AMS02 Analysis Software Overview

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Aachen, October 16, 2003

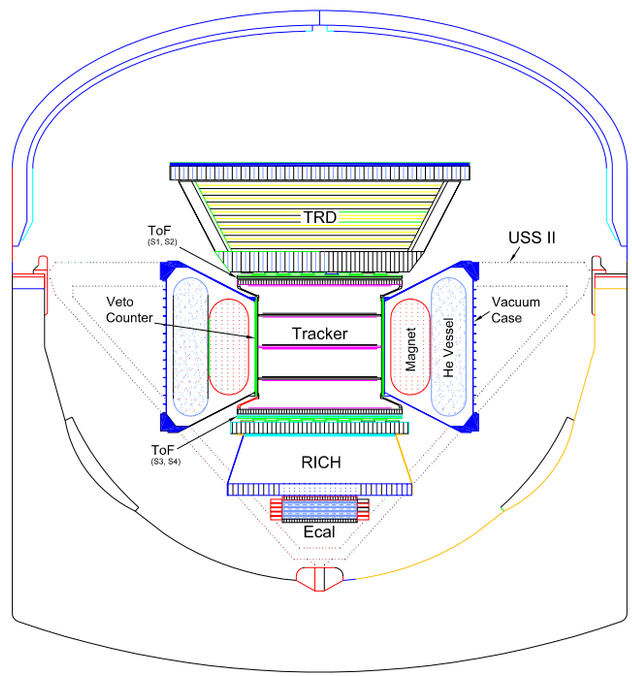
Available at:
http://ams.cern.ch/AMS/Analysis/hpl3itp1/ams02_ss_2003.pdf

Outline

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 goals are:

- Convert raw information recorded by AMS detector on board of the ISS to a "reconstructed events", containing all necessary reconstructed parameters of the particle(s) crossing the AMS and being ready for the further physics analysis.

- Evaluate AMS detector performance using simulated events, taking into account the cosmic ray fluxes, AMS detector geometry and all relevant physics processes.

Mission Statement

AMS02 analysis software provides:

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

Getting Started:
http://ams.cern.ch/AMS/Analysis/hpl3itp1/readme.txt

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

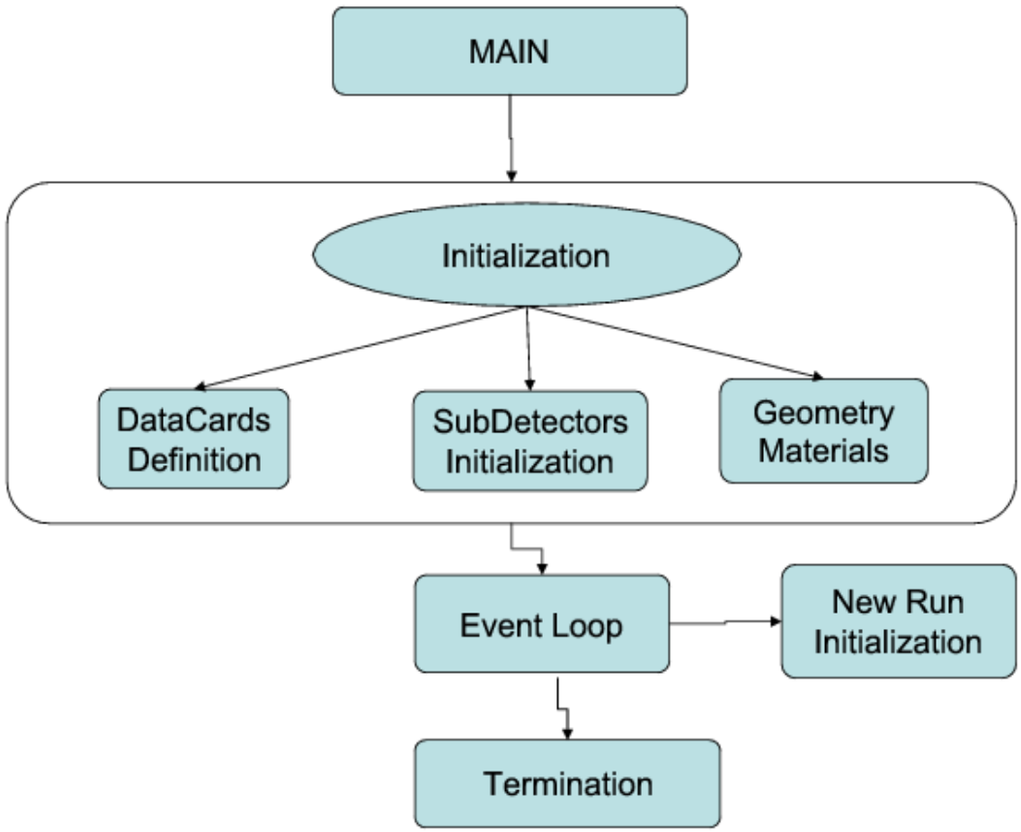
AMS Repository Structure

Software sources are organizing in CVS repository:

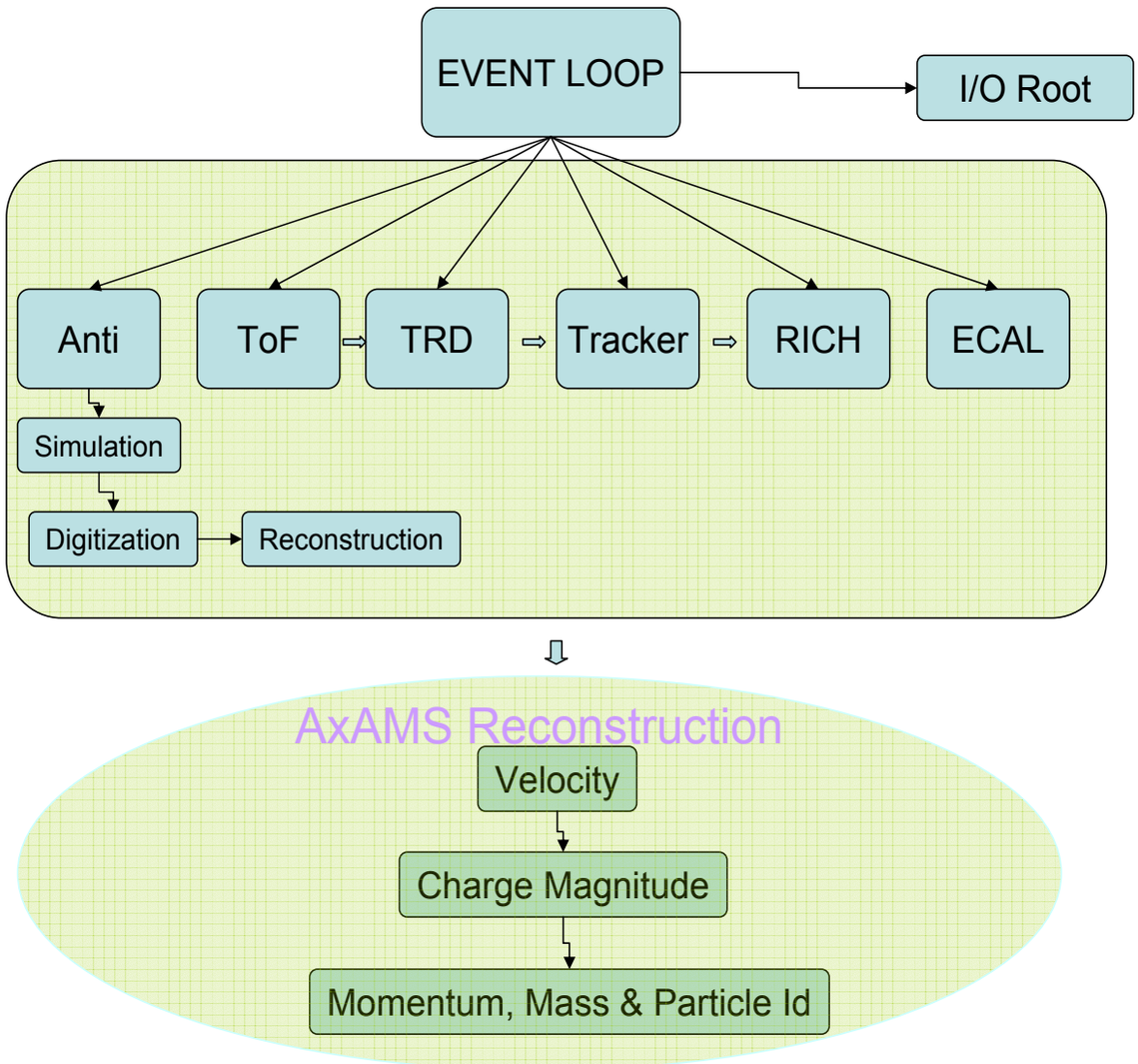
AMS/CC	C++ sources
AMS/F	F77/F90 sources
AMS/analysis	AMS01/AMS02 analysis (paw functions mainly) files
AMS/include	header files
AMS/bin	object files
AMS/display	event visualization
AMS/online	event visualization
AMS/doc	documentation
AMS/datacards	various datacards
AMS/examples	job examples
AMS/install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

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

Program Flowchart



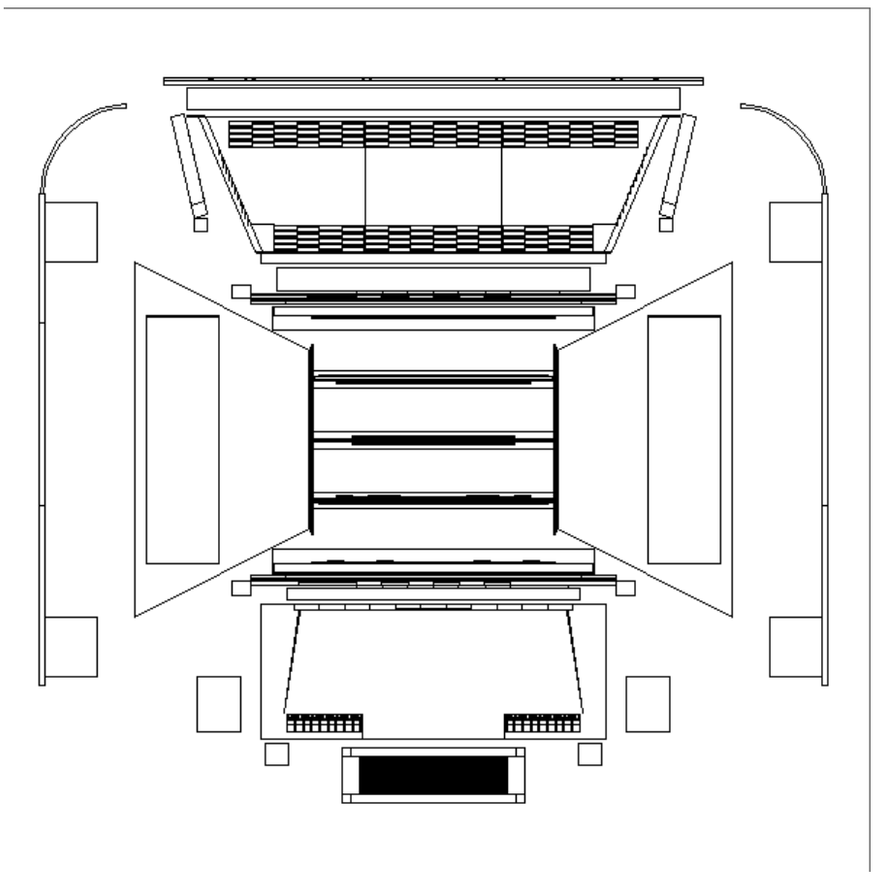
Program Flowchart

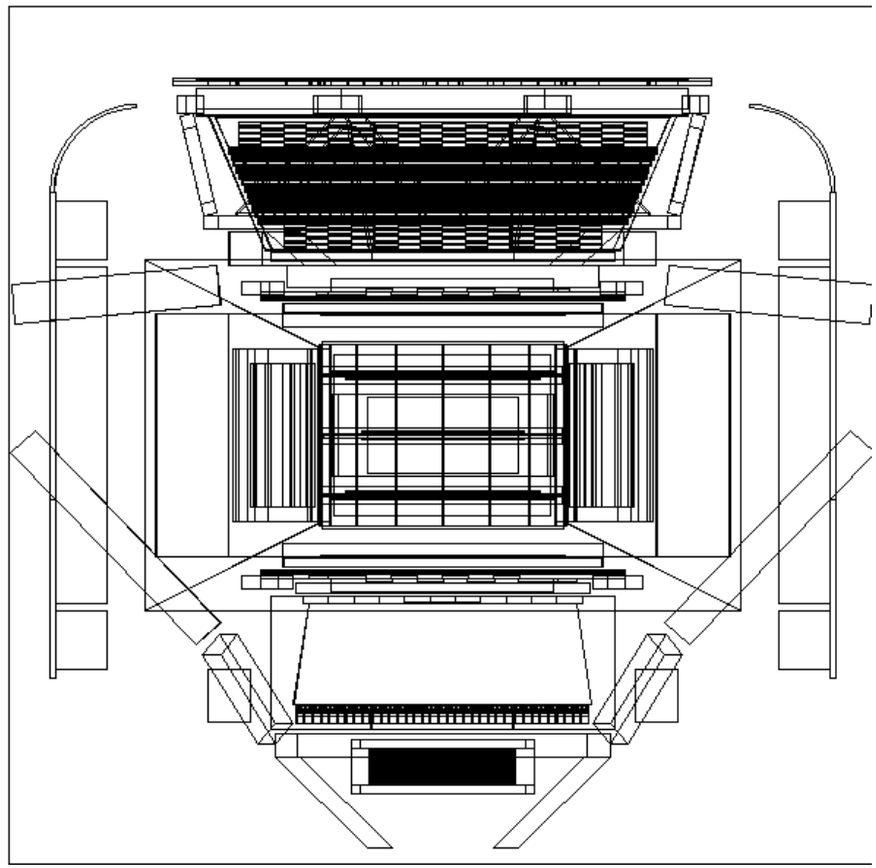


Geometry

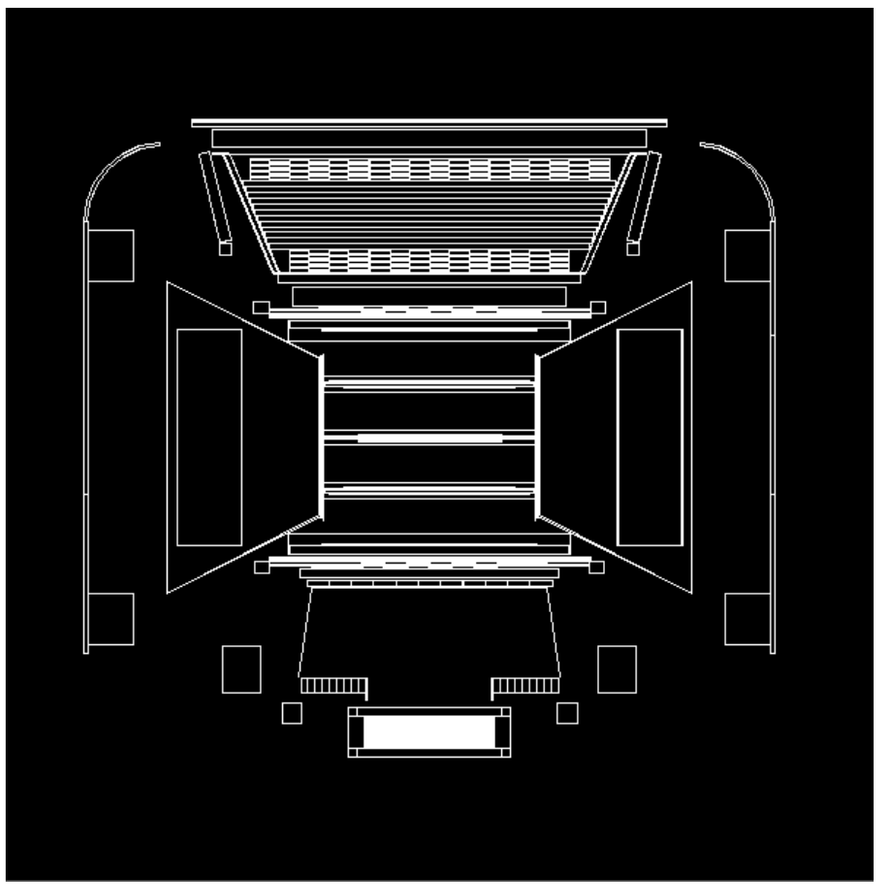
Based on *AMSgvolume* class, which follows quite closely the GEANT3 volume definition with some extensions.
Provides user transparent GEANT3 and GEANT4 interfaces.
Sources: include/amsgeom.h CC/amsgeom.C, CC/richgeom.C
Detector parameters mainly in: include/*dbc.h CC/*dbc.C

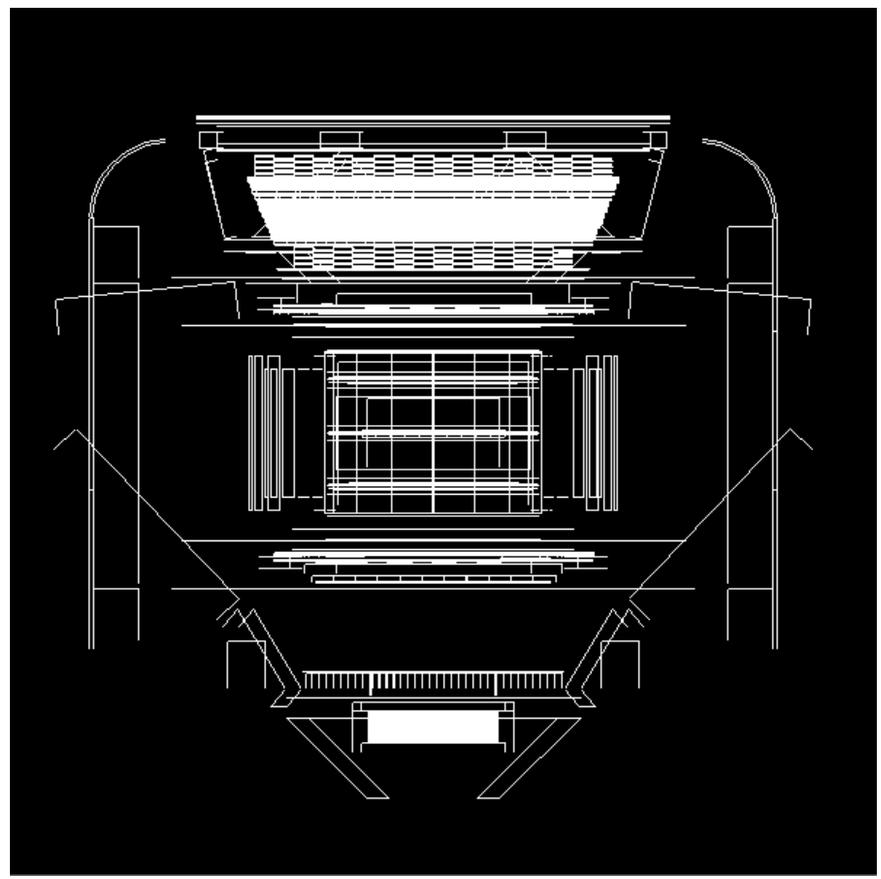
AMS02 GEANT3 Geometry





AMS02 GEANT4 Geometry





GEANT3 Interface

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, CC/geant3.C

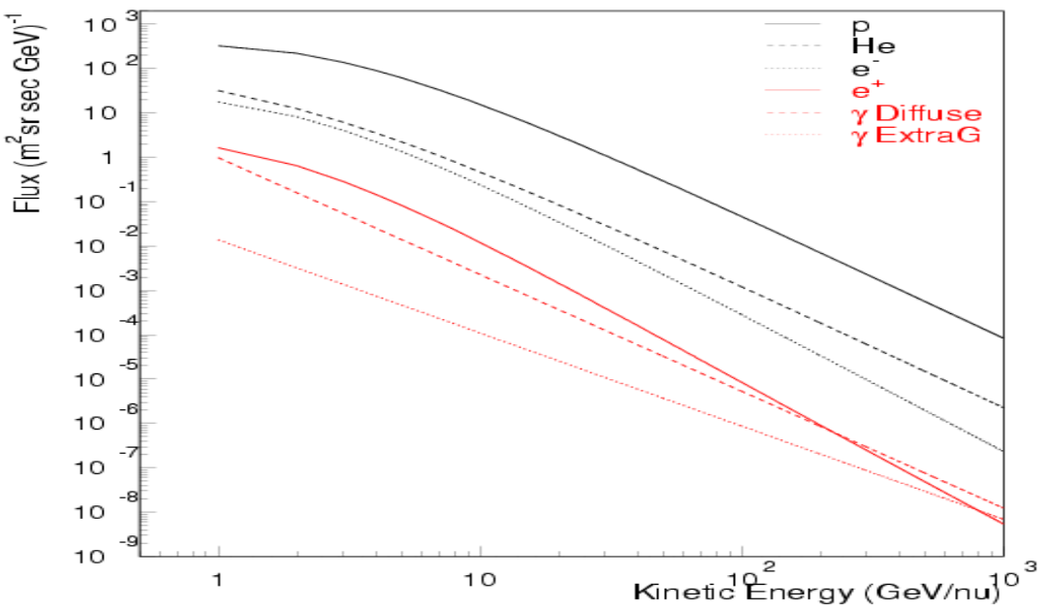
Includes:

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

MC Generator

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



MC Related Objects

Object	Properties	Comments
MC "Hits" or "Clusters"	Coordinates Time Energy Deposition MC Particle Parameters	Store G3/G4 hits according AMS format
"Digitized" or "Raw" Clusters	ADC Amplitudes TDC Values	Transform MC Hits to "Readout" ones according to subdetectors specs and 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"

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

Trigger Objects

Sources: CC/trigger102.C, CC/trigger302.C

LVL1 Trigger Elements(not finalized, alternative scheme for ECAL-trigger is under study)

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:

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
```

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	AMSRichHit→AMSRichRing	CC/richrec.C
ECAL	EcalHit → Ecal1DCluster → Ecal2DCluster → EcalShower	CC/ecalrec.C
Vertex	AMSTrTrack→AMSVertex	CC/vertex.C
AxAMS	AMSBeta → AMSCharge → AMSParticle	CC/beta.C CC/charge.C CC/particle.C

"Software Id"

```
class AMSTRDIdSoft{
uinteger _layer;    // from 0 to TRDDBc::LayersNo(_octagon)-1
uinteger _ladder;   // from 0 to TRDDBc::LaddersNo(_octagon,_layer)-1
uinteger _tube;   // from 0 to TRDDBc::TubesNo(_octagon,_layer,_ladder)-1
uinteger _address; // aux address (== cmpta)
int16u   _haddr;   // hardware address
int16u   _crate;   // crate no
integer  _dead;    //  dead if 1 ; alive otherwise
static uinteger _CrateNo[trdid::ncrt];
void _check();
void _mkhaddr();
void _mkcrate();
 static integer _GetGeo[trdid::ncrt][trdid::nudr][trdid::nufe][trdid::nute][2];   // crate,nufe,nudr,
 static integer _GetHard[trdconst::maxlay][trdconst::maxlad][4];     // layer,ladder ->// nute,nufe,n
static geant *_ped;
static geant *_sig;
static geant *_gain;
static uinteger *_status;
...
}
```

include/trdid.h
CC/trdid.C

"Raw" or "Daq" Hit

```
class AMSTRDRawHit: public AMSlink {
AMSTRDIdSoft _id;
uinteger _Amp;
public:
AMSTRDRawHit( const AMSTRDIdSoft & id,uinteger amp):AMSlink(),_id(id),_Amp(amp);
uinteger getid() const return _id.cmpt();
AMSTRDIdSoft & getidsoft()  return _id;
number  Amp()return number(_Amp)/TRDMCFFKEY.f2i;

//interfce with lvl3
integer lvl3format(int16 * ptr, integer nmax);

//interface with mc
static void sitrddigi();
static void sitrdnoise();

//interface withdaq

static void builddaq(int n, int16u* p);
static void buildraw(int i, int n, int16u*p);
};
```

include/trdsim.h
CC/trdsim.C

Cluster - Collection of (adjacent hits)

```
class AMSTRDCluster: public AMSlink{
protected:
AMSPoint _Coo;   // Global Coordinates
integer _layer;  //  layer from 0 to 19 increasing with z
number _ClSizeR;       // tube radius
number _ClSizeZ;      // tube 1/2 length
AMSDir   _CooDir;      // Dir Cosinuses
uinteger _Multiplicity;
uinteger _HighMultiplicity;
float    _Edep;    // in KeV;
AMSTRDRawHit *_pmaxhit;
public:
number getEdep() const return _Edep;
number getHit(uinteger i);
number getEHit()return _ClSizeR;
number getHitL()return _ClSizeZ;
uinteger getlayer()const return _layer;
AMSPoint & getCoo() return _Coo;
uinteger getmult()constreturn _Multiplicity;
uinteger gethmult()const return _HighMultiplicity;
```

include/trdrec.h
CC/trdrec.C

TRD Reconstruction

```
//
//  Segments - somewhat arbitary division on two x and two y segments
//  May be changed from the datacards
//

class AMSTRDSegment: public AMSlink{
protected:
integer _Orientation;
number _FitPar[2];
number _Chi2;
uinteger _NHits;
integer _Pattern;
integer _SuperLayer;
public:
integer getslayer()constreturn _SuperLayer;
uinteger getNHits()const return _NHits;
number getFitPar(uinteger i)const return i<2?_FitPar[i]:0;
AMSTRDCluster *getpHit(uinteger i)return i<_NHits?_pCl[i]:0;
void Fit();    //  Straight line fit
static bool Distance1D(number par[2], AMSTRDCluster *ptr);
};
```

include/trdrec.h
CC/trdrec.C

```
//
// Track consists of at least one x and one y segment
// Segment orientations do not required to be along x and/or y or perpendicular to each other
// Iterative straight of straight line segments (hits) to straight line is done
// Magnetic field fitting is also done but essentially useless.
//
class AMSTRDTrack: public AMSlink{
protected:
//  Aux Track Parameters Class
//
class TrackPar{
public:
bool _FitDone;
AMSPoint _Coo;
AMSPoint _ErCoo;
number  _InvRigidity;
number _ErrInvRigidity;
number _Phi;
number _Theta;
number _ErPhi;
number _ErTheta;
number _Chi2;
};
// Aux Track Base class
//
class TrackBase{
```

TRD Reconstruction

```
public:
integer _NHits;
integer _Pattern;
AMSTRDCluster * _PCluster[trdconst::maxlay];
AMSPoint _Hit[trdconst::maxlay];
AMSPoint _EHit[trdconst::maxlay];
AMSDir _HDir[trdconst::maxlay];
};
TrackPar _StrLine;
TrackPar _Real;
TrackBase _Base;
static integer _TrSearcher(int icall);  // Pattern Recognition Searcher
public:
void StrLineFit();    // Straight Line Fit
void RealFit();       // Magnetic Field Fit
AMSPoint getCooStr()const return _StrLine._Coo;
AMSDir getCooDirStr()const return AMSDir(_StrLine._Theta,_StrLine._Phi);
AMSPoint getECooStr()const return _StrLine._ErCoo;
bool IsEcalCandidate();
bool Veto(int last);
bool IsHighGammaTrack();
number getphi()return _StrLine._Phi;
number gettheta()return _StrLine._Theta;
AMSPoint getcoo()return _StrLine._Coo;
```

include/trdrec.h
CC/trdrec.C

Particle Identification

Parameter	Derived from	Method(s)
Rigidity	Tracker/TRD	Circular/sz Fit 5X5 nonlinear fit PathIntegral 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 Vertex	Custom fits
γ Factor	TRDTrack	Truncated mean,Likelihood
Particle Id	Velocity, Charge, Rigidity Energy, γ Factor	

I/O

- Input: via FFREAD Datacards.
- DST Output: Ntuples (PAW) or RootFiles(ROOT).
  - **RootFiles based on STL vectors are currently the default DST**. The extensive set of automated documentation including examples is available at http://ams.cern.ch/AMS/Analysis/hpl3itp1/root02/html or .../root02/latex/refman.pdf.

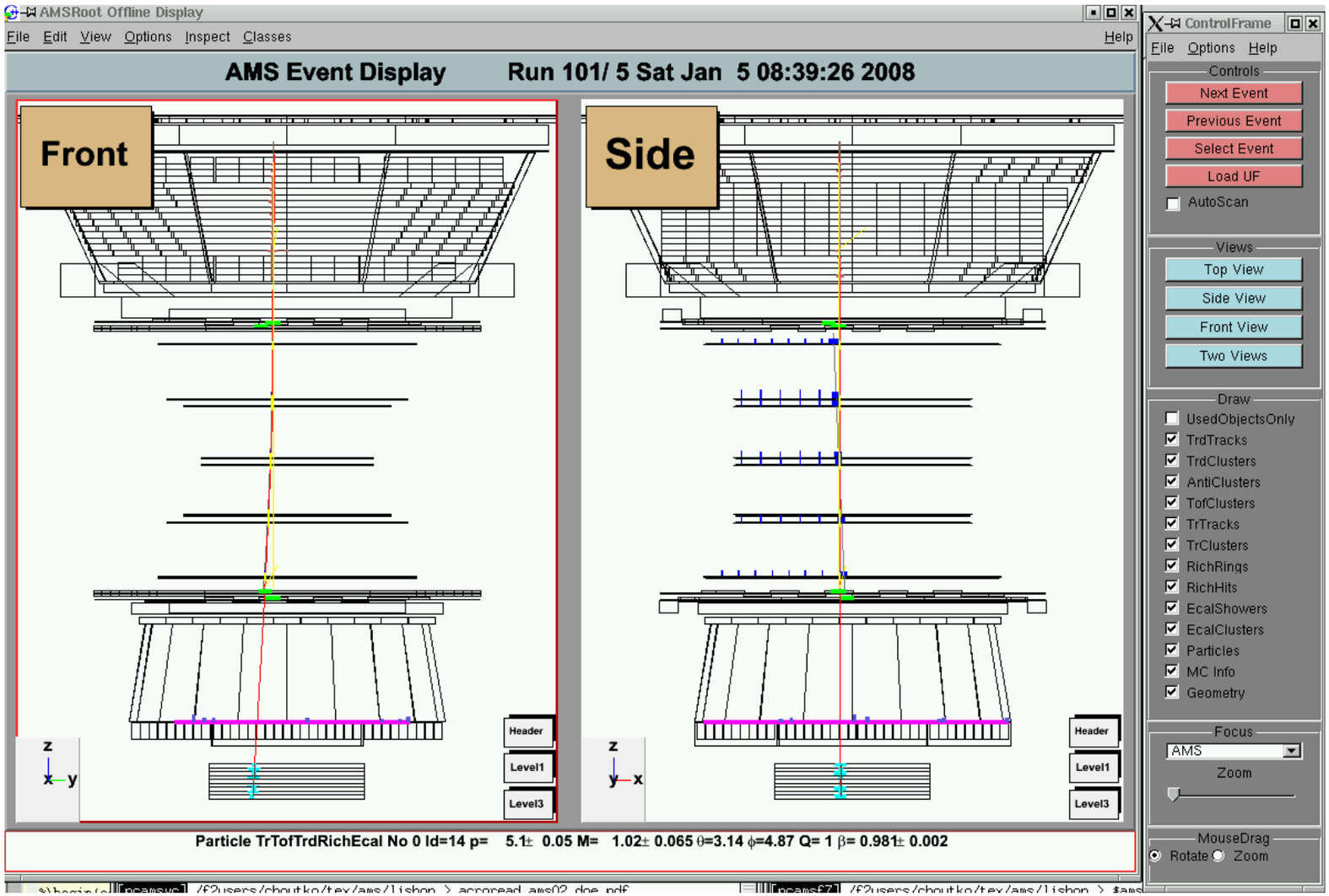
    RootFiles are going to be written in compress mode which results in a 40% smaller DSTs w/r ntuple based ones.
  - **Ntuples are considered obsolete now.** Ntuple description is in doc/ntuple02.doc. Known ntuple limitations include $\approx$ 200Mb file size limit, 50KW record length limit and fixed size arrays. As a consequence some AMS02 ntuple events may have dangled pointers and incomplete data[1].

[1] 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.

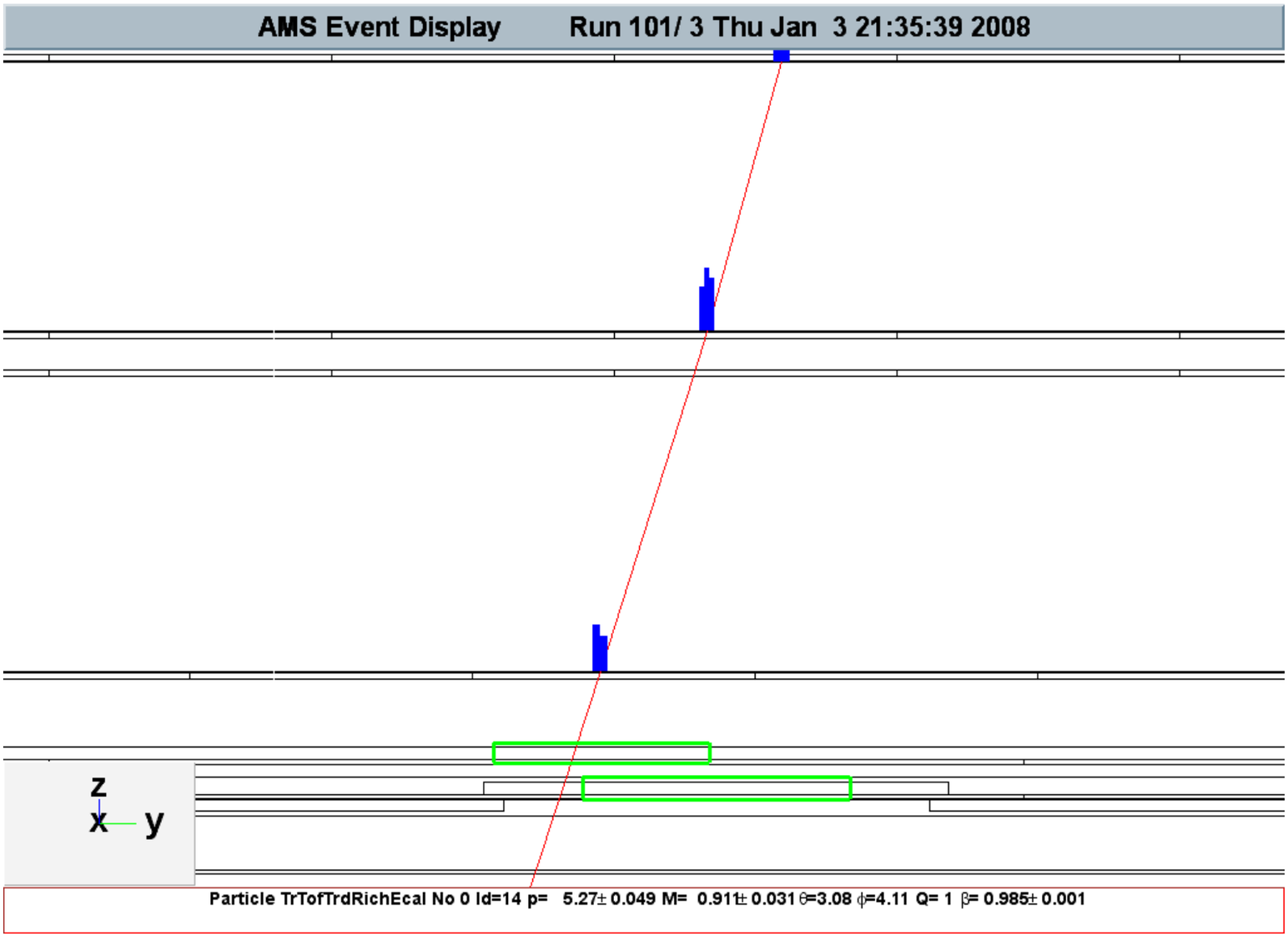
Visualization: Event Display

Source Code: display/*

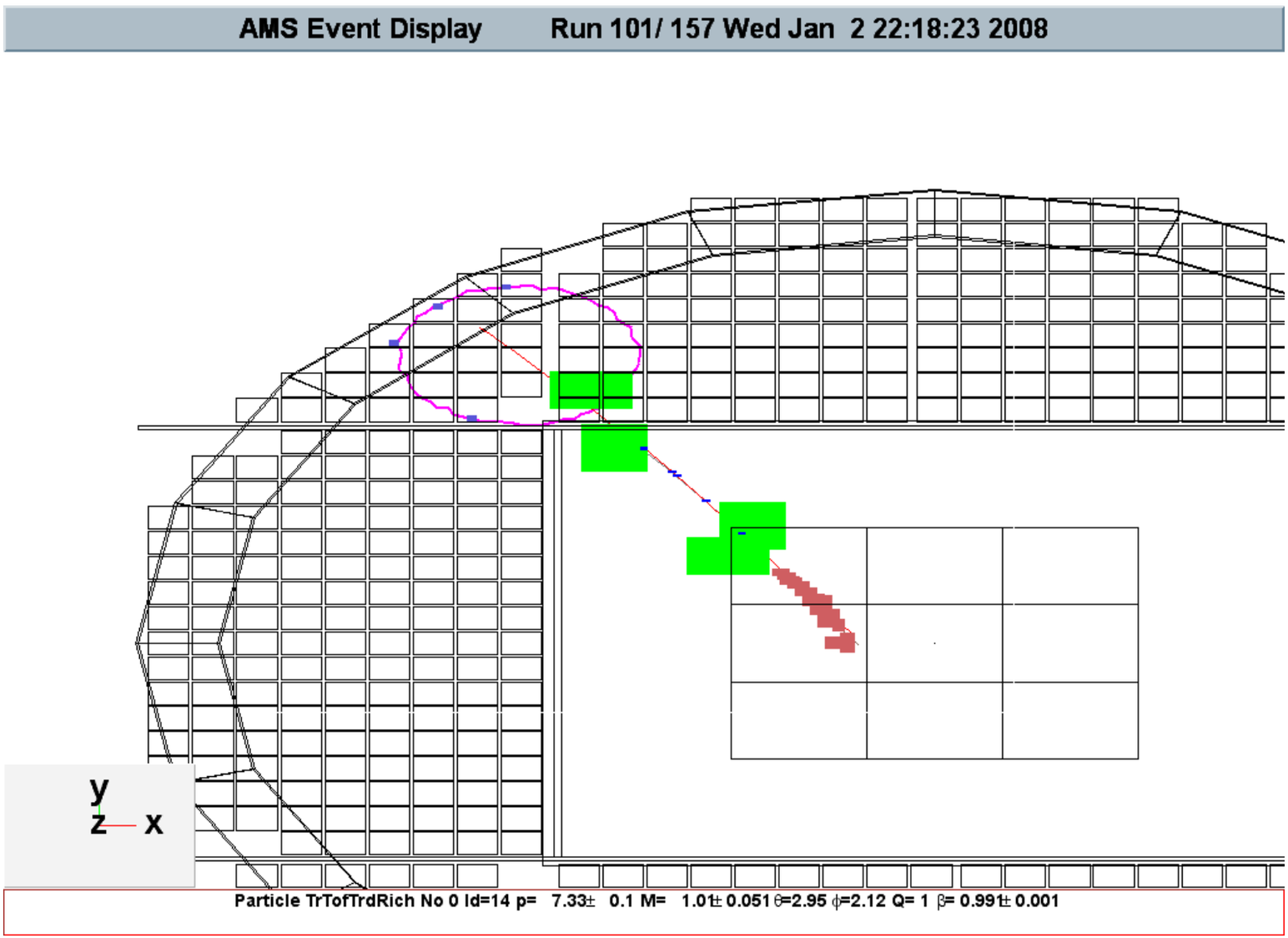
Main Features: AMS Objects Browser, Zoom, AutoScan, Pluggable Selection Function



Visualization: Event Display



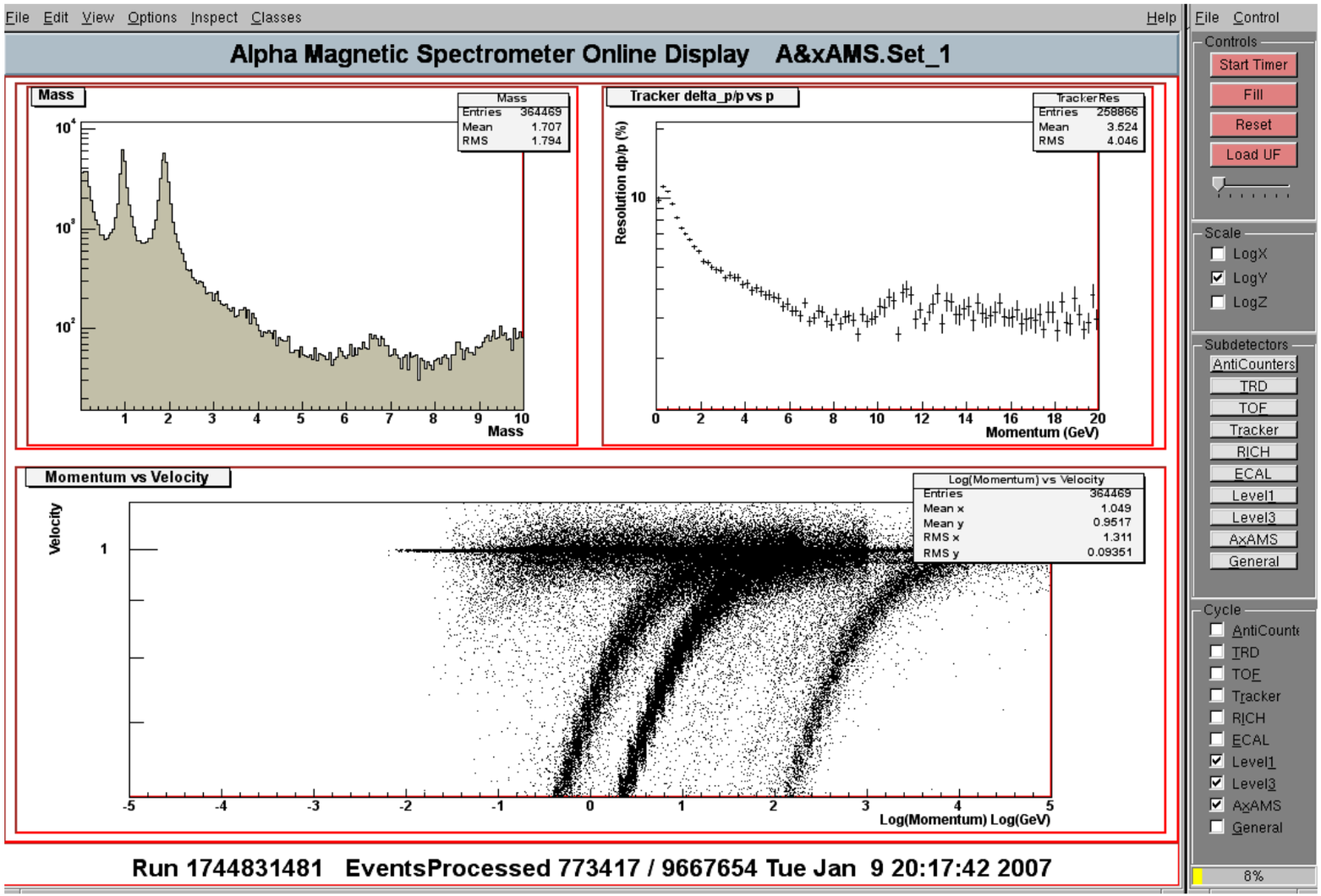
Visualization: Event Display



Visualization: Offline Monitor

Source Code: online/*

Features: Fills/Shows Various Histograms for Different Subdetectors in Real Time



ToDo List

Geometry

(Sub)Detector	To Do	Responsible	Priority
TRD	Update Zenith Radiator	V. Choutko	High
	Update G4 Geometry	V. Choutko	Low
	Update M-Structure	E. Choumilov	High
Tracker	Implement final design of inclined radiators	E. Choumilov	High

Simulation

(Sub)Detector	To Do	Responsible	Priority
TOF	Finalize counter/electronics parameters according to beam/laboratory test results	E. Choumilov	High
ANTI	Finalize counters parameters according test beam results	E. Choumilov	High
Tracker	Update simulation of Si strips induced charge	J. Alcaraz	Medium
RICH	Finalize aerogel refraction index	C. Delgado	High
ECAL	Finalize ECAL trigger scheme/parameters	E. Choumilov	Medium

ToDo List

Reconstruction

(Sub)Detector	To Do	Responsible	Priority
TRD	Improve particle Id	K. Scholberg	Medium
	Introduce charge measurement	K. Scholberg	Medium
Tracker	Improve coo measurement accuracy using η function	J. Alcaraz	Medium
	Alignment	B. Burger	Medium
RICH	Implement LIP velocity/charge finding algos	F. Barao	Medium
ECAL	Improve particle Id	??	Medium
AxAMS	Finalize converted γ reconstruction	J. Alcaraz G. Lamanna	High
	Implement AMS global charge finding algo	J. Casaus	Medium

Miscellaneous

Category	To Do	Responsible	Priority
Offline Monitor	Fill subdetectors histograms	ToF, Anti: D. Casadei Trd: V. Zhukov K. Scholberg Trigger1: E. Choumilov Trigger3, AxAMS: V. Choutko Tracker:P.Azzarello, P.Zuccon, W.J. Burger Rich: C. Delgado Ecal: ? Header: D. Grandi	High
General Software	Update to latest G4 version	V. Choutko	Medium

People

Subject	Coordinator	(Sub)Detector Contact Person
Magnet/USS Geometry	E. Choumilov	R. Becker
ToF	E. Choumilov	D. Casadei
Anti	E. Choumilov	W. Wallraff
TRD Geometry	K. Scholberg	T. Siedenburg
TRD	V. Choutko	T. Siedenburg
Tracker	J. Alcaraz	B. Bertucci
Trigger-LVL1	E. Choumilov	A. Lebedev C. Lin
Trigger-LVL3	V. Choutko	X. Cai
ECAL	E. Choumilov	??
RICH	C. Delgado	ibid
I/O Root	V. Choutko A. Klimentov	-
Event Display	V. Choutko	M. Levtchenko (Geometry)
Offline Monitor	V. Choutko@cern.ch	(Sub)Detector volunteers
MC Production	A. Klimentov@cern.ch	Remote MC centers responsibles

MC Production Plans

Complete AMS02 Physics Performance Evaluation, including $p, \bar{p}, e^{\pm}, \gamma, He, \bar{He}, Li, Be, C, d, \bar{d}$ cosmic ray sources.
Starting: October 2003, provided all high priority problems from "ToDo List" solved.

Estimated Disk(Tape) Space and CPU Time Needed:

- Disk Space: 6 TBytes (Available);
- CPU: 10000 PIII-1000 CPU days (?);

MC Production Plans

MC Production Center	Responsible	Declared GHz Available for AMS	Trained
Academia Sinica Taiwan	Z. Ren	47 (100)	Yes
ETH Zurich	A. Biland	35 (100)	Yes
Universitaet Karlsruhe	V. Zhukov	30	Yes
Kyungpook Nat. Univ.	J. Shin	23	Yes
INFN Milano	D. Grandi	22 (31)	Yes
CIEMAT Madrid	J. Casaus	20	Yes
INFN and Univ. Siena	P. Maestro	20	Yes
CERN	V. Choutko	16	Yes
University of Maryland	A. Malinin	8	Yes
INFN Bologna	D. Casadei	6 (24)	Yes
Groupe d'Astroparticules de Montpellier	M. Sapinski	6	Yes
IN2P3 Lyon	C. Goy	? (16)	Yes
INFN and Univ. Perugia	P. Zuccon	? (7)	Yes
MIT	K. Scholberg	2 (12)	No
Total Of		235 (380)	

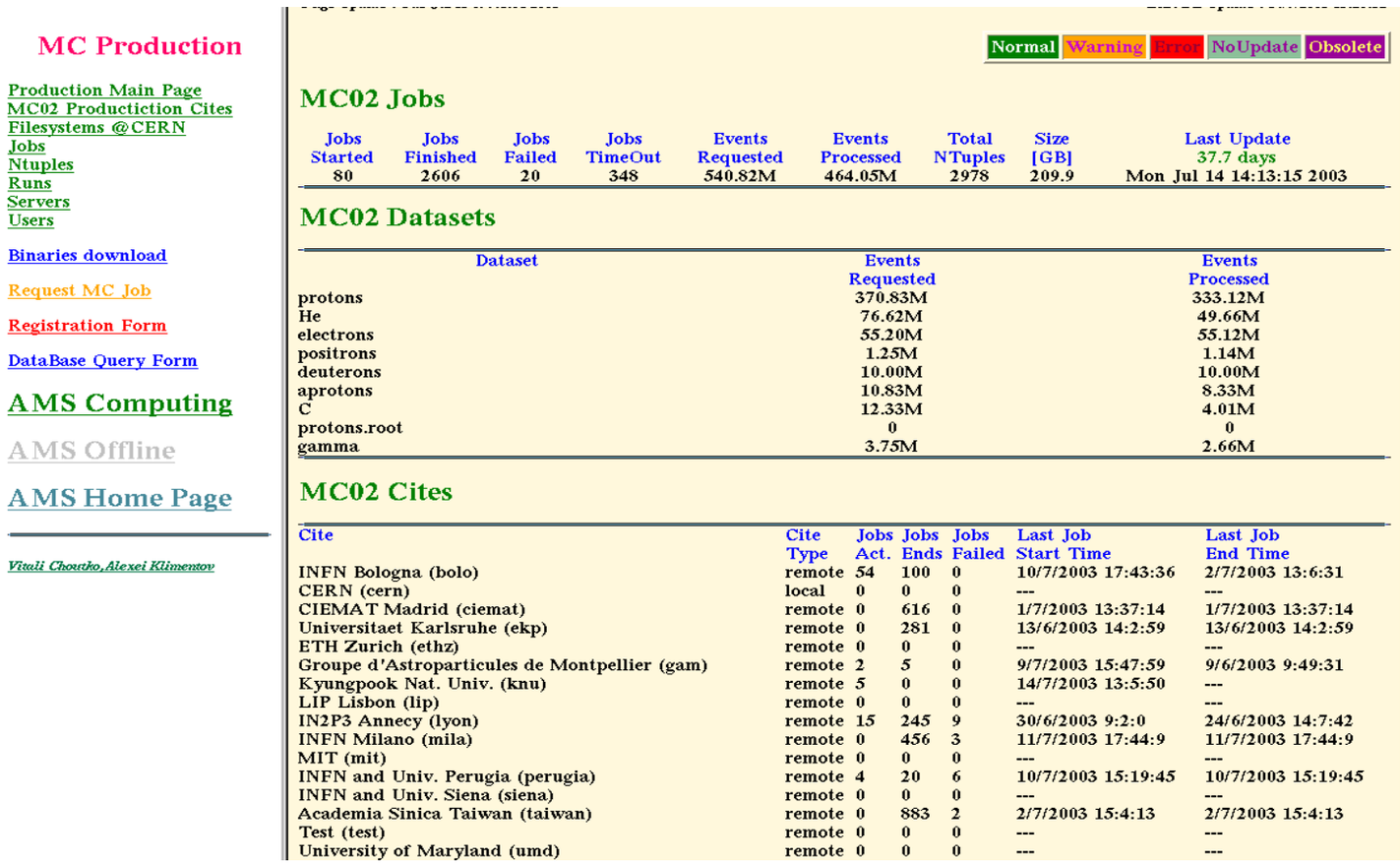
GHz == Normalized to P-IIIM-1GHz Performance

? == No Data

() == May Become Available

MC Production Plans

To allow effective use of the worldwide off-cite computer facilities for AMS02 MC production, special software based on Oracle(MySQL) database, perl-cgi scrips and CORBA had been developed. Web user interface is provided via http://pcamsf0.cern.ch/rc.html. The registration and working procedure is described in ReadMeFirst. At the moment 15 MC remote centers are registered.



MC Production

Production Main Page
MC02 Productiction Cites
Filesystems @CERN
Jobs
Ntuples
Runs
Servers
Users

Binaries download

Request MC Job

Registration Form

DataBase Query Form

AMS Computing

AMS Offline

AMS Home Page

Vitali Choutko,Alexei Klimentov

Normal Warning Error NoUpdate Obsolete

MC02 Jobs

Jobs Started	Jobs Finished	Jobs Failed	Jobs TimeOut	Events Requested	Events Processed	Total NTuples	Size [GB]	Last Update 37.7 days
80	2606	20	348	540.82M	464.05M	2978	209.9	Mon Jul 14 14:13:15 2003

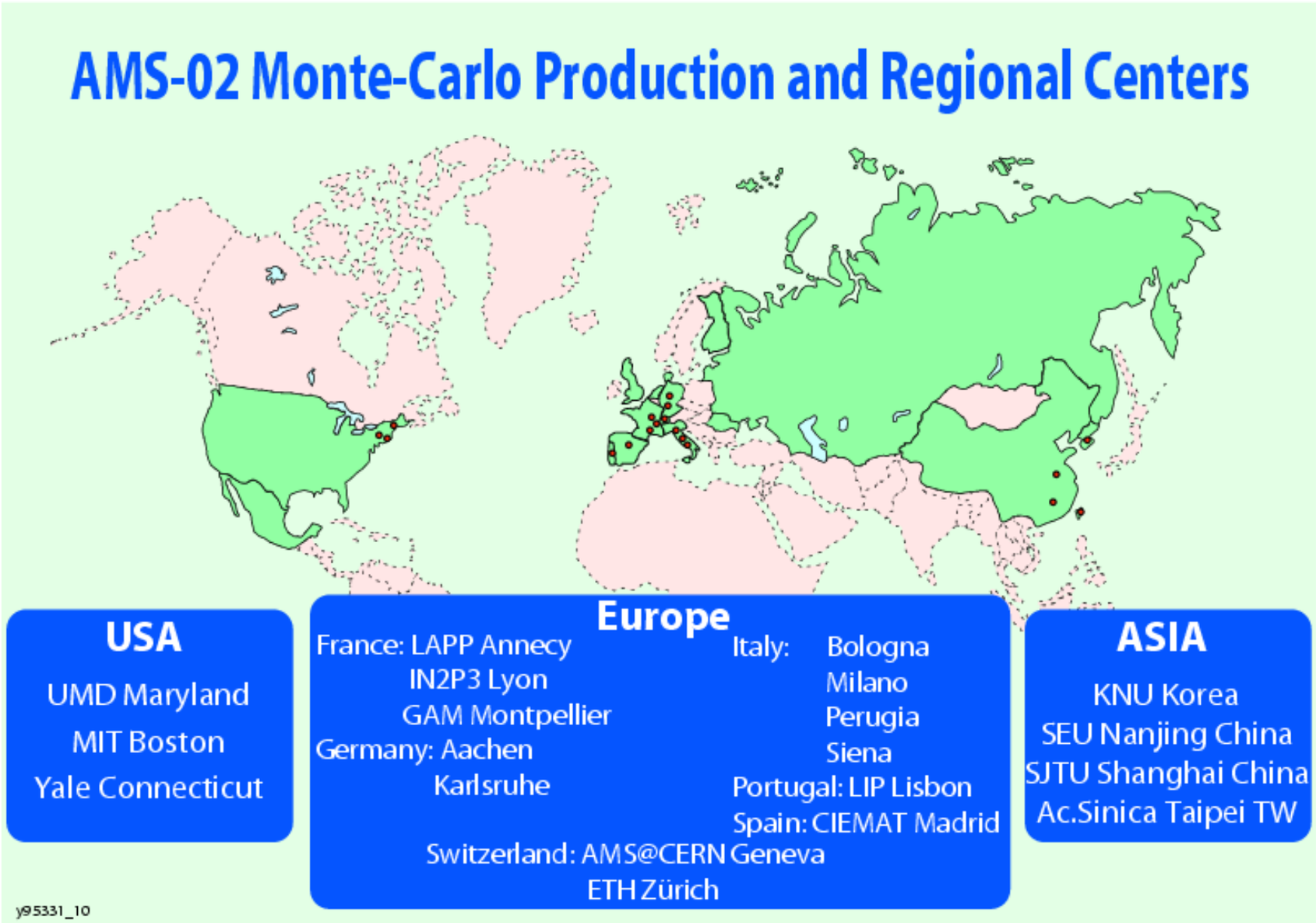
MC02 Datasets

Dataset	Events Requested	Events Processed
protons	370.83M	333.12M
He	76.62M	49.66M
electrons	55.20M	55.12M
positrons	1.25M	1.14M
deuterons	10.00M	10.00M
aprotons	10.83M	8.33M
C	12.33M	4.01M
protons.root	0	0
gamma	3.75M	2.66M

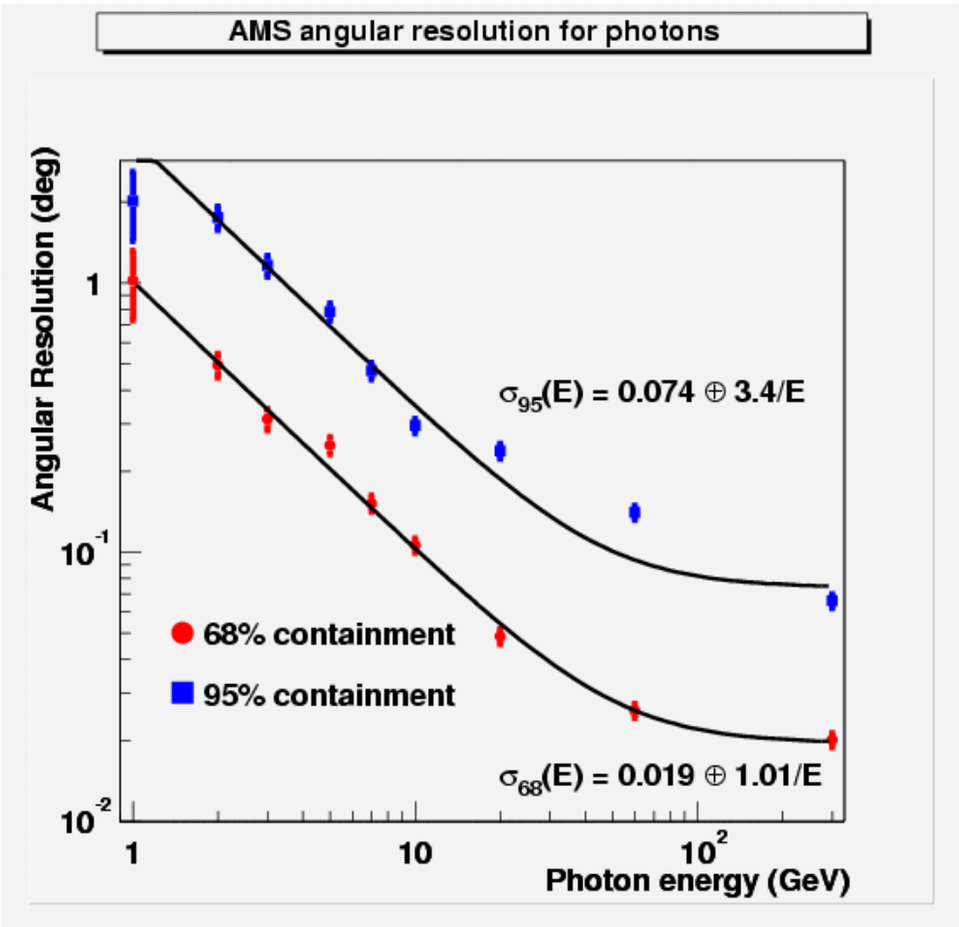
MC02 Cites

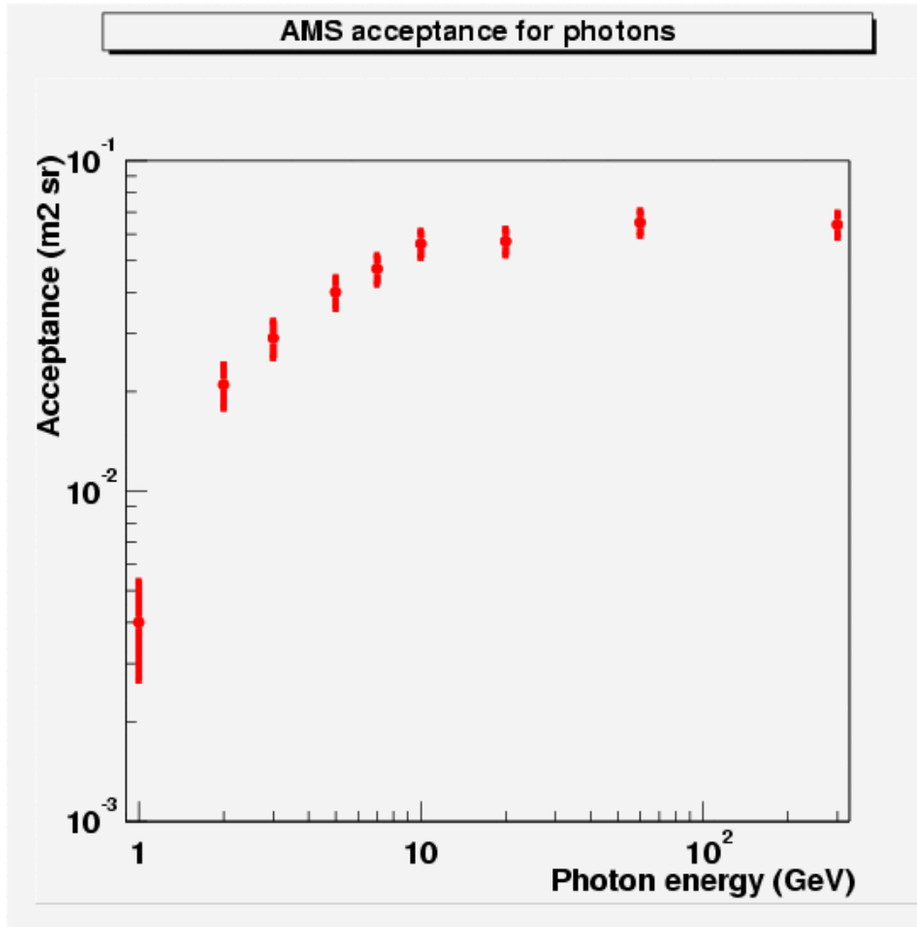
Cite	Cite Type	Jobs Act.	Jobs Ends	Jobs Failed	Last Job Start Time	Last Job End Time
INFN Bologna (bolo)	remote	54	100	0	10/7/2003 17:43:36	2/7/2003 13:6:31
CERN (cern)	local	0	0	0	---	---
CIEMAT Madrid (ciemat)	remote	0	616	0	1/7/2003 13:37:14	1/7/2003 13:37:14
Universitaet Karlsruhe (ekp)	remote	0	281	0	13/6/2003 14:2:59	13/6/2003 14:2:59
ETH Zurich (ethz)	remote	0	0	0	---	---
Groupe d'Astroparticules de Montpellier (gam)	remote	2	5	0	9/7/2003 15:47:59	9/6/2003 9:49:31
Kyungpook Nat. Univ. (knu)	remote	5	0	0	14/7/2003 13:5:50	---
LIP Lisbon (lip)	remote	0	0	0	---	---
IN2P3 Annecy (lyon)	remote	15	245	9	30/6/2003 9:2:0	24/6/2003 14:7:42
INFN Milano (mila)	remote	0	456	3	11/7/2003 17:44:9	11/7/2003 17:44:9
MIT (mit)	remote	0	0	0	---	---
INFN and Univ. Perugia (perugia)	remote	4	20	6	10/7/2003 15:19:45	10/7/2003 15:19:45
INFN and Univ. Siena (siena)	remote	0	0	0	---	---
Academia Sinica Taiwan (taiwan)	remote	0	883	2	2/7/2003 15:4:13	2/7/2003 15:4:13
Test (test)	remote	0	0	0	---	---
University of Maryland (umd)	remote	0	0	0	---	---

MC Production Plans



AMS MC Converted Photon Performance Evaluation





AMS MC Converted Photon Performance Evaluation