AMS02 Analysis Software Overview

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Available at:
http : //ams.cern.ch/AMS/Analysis/hpl3itp1/ams02_ss_2002.ps

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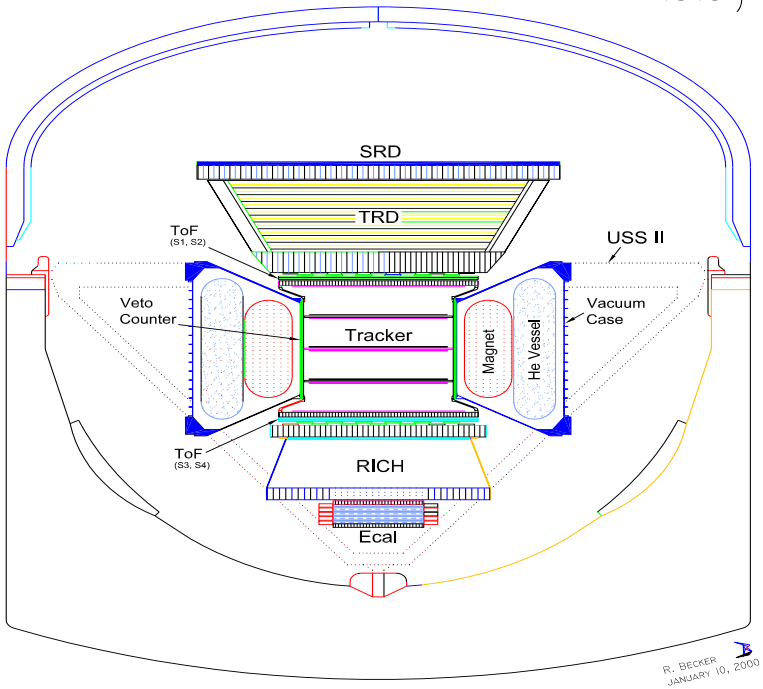
Introduction

The Alpha Magnetic Spectrometer (AMS) is a high energy physics experiment scheduled for a three year mission on board the ISS, featured:

- Superconducting Magnet: 0.8 Tesla;
- TOF: Four Layers of Scintillators (120 ps);
- Tracker: Eight Layers of Silicon Detectors (10 μ);
- Gaseous TRD Detector: h/e Rejection O(10^2);
- Pb/Sc EM Calorimeter: h/e Rejection O(10^4);
- RICH Detector: Precise Velocity Measurement;



The physics goals of the AMS are to search for antimatter in the Universe on the level of less than 10^{-9}, to search for dark matter and to make high statistics measurements of cosmic rays composition as well as γ rays.

Mission Statement

The AMS analysis software main goal is to convert "raw" events written on board of the ISS to a "reconstructed" ones, containing all necessary reconstructed particle(s) parameters and being ready for the further physics analysis.

To evaluate AMS detectors performance AMS analysis software should also be capable to "simulate" the real events taking into account the cosmic ray fluxes, AMS detectors geometry and all relevant physics processes.

AMS02 analysis software provides:

- Detectors Geometry Description;
- Cosmic Ray Fluxes Simulation;
- Events Simulation with GEANT3/4 Packages;
- Trigger Simulation;
- Events Reconstruction;
- Visualisation (Event Display);
- Production Tools.

Tecnhicalities

Supported Computer Platforms:

- osf1-alpha cxx v6.2++ ;
- linux-i686(amd) g++ 2.95.3++ and g77/intel ifc ;
- sparc-sunos C++5.2

News/Updates/HowToStart via

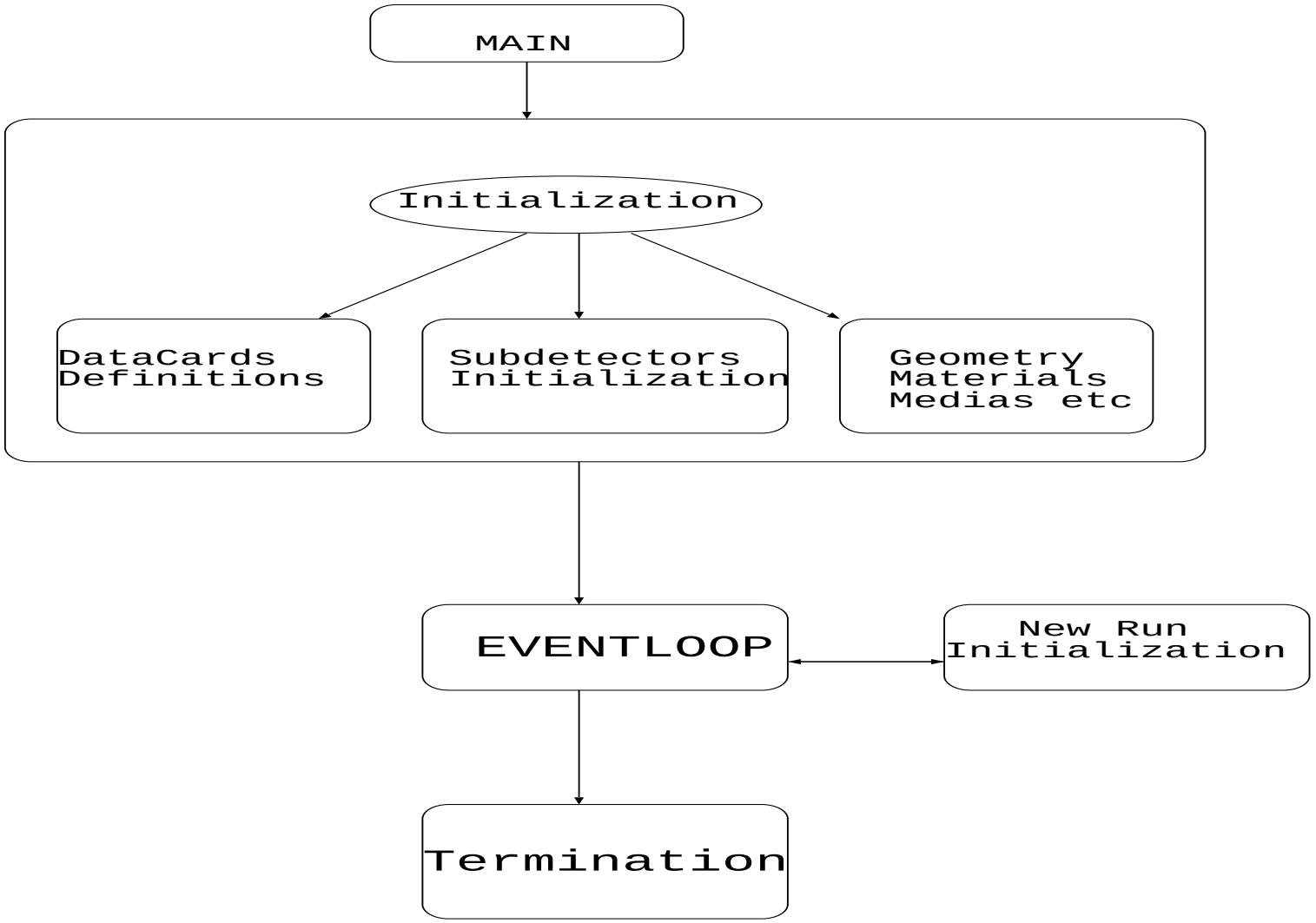
http://ams.cern.ch/AMS/Analysis/hpl3itp1/ams02.html

Software sources are organising in CVS repository:

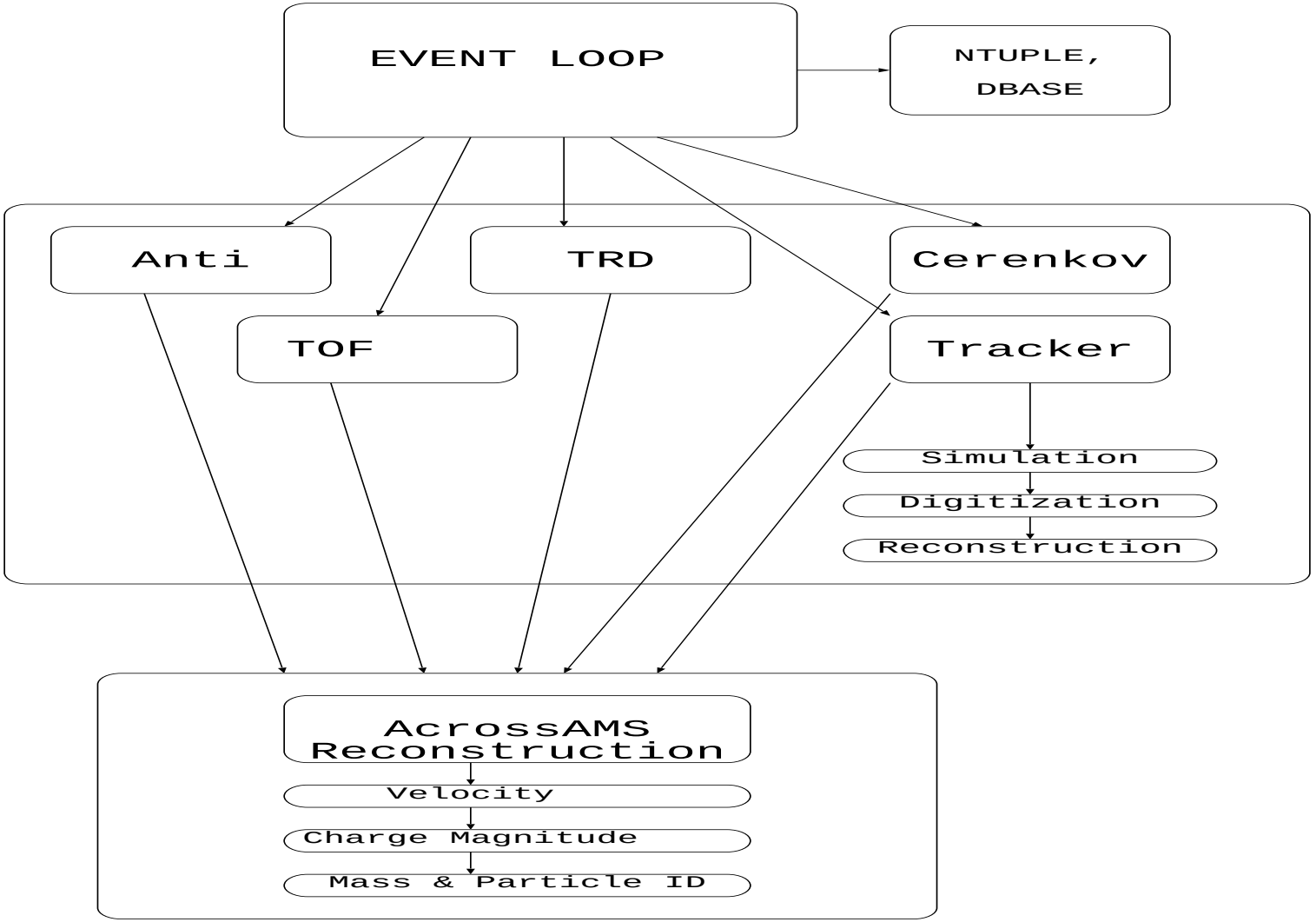
AMS/CC	C++ sources
AMS/F	F77/F90 sources
AMS/analysis	AMS01/AMS02 analysis (paw functions mainly) files
AMS/include	header files
AMS/bin	object files
AMS/display	event visualisation
AMS/doc	documentation
AMS/datacards	various datacards
AMS/examples	job examples
AMS/install	installation files
AMS/perl	perl scripts
AMS/test	some test files
AMS/exe	exe module

In (almost) every directory there is 00index.txt file which contains short description of the directory files.

Program Flowchart



Program Flowchart



Main Features: MC Generator

Generates cosmic ray spectra of various particles such as sea level μ; radiation belts e^-; albedo p, e^-; cosmic $p, e^{\pm}, \bar{p}, \gamma$ and HeavyIons.
Class name: *AMSmceventg*.
User interaction via **MCGEN** datacard[3].
Allows one or multi particle event generation.
Simulates the ISS movement on the predefined orbit.
Sources: CC/mceventg.C include/mceventg.h

[3]Datacards Description in AMS/doc/datacards.doc

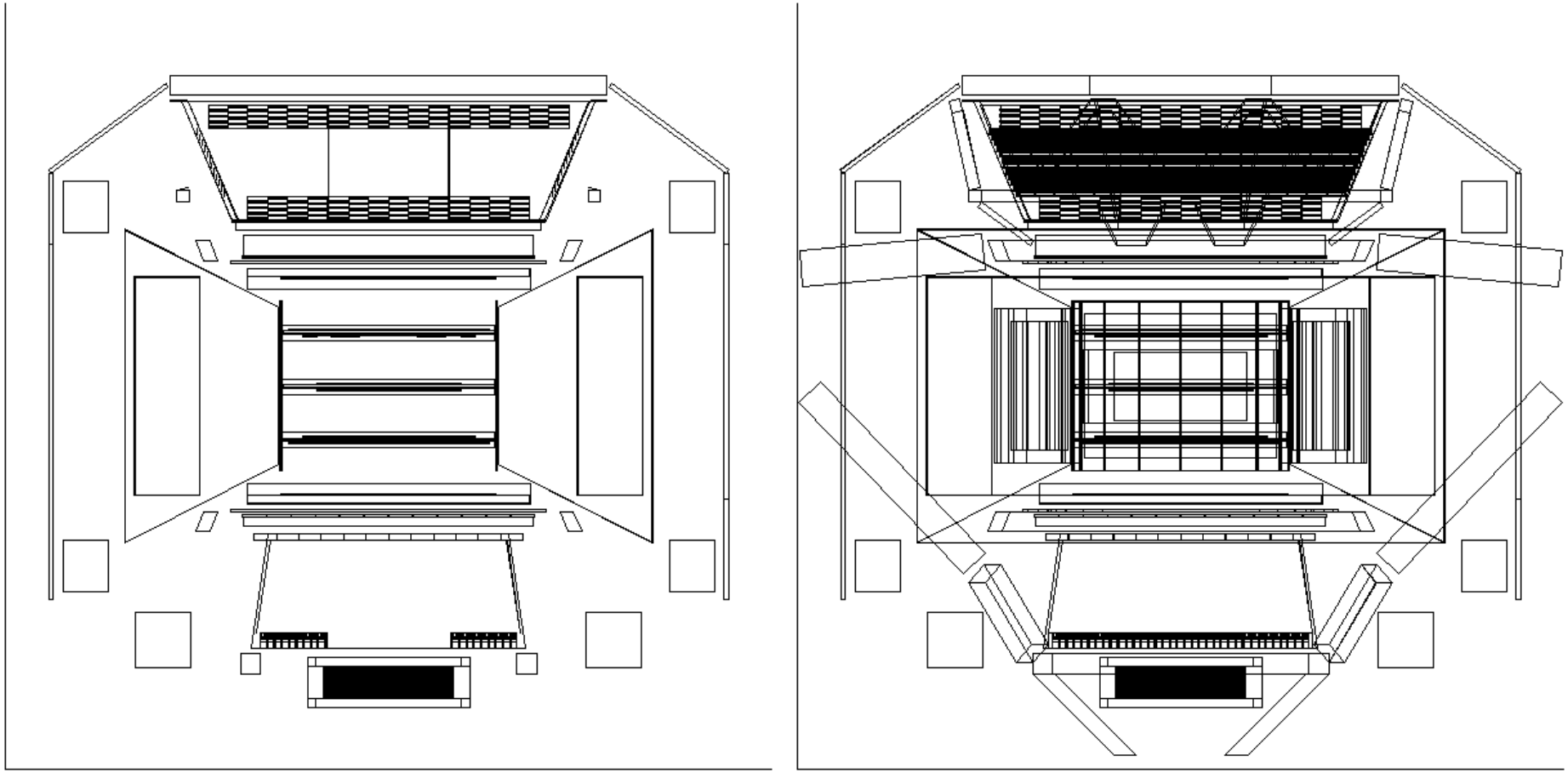
Main Features:Geometry

Based on *AMSgvolume* class[4], which follows quite closely the GEANT3 volume definition with some extentions.
Provides user transparent GEANT3 and GEANT4 interfaces.
Sources: include/amsgeom.h CC/amsgeom.C, richgeom.C
Detector parameters mainly in: include/*dbc.h CC/*dbc.C

[4]Sources: CC/gvolume.C include/gvolume.h

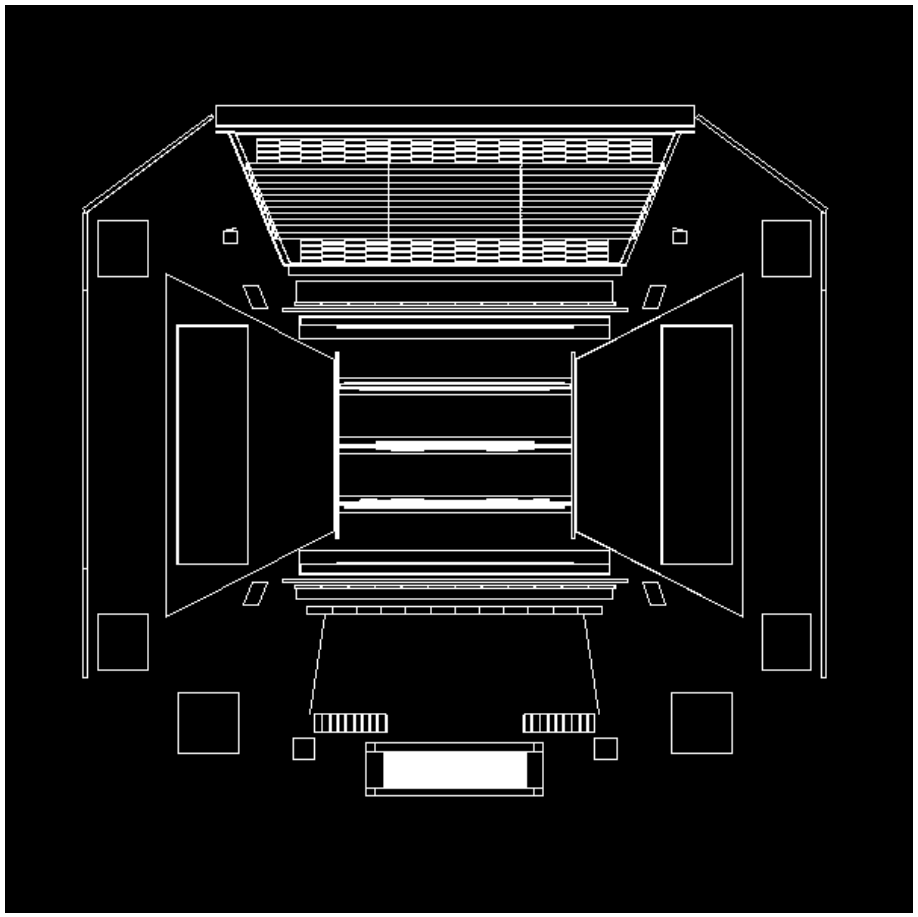
Main Features:Geometry

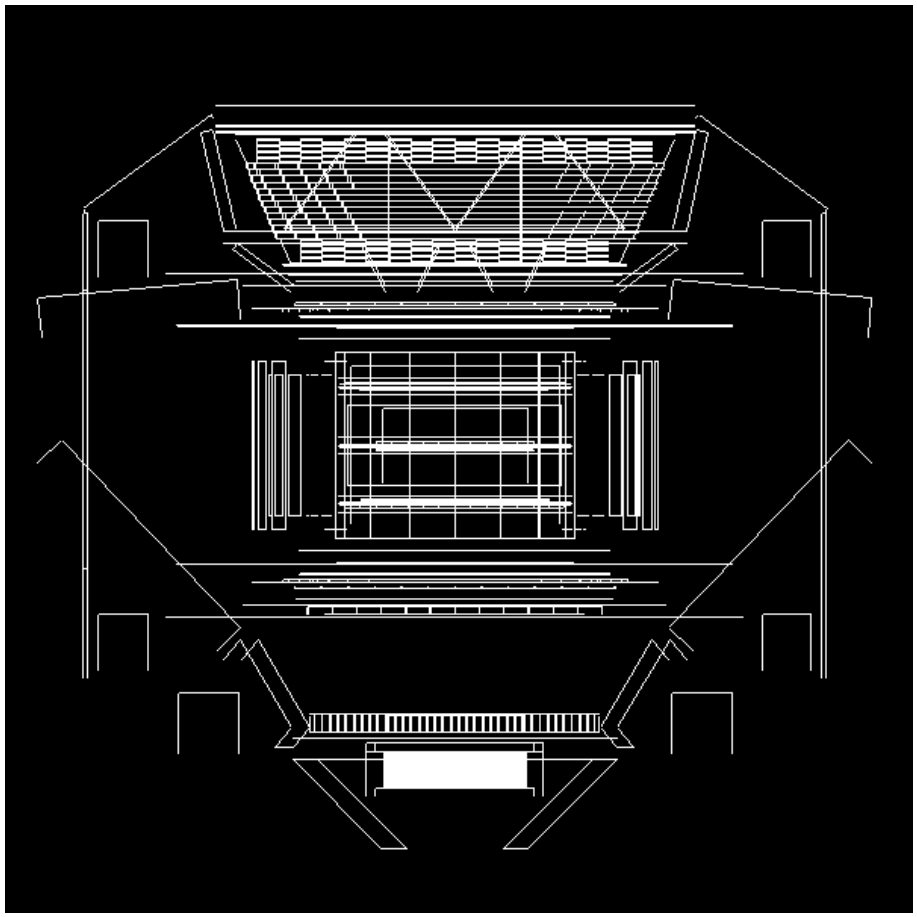
AMS02 GEANT3 Builded Geometry



Main Features:Geometry

AMS02 GEANT4 Builded Geometry





Includes:

- Geometry Constructors: built-in *AMSgvolume* class;
- Initialization via *uginit* routine;
- KINE/VERTEX via *gukine* routine and AMSmceventg class;
- GEANT3 hits storing via *gustep* routine;
- Event digitization/rec via *guout* routine.
- Termination via *uglast* routine;

Sources: CC/geant.C, geant3.C

Includes:

- Geometry Constructors: built-in *AMSgvolume* class;
- Initialization via *G4INIT* routine;
- KINE/VERTEX via *BeginOfEventAction*, *GeneratePrimaries* routines and AMSmceventg class;
- Geant4 hits storing via *UserSteppingAction* routine;
- Event digitization/rec via *EndOfEventAction* routine.
- Termination via *G4LAST* routine;

Sources: CC/geant.C, geant4.C.
N.B. Only linux-i686(amd) AMS/GEANT4 version is supported.
AMS/GEANT4 related documentation: doc/g4.doc

Main Features: MC Related Objects

Object	Properties	Comments
MC "Hits" or "Clusters"	Coordinates Time Energy Deposition MC Particle Param	Simply records G3/G4 quantities in AMS format
"Digitized" or "Raw" Clusters	ADC Amplitudes TDC Values	Transform MC Hits to "Readout" ones according to subdetectors performance specs and writeout according to real data format

Complete List of MC Related Classes:

Class Name	Sources	Comments
AMSTOFMCCluster	CC/mccluster.C	ToF MC "Cluster"
AMSAntiMCCluster	CC/mccluster.C	Veto Counter MC "Cluster"
AMSEcalMCHit	CC/mccluster.C	ECAL MC "Cluster"
AMSRichMCHit	CC/mccluster.C	RICH MC "Cluster"
AMSTrMCCluster	CC/mccluster.C	Tracker MC "Cluster"
AMSTRDMCCluster	CC/mccluster.C	TRD MC "Cluster"

Main Features: MC Related Objects

Class Name	Sources	Comments
TOF2RawEvent	CC/tofsim02.C	ToF "Raw" Data
Anti2RawEvent	CC/antirec02.C	Veto "Raw" Data
AMSEcalRawEvent	CC/ecalrec.C	ECAL "Raw" Data
AMSRichRawEvent	CC/richrec.C	RICH "Raw" Data
AMSTrRawCluster	CC/trrawcluster.C	Tracker "Raw" Data
AMSTRDRawHit	CC/trdsim.C	TRD "Raw" Data

Main Features: Trigger Objects

Sources: CC/trigger102.C, trigger302.C

LVL1 Trigger Elements

Element	Comment
TOFZ1	2 to 4 ToF Over Threshold (0.35 MeV) coincidence
TOFZ2	2 to 4 ToF Over Threshold (6 MeV) coincidence
VETO0	No Veto Counters Fired
VETO1	At Most One Veto counter Fired
ECALESOFT	ECAL Total Energy > Threshold (3 GeV)
ECALEHARD	ECAL Total Energy > Threshold (8 GeV)
ECALSS	ECAL Shower Shape Consisted with that of emag particle

LVL1 Trigger Description: All Rows Are Combined by Or

Trigger	Primary Target(s)
TOFZ1 & VETO0 if θ_{Mag} >0.7	Protons, He
TOFZ1 & VETO1 if θ_{Mag} <0.7	High Energy Protons, He
TOFZ2	He, HeavyIons
TOFZ1 & ECALESOFT	$e^{\pm}$
ECALHARD & ECALSS	γ

LVL3 Trigger Description[5]

Main purpose is identification of different event classes and possible rejection depending on event rates, transmission bandwidth, buffer capacities etc. Using ToF, TRD, Tracker, ECAL info.

```
// bit  0 No Tr Tracks found
// bit  1 Too Many Hits in Tracker
// bit  2 Too Many Hits in TRD
// bit  3 Too Many Hits in TOF
// bit  4 No TRD Tracks found
// bit  5 Upgoing event found
// bit  6 No TOF Time Information found
// bit  7 Positive Rigidity(Momentum) found
// bit  8 Ambiguous Rigidity (Case A) found
// bit  9 Ambiguous Rigidity (Case B) found
// bit  10  Negative Rigidity(Momentum) found
// bit  11  High Gamma candidate (TRD)
// bit  12   Heavy Ion candidate (Tracker)
// bit  13  EMag Candidate       (ECAL)
// bit  14 Prescaled event
```

[5] see also AMS01 Level3 Trigger Description in http://ams.cern.ch/AMS/Analysis/hpl3itp1/zurich.trig.ps

Main Features: Reconstruction Related Objects

Subdetector	Object Chains	Sources
TRD	AMSTRDCluster → AMSTRDSegment → AMSTRDTrack	CC/trdrec.C
TOF	TOF2RawCluster → AMSTOFCluster	CC/tofrec02.C
Veto	AMSAntiRawCluster → AMSAntiCluster	CC/antirec02.C
Tracker	AMSTrCluster → AMSTrRecHit → AMSTrTrack	CC/trrec.C
RICH	AMSRichRing	CC/richrec.C include/richrec.h
ECAL	AMSEcalHit → Ecal1DCluster → Ecal2DCluster → EcalShower	CC/ecalrec.C
AxAMS	AMSBeta → AMSCharge → AMSParticle	CC/beta.C charge.C particle.C

Main Features: Reconstruction Related Objects

Particle Parameters

Parameter	Derived from	Method(s)
Rigidity	Tracker/TRD	Circular/sz Fit 5X5 nonlinear fit
Velocity	Track parameters TOF global cl RICH global cl	 TOF Linear Fit RICH Angular Fit
Charge Magnitude	Beta TOF,Tracker,RICH Clusters	Likelihood Fit
Energy	ECALShower	Leakage Corrected ECAL Energy Sum
Direction	Tracker,TRD ECAL ToF	Custom fits
γ Factor	TRDTrack	Truncated mean,Likelihood
Particle Id	Velocity, Charge, Rigidity Energy, γ Factor	

Main Features: I/O

Input: via FFREAD[6] Datacards.
DST Output: Ntuples[7] (PAW[8]) or RootFiles(ROOT[9]).
Ntuples are the default DST now. Ntuple Description is in doc/ntuple02.doc. Known ntuple limitations include $\approx$ 200Mb file size limit, 50KW record length limit and fixed size arrays. As a consequence some AMS02 ntuple events may have dangled pointers and incomplete data[10].
Work is undergone to benchmark Rootfiles performance to (eventually) migrate to it in the (nearest) future.
RootFile based on *TCloneArrays*, *TRef*, *TRefArrays*[11] is under evaluation at the moment.

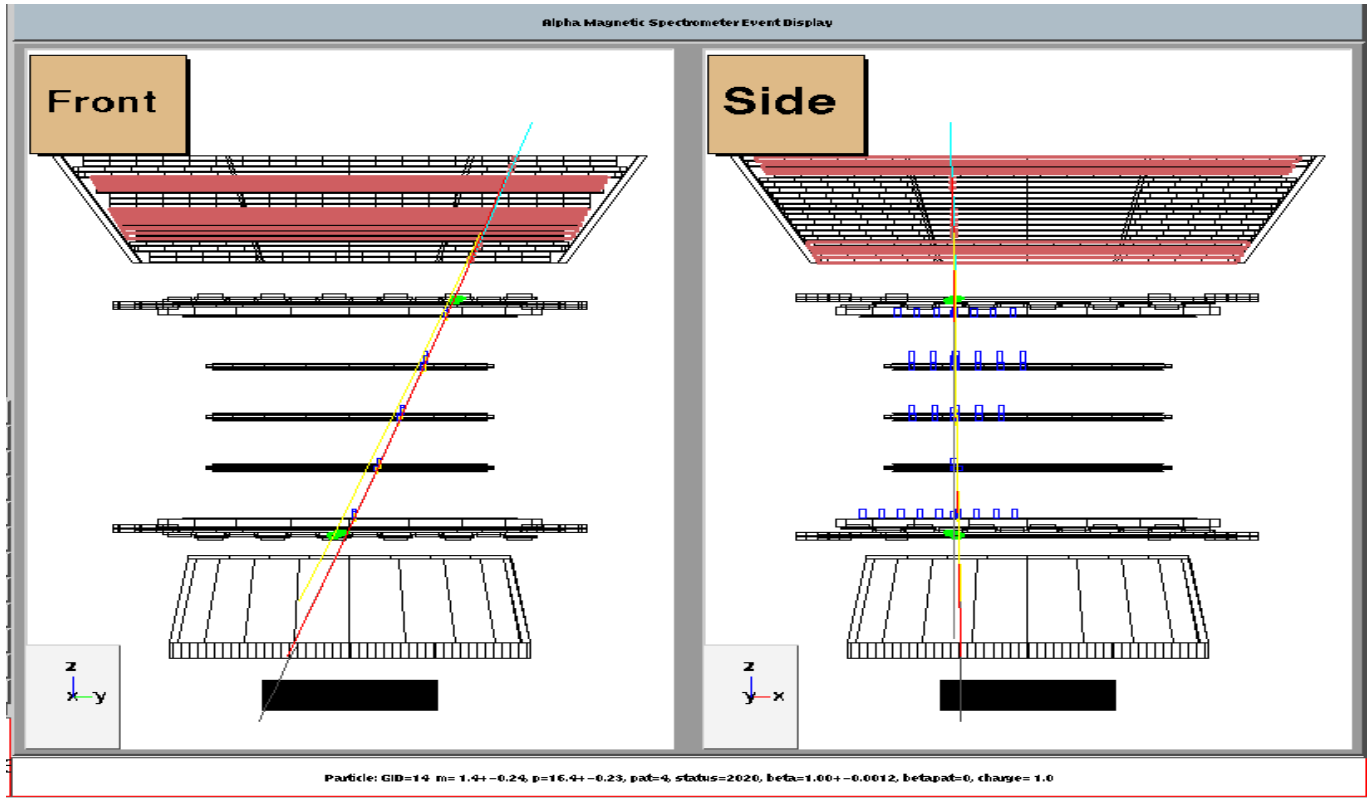
[6] http://wwwinfo.cern.ch/asdoc/WWW/ffread/ffmain/ffmain.html
[7] http://wwwinfo.cern.ch/asdoc/hbook_html3/node31.html
[8] http://paw.web.cern.ch/paw
[9] http://root.cern.ch
[10] Such events can be identified by comparison the arrays length in the event header and in the arrays themselves, which should be the same for "good" events.
[11] http://root.cern.ch/root/htmldoc/ClassIndex.html

Main Features: Visualization: Event Display

Source Code: display/ams02/*

To Start:

```
source install/amsvar
$amsed02  NtupleOrRootfilePath
```



People

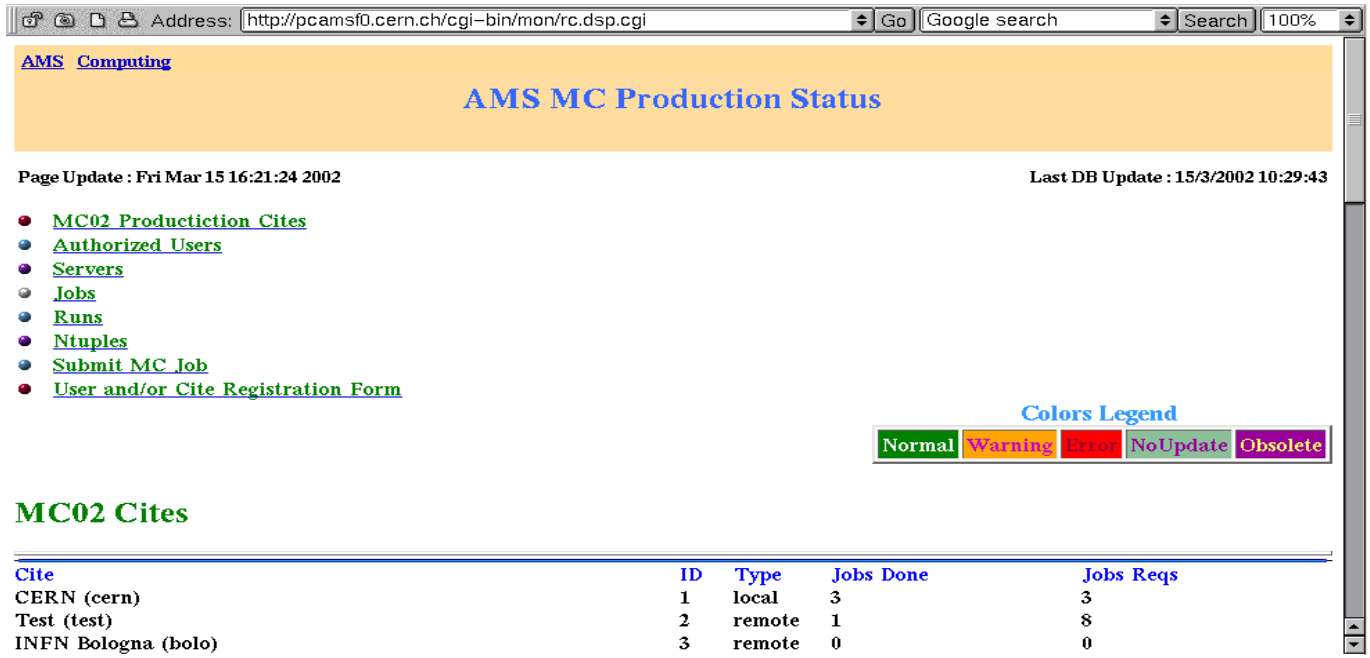
Subject	Coordinator
Magnet	e.choumilov@cern.ch
ToF	e.choumilov@cern.ch
Anti	e.choumilov@cern.ch
TRD Geometry	k.scholberg@cern.ch
TRD Sim/Rec	v.choutko@cern.ch
Tracker	v.choutko@cern.ch
Trigger-LVL1	e.choumilov@cern.ch
Trigger-LVL3	v.choutko@cern.ch
ECAL	e.choumilov@cern.ch
RICH	Carlos.Jose.Delgado.Mendez@cern.ch
I/O Ntuples	v.choutko@cern.ch
I/O Root	A.Klimentov@cern.ch, d.grandi@cern.ch
Event Display	k.scholberg@cern.ch
Geant4 Interface	v.choutko@cern.ch

Outstanding Things In Progress

- Root /Ntuple Comparison; Root Tree Improvement: D. Grandi, A. Klimentov
- Two Prong Tracks Reconstruction: G. Lamanna
- New Tracker Digitization Scheme: Tracker Group;
- Tracker Coordinate Measurement Improvement via Using η Function: Tracker Group;
- TRD Particle Identification: Aachen Group, MIT;
- RICH Velocity Measurement without Tracker Guidance: Madrid & Lisbon Group;
- RICH Charge Measurement: Madrid & Lisbon Group;
- ECAL Particle Identification Improvement: ECAL Group;
- AMS02 Production Scheme/Database: A. Klimentov.

Remote MC Client Web Form

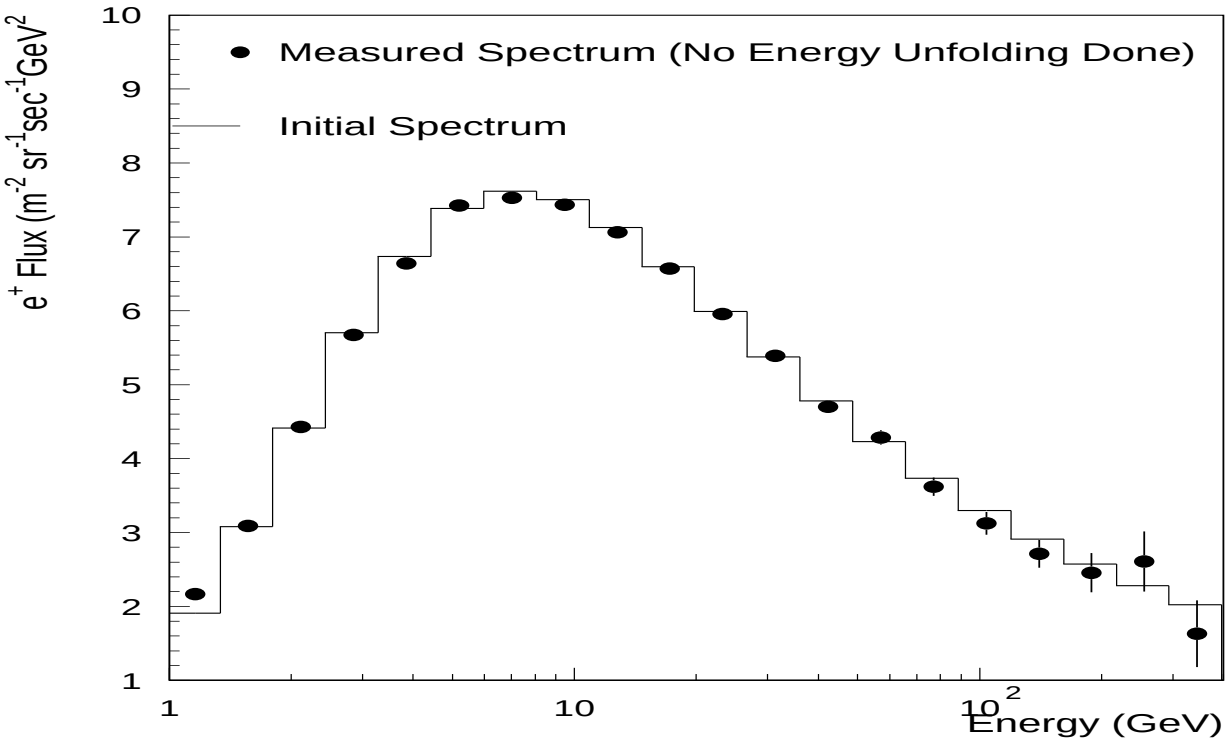
To allow use of the worldwide off-cite computer facilities for AMS02 MC production, a special server has been written.
Web user interface is provided via http : //pcamsf0.cern.ch/cgi − bin/mon/rc.dsp.cgi
New users undergo special *Registration Procedure*. After been registered user may use the form to submit MC production requests to the server. Server then returns the necessary files to the user via e-mail together with the instructions of how to use them.



AMS MC Performance Evaluation Examples

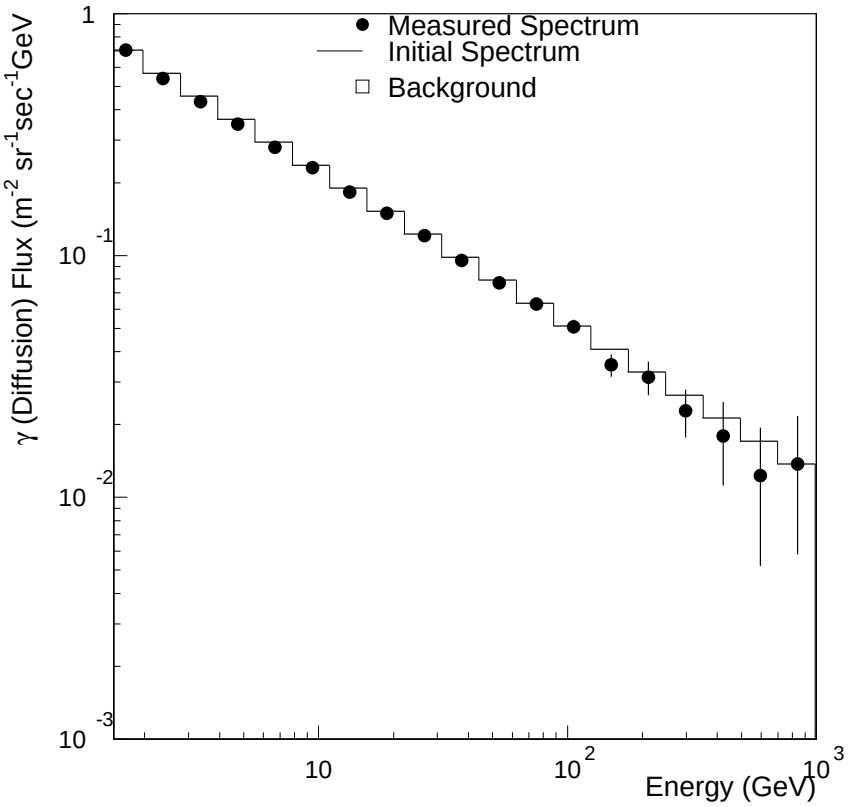
- AMS Photons & Positron Detection Capabilities:
  V. Choutko, G. Lamanna and A. Malinin in *Int. Journal Mod. Phys A17, 1817 (2002)*

AMS02 3 Years Positron Spectrum Measurement Example

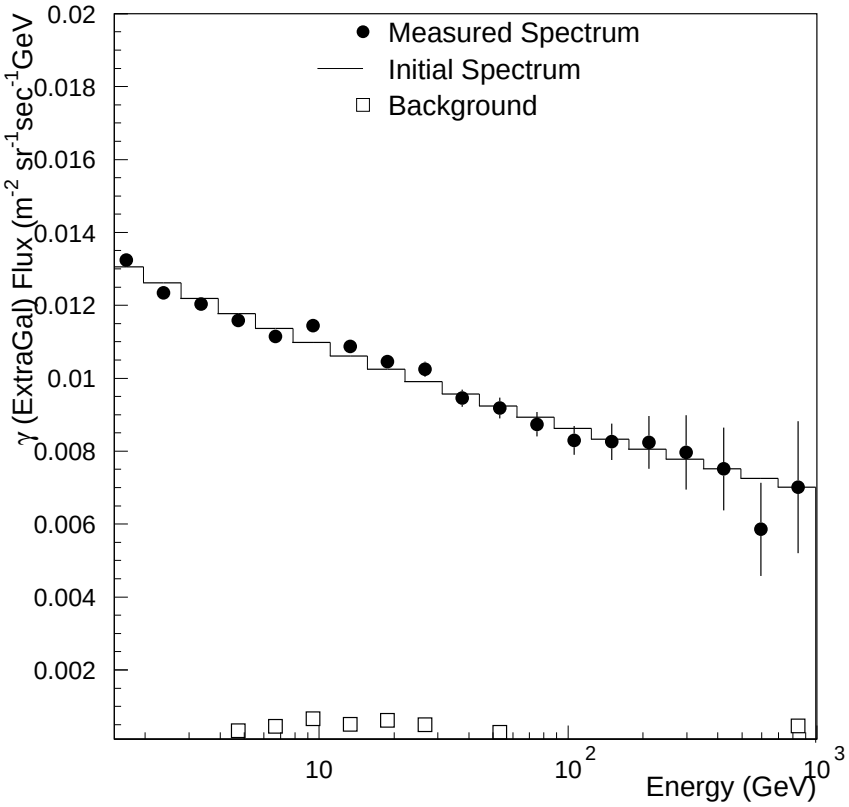


AMS MC Performance Evaluation Examples

AMS Diffuse Galactic γ's

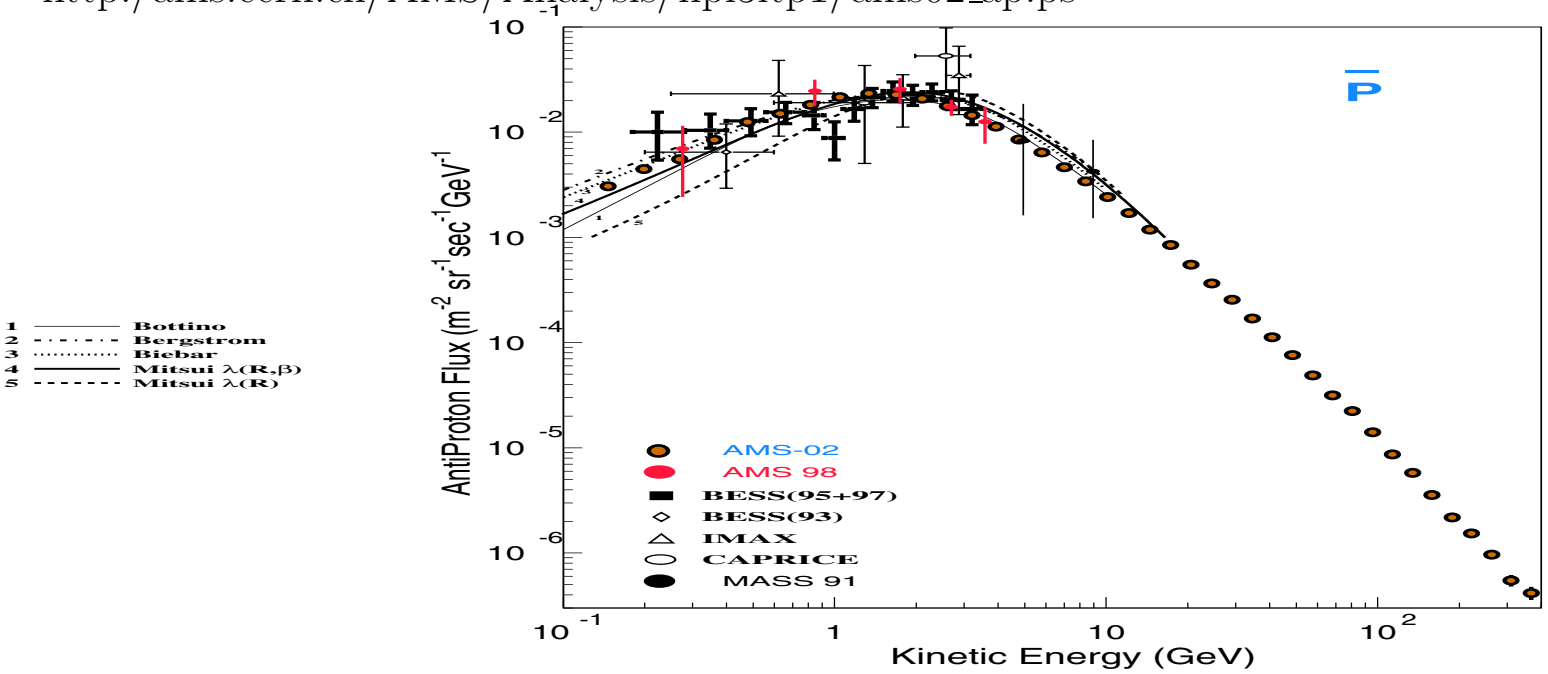


AMS ExtraGalactic γ's



AMS MC Performance Evaluation Examples

- AMS AntiProton Detection Capabilities:
  V. Choutko, to be published, see also
  http:/ams.cern.ch/AMS/Analysis/hpl3itp1/ams02_ap.ps



MC Production Plans

The following topic is foreseen for Y2003:
Complete AMS02 Physics Performance Evaluation, including
$p, \bar{p}, e^{\pm}, \gamma, He, \bar{He}, Li, Be, C, d, \bar{d}$ cosmic ray sources.

Estimated Disk(Tape) Space and CPU Time Needed:

- Disk Space: 10 TBytes;
- CPU: 10000 PIII-1000 CPU days;

Addendum

CINT2000,CFP2000 from http://www.spec.org/cpu2000

CPU	Clock (GHz)	CINT2000(I)	CFP2000(F)	Relative $\sqrt{\text{IF}}$	AMS02 Offline
Intel P-III	1	402	254	1	1
AMS MP1800+	1.533	587	504	1.7	2.12
AMS MP2400+	2	737	605	2.1	2.6(?)
SGI MIPS R14kA	0.6	471	472	1.47	(?)