+03	1,72E+02	3,43E+00
He	1,08E+08	1,08E+09	2,15E+08	4,28E+06	7,77E+04	1,55E+03	3,09E+01	6,17E-01
Detectors	tracker, TOF, RICH	Tracker, (RICH)	Tracker	Tracker	Tracker	TRD +ECAL ?		
Variables	R, beta	R	R	R	R, gamma	gamma		
Physics	Van Allen, solar, subcutoff	solar, geomagnetic, galactic	galactic	galactic	galactic, moon shadow, sun shadow	galactic, moon shadow, sun shadow	galactic	extragalactic, knee
Tools	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, RICH calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, , RICH calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, RICH calibration, backtracing near Earth)	acceptance vs R, live time, efficiency, MC, inner/outer tracker, alignement, backtracing Earth-Moon, Earth- Sun)	acceptance vs R, live time, efficiency, MC, outer tracker, alignement, , ECAL calibration, backtracing Earth-Moon, Earth-Sun	acceptance vs R, live time, efficiency, MC, outer tracker, alignement, TRD calibration, ECAL calibration, backtracing Earth-Moon, Earth- Sun)	acceptance vs R, live time, efficiency, MC, outer tracker, alignement, TRD calibration, ECAL calibration, backtracing Earth-Moon, Earth- Sun)	
Background p	-	-	-	-	e-	e-	e-	
Background He	He3/He4	He3/He4	He3/He4	He3/He4	-	-	-	
Limitations	multiple, scattering, acceptance,AMS02 magnetic field	-	-	different tracker acceptances, alignement	momentum resolution runs out, TRD comes in ?, if ECAL is used loss of factor 10 acceptance	only TRD has limited gamma resolution, if ECAL is used we lose a factor 50	only TRD has limited gamma resolution, if ECAL is used we lose a factor 50	no statistics

Improved AMS : expected rates detection tools/limitations

ELECTRON AND POSITRON PHYSICS @ AMS-03

	5 m2 sr	3,14E+07 s/y				ACCESSIBLE	EXCLUDED	EXCLUDED
eV	10^8	10^9	10^10	10^11	10^12	10^13	10^14	10^15
scale	100MeV	GV			TV			PV
Integral . 1/y	.@ 0,1-1	.@ 1-10	.@ 10-100	.@ 100-1000	.@ 1.000 ->	.@ 10.000 ->	.@ 100.000 ->	.@ 1.000.000 ->
e-	4,99E+10	3,11E+09	1,56E+08	9,33E+05	7,78E+03	7,78E+01	7,78E-01	7,78E-03
e+	2,50E+09	1,56E+08	1,56E+07	1,40E+05	1,17E+03	1,17E+01	1,17E-01	1,17E-03
Detectors	tracker, TOF, TRD, ECAL	tracker, TOF, TRD, ECAL	Tracker, TRD, ECAL	Tracker, TRD, ECAL	Tracker,SRD,ECAL	Tracker,SRD,ECAL		
Variables	R, beta, gamma, energy	R, beta, gamma, energy	R, gamma, energy	R, gamma, energy	R,Energy, Syncrotron Radiation	R, Energy, Synchroton Radiation		
Physics	Van Allen, solar, subcutoff	solar, geomagnetic, galactic	DM, galactic, asymmetries	DM, galactic, asymmetries	DM, galactic	DM, galactic, moon shadow, sun shadow	DM, galactic	DM, extragalactic, knee
Tools	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, TRD calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, TRD calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, TRD calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner/outer tracker, TRD, alignement, backtracing (Earth-Moon, Earth- Sun)	acceptance vs R, live time, efficiency, MC, outer tracker, alignement, SRD calibration, ECAL calibration, backtracing Earth-Moon, Earth-Sun	acceptance vs R, live time, efficiency, MC, tracker, alignement, SRD calibration, ECAL calibration, backtracing Earth-Moon, Earth-Sun		
Background e-	-	-	-	p	p	p	p	p
Background e+	p	p	p	p	p	p	p	p
Limitations	multiple, scattering, acceptance,AMS02 magnetic field		-		SRD Acceptance, MDR Tracker, ECAL must be in accceptance	SRD acceptance, MDR Tracker, ECAL must be in accceptance	no statistics	no statistics

Improved AMS : expected rates and detection tools/limitations

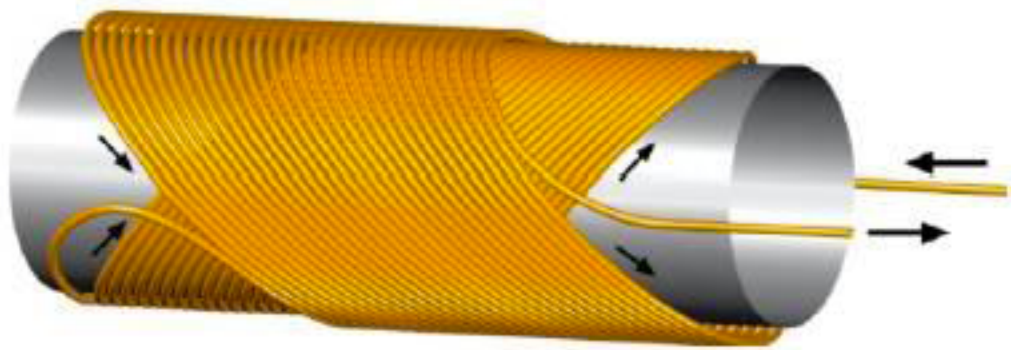
PROTON and HELIUM PHYSICS @ AMS-03

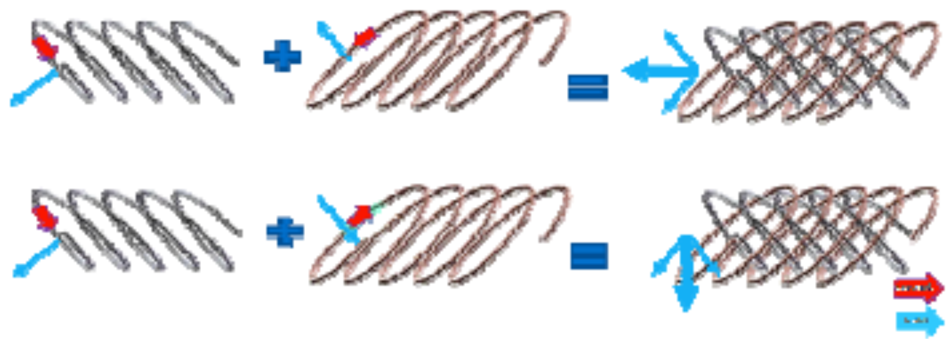
5 m2 sr — 3,14E+07 s/y

						ACCESSIBLE	ACCESSIBLE	ACCESSIBLE
	10^8 **100MeV**	**10^9** **GV**	**10^10**	**10^11**	**10^12** **TV**	**10^13**	**10^14**	**10^15** **PV**
Integral . 1/y	**.@ 0,1-1**	**.@ 1-10**	**.@ 10-100**	**.@ 100-1000**	**.@ 1.000 ->**	**.@ 10.000 ->**	**.@ 100.000 ->**	**.@ 1.000.000 ->**
p	4,99E+10	9,96E+10	1,99E+10	3,97E+08	7,19E+06	1,44E+05	2,86E+03	5,71E+01
He	1,80E+09	1,79E+10	3,58E+09	7,14E+07	1,29E+06	2,58E+04	5,15E+02	1,03E+01
Detectors	tracker, TOF, RICH	Tracker, (RICH)	Tracker	Tracker	Tracker	Tracker+ HCAL	Tracker+ HCAL	Tracker+ HCAL
Variables	R, beta	R	R	R	R	R, Energy	Energy	Energy
Physics	Van Allen, solar, subcutoff	solar, geomagnetic, galactic	galactic	galactic	galactic, moon shadow, sun shadow	galactic, moon shadow, sun shadow	galactic	extragalactic, knee
Tools	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, RICH calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, , RICH calibration, backtracing (near Earth)	acceptance vs R, live time, efficiency, MC, inner tracker, alignement, TOF calibration, RICH calibration, backtracing near Earth)	acceptance vs R, live time, efficiency, MC, inner/outer tracker, alignement, backtracing Earth-Moon, Earth- Sun)	acceptance vs R, live time, efficiency, MC, outer tracker, alignement, , ECAL calibration, backtracing Earth-Moon, Earth-Sun	acceptance vs R, live time, efficiency, MC, tracker, alignement, HCAL calibration, backtracing Earth-Moon, Earth- Sun	acceptance vs R, live time, efficiency, MC, tracker, alignement, HCAL calibration, backtracing Earth-Moon, Earth- Sun	HCAL calibration, backtracing Earth-Moon, Earth- Sun
Background p	-	-	-	-				
Background He	He3/He4	He3/He4	He3/He4	He3/He4	-	-	-	
Limitations	multiple, scattering, acceptance,AMS02 magnetic field	-	-	different tracker acceptances, alignement	MDR	MDR+ HCAL	HCAL	HCAL

Table 3. Intrinsic resolution measurements for APS devices

Sensor	Telescope Method	Sigma of the Fit	Telescope on-a-chip	Telescope on-a-chip with $\sigma_{predicted}$ subtraction
	[μm]		[μm]	[μm]
RAPS03 (small phot.)	1.400 ± 0.260	1.870 ± 0.500	1.560 ± 0.100	n.a.
RAPS03 (large phot.)	n.a.	1.780 ± 0.920	1.100 ± 0.240	n.a.
MT9V011	n.a.	0.851 ± 0.185	0.694 ± 0.478	0.580 ± 0.230
MT9T031	n.a.	0.739 ± 0.150	0.493 ± 0.280	0.375 ± 0.158
MT9T012	n.a.	0.323 ± 0.081	0.287 ± 0.216	0.297 ± 0.053
MT9T013	n.a.	0.280 ± 0.103	0.240 ± 0.122	0.166 ± 0.037
MT9J003	n.a.	0.311 ± 0.073	0.137 ± 0.087	0.090 ± 0.027





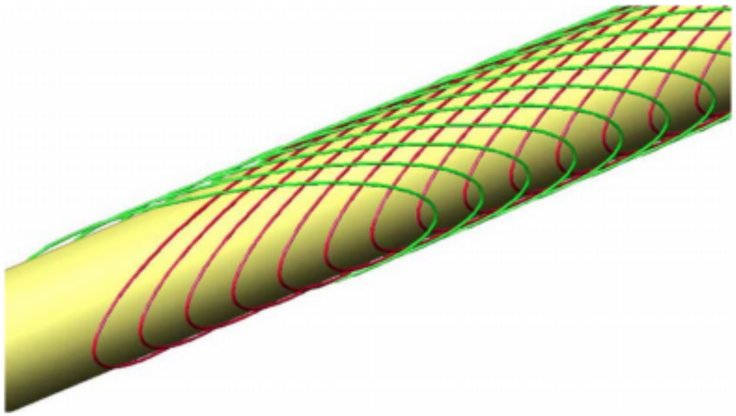


Fig. 2. Conceptual view of pure dipole windings.

The current density at any given location in z is a function of ϑ only, whereas $J = J_0(\vartheta)$ and its components are proportional to:

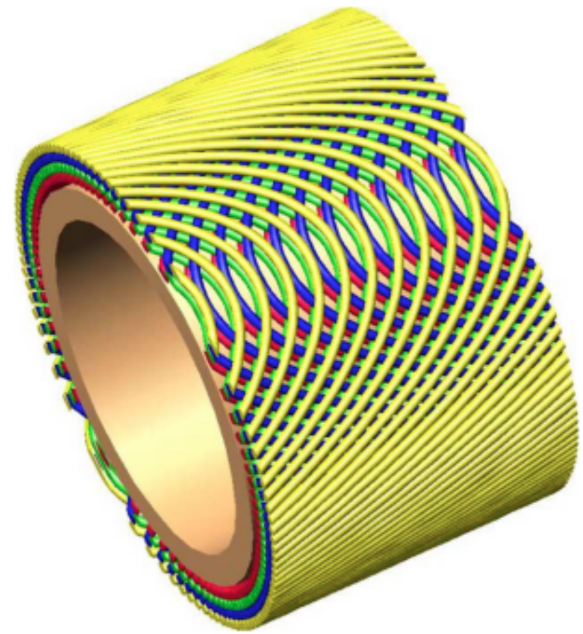


Fig. 3. Center cut of the 4 layer "cos-theta" dipole.

Fig. 8. Actual cross section of the dipole tested.

European Seventh Framework Program

Space Radiation Superconductive Shield (SR2S)

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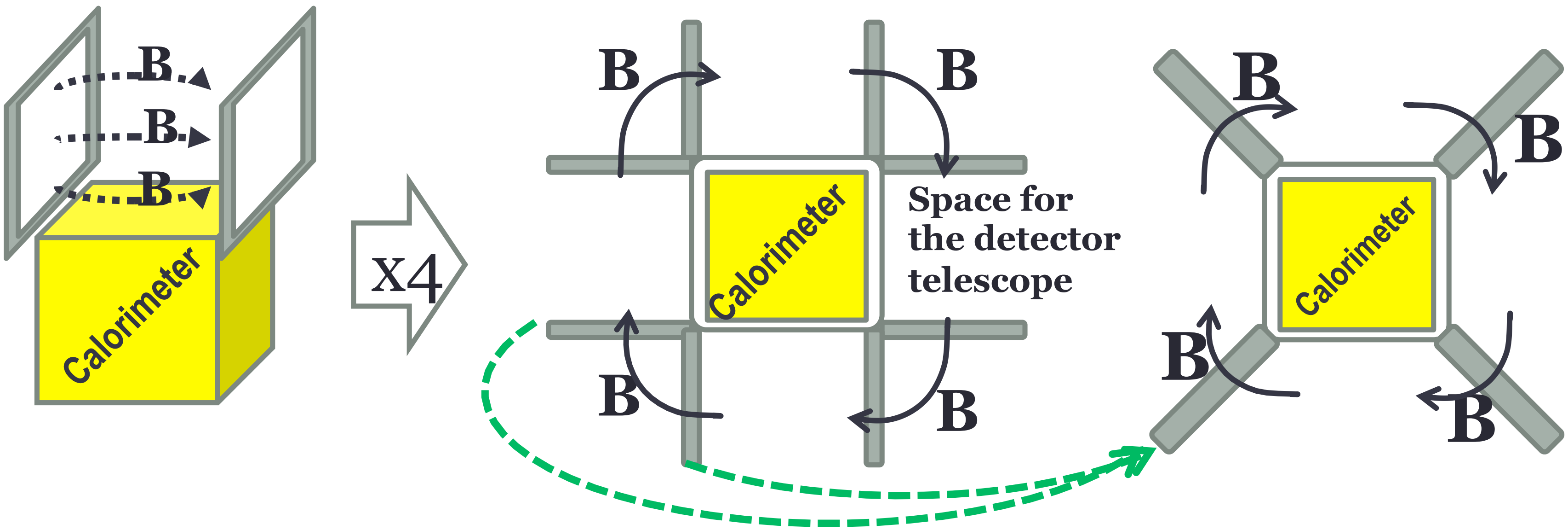
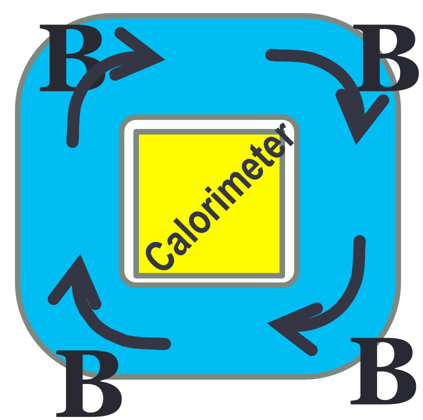
R. Destefanis, Thales Alenia Space, Italy
C. Lobascio, Thales Alenia Space, Italy
E. Gaia, Thales Alenia Space, Italy

intense magnetic field

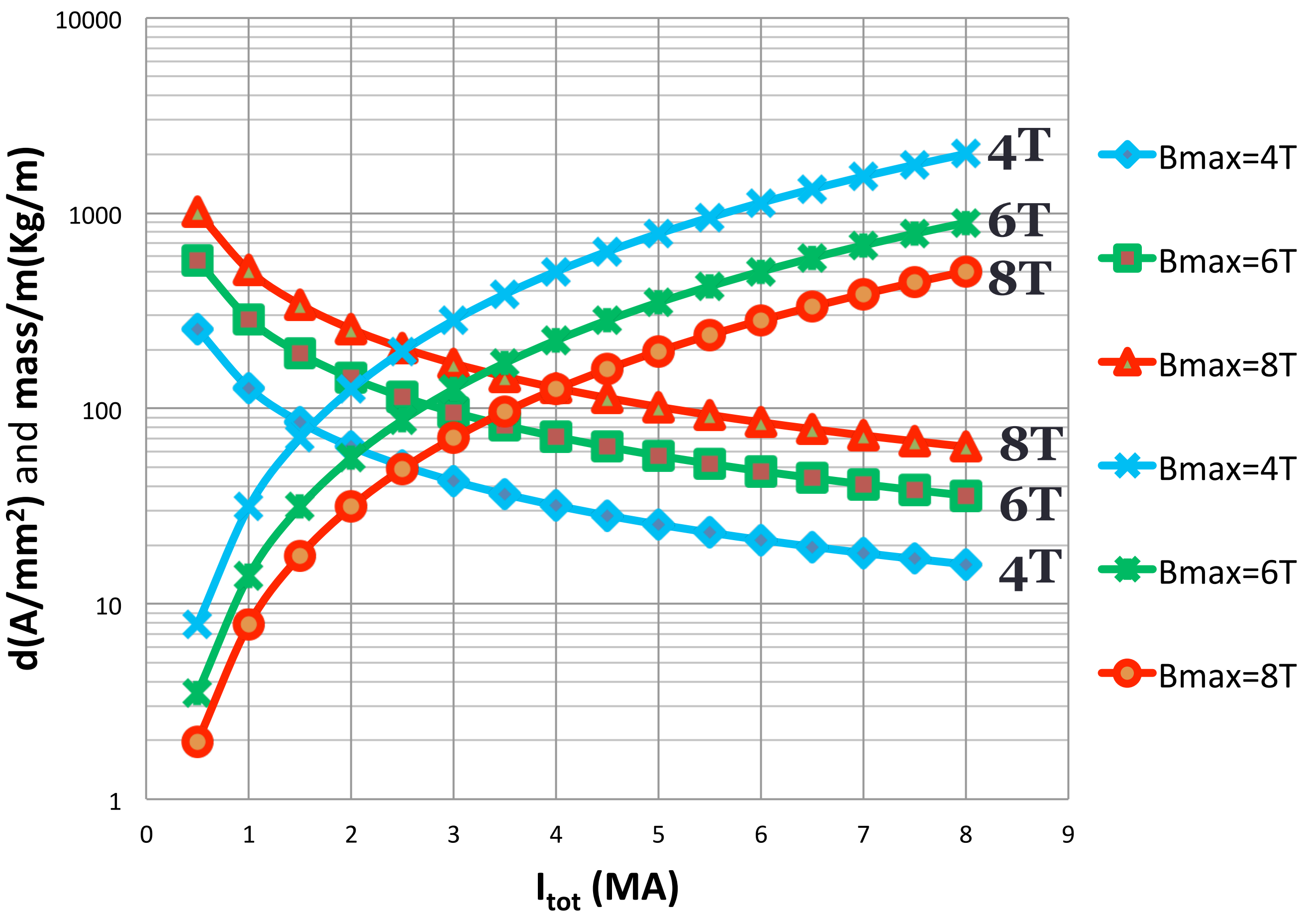
- New technologies:
  - Wide scale production of ITS (MgB_2) and HTS cables
  - Higher operative temperature (>10K → cryocoolers → CFSM)



The 'torus' concept, **B** running around four faces of the calorimeter
magnetic dipole = null
suitable for CR experiments in space



$B_{max}(T) = 0.2\ I_{tot}(MA)/R(m)$



Current limits: neutralino/chargino

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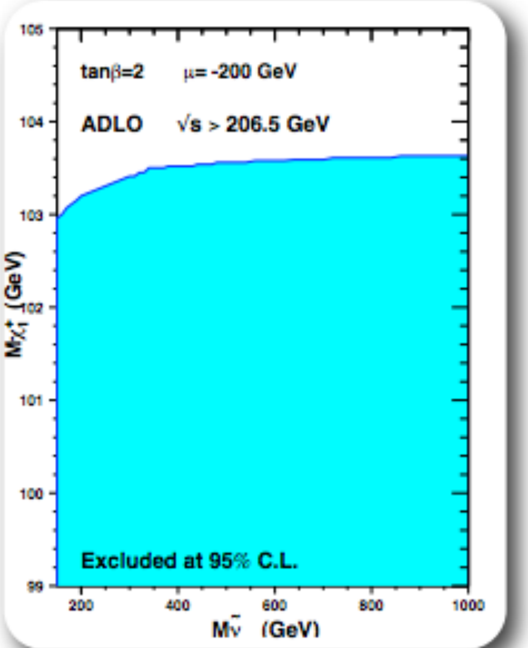
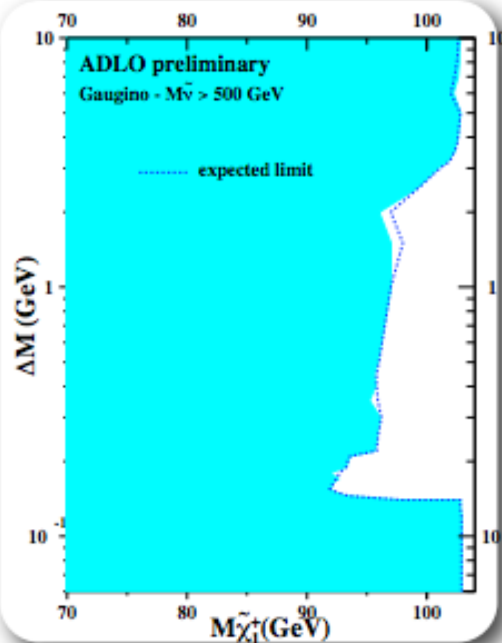
canonical case



$m\chi_1^\pm > 103.5$ GeV
for $m_{snue} > 300$ GeV

LEPSUSYWG/01-03.1

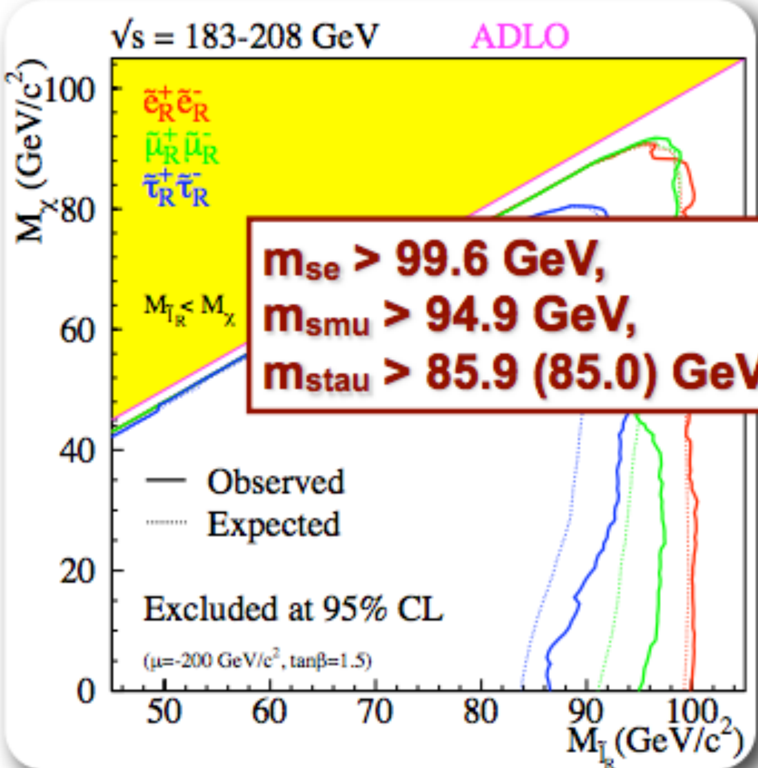
degenerate case



$m\chi_1^\pm > 91.9$ /92.4 GeV

LEPSUSYWG/02-04.1

$m\chi_1^0 > 47/50$ GeV
(CMSSM, mSUGRA)
No mass limit in general



$m_{se} > 99.6$ GeV,
$m_{smu} > 94.9$ GeV,
$m_{stau} > 85.9$ (85.0) GeV

S. Su

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LEPSUSYWG/04-01.1