Selected AMS01 Reconstruction Software Issues [1]

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

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AMS01 DAQ Format

- —EL—EID—HL—HID—Run(2)—AuxR(2)—Event(2)—Time(4)—LSubDBl—IDSubDBl—..dataSubDBl.—

  Legend:
  EL - low 16bits of total event length -1
  EID - upper 6 bit of total event length, then 0x0 if event data
  HL - header ==general run length - 1
  HID - header id = 1 ¡¡ 9;
  Run(1:2) - run number 32bit
  AuxR(1:2) - run type 32bit // 1F0100 (Normal)
  Evt(1:2) - event number 32bit
  Time(1:2) - time 32bit unix format (number of sec from epoch==1970)
  Time(3:4) - number of usec
  LSubDBl - length of subdet block (LVL1,LVL3,TOF,Anti,Tracker,CTC)-1
  IDSubDBl- id sub det block

- Description I: /offline/v3.00/doc/daqevt.doc
- Program Code: /offline/v3.00/CC/daqevt.C, include/daqevt.h
- Description II: http://ams.cern.ch/AMS/Dataformats/

- AMS01 Level-1 Trigger consisted of
  - 4 fold coincidence of ToF signals over threshold (0.3-0.4 MeV) combined by OR in a ToF layer, left/right readout side separately. Time window was about 150 nsec.
  - Absence of any signals from Veto counters over threshold (about 0.15 MeV)

– Special "Pattern" match between ToF Bar in 1st and last layers:

0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	1	1	0	0
0	0	0	0	0	0	0	1	1	1	1	1	0	0
0	0	0	0	0	0	1	1	1	1	1	1	0	0
0	0	0	0	0	1	1	1	1	1	1	1	0	0
0	0	0	0	1	1	1	1	1	1	1	0	0	0
0	0	0	1	1	1	1	1	1	1	0	0	0	0
0	0	1	1	1	1	1	1	1	0	0	0	0	0
0	0	1	1	1	1	1	1	0	0	0	0	0	0
0	0	1	1	1	1	1	0	0	0	0	0	0	0
0	0	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0

- Fortran code which reproduce Level-1 Trigger for Data and MC resides in /offline/v3.00/analysis/xtrig.f

- Description of Level-3 Trigger may be found in http://ams.cern.ch/AMS/Analysis/hpl3itp1/lvl3.ps http://ams.cern.ch/AMS/Analysis/hpl3itp1/zurich.trig.ps
- There were two different types of Trigger level-3 used during STS91 flight:
  - Before Docking: One and Only one ToF Cluster in 1st and last ToFLayers, at least 3 Tracker hits and at most 20 Tracker hits in the ToF Defined Road in bending projection AND rejection of low positive rigidity Z=1,2 events.
  - During & After Docking: Dropped the rejection of low positive rigidity events.

Cluster Finding TOF

E.Choumilov will write something here soon.

- OnBoard Compression: For S side (bending side): find a strip with S/N > 3.5, add adjacent strips and adjacent to adjacent provided the latter have amplitude>0. Form cluster. Repeat.

  For K side (non-bending side): find a strip with S/N>2.75, add adjacent strips provided they have amplitude>0. Check if there is at least one S cluster for given ladder. Form cluster if yes, discard if no. Repeat if necessary.

- Offline Clustering: Works in a similar way as Onboard software with normally higher thresholds (4.5 & 3.75 σ) PLUS checks for bad strips, i.e. does not form clusters from noisy strips. Adds adjacent to maximal (or adjacent to adjacent) strips only if their amplitude is greater than their sigma value.

- 3-D Hits Construction: Simply takes all possible S(y) and K(x) hits belonging same ladder are combines them into 3-D hits. No discrimination based on relative amplitudes is performed.

Cluster Finding Tracker

Due to the fact that for K cluster one readout channel corresponds 6 to 8 geographical positions equally spaced, a single S,K cluster pair creates 6 to 8 3-D hits. To (nearly) resolve this ambiguity on a track level the spacing between such a hits was mad different for inner (2-5) and outer 1,6 tracker planes.

A general idea of track finding is based on the fact that the magnetic field, though inhomogenious, has different strength along x an y axis, therefore particle trajectory still may be approximated by helix.

- Find the most populated with at least four hits combination which straight line (in sz projection) fit χ^2 less than (typically 5) and with helix fit χ^2 less than (typically 1000)
- Fit the combination taking into account real magnetic field distribution. Accept if χ^2 is less than (100).

Sometimes no track is found using this method. It is often related to the fact that K (nonbending) clusters S/N is too low. In this case the above procedure is repeated accepting any three-hits combinations, and then trying to add the false K (FalseX) hit(s) in the complimentary ladders according the predictions obtained from the track. Then new attempt to reconstruct at least four

hits track is made.
Sometimes no track with even three hits is found. In this case the FalseTOF K clusters are created in all ladders, using the straight line fit to the available ToF clusters.
In fact the last procedure is applied to all events independently on whether or not “normal” tracks were found. This is done to check against the events in which some S clusters where dropped from the fit because the their K-cluster partners in a 3-D hit were generated by noise.

Why Events Often Have More than One Track

- Particle interactions inside the AMS detector
- In case of track contains only inner tracker plane hits, the 6 fold tracker ambiguity could not be resolved. Using ToF allows to reduce it to two fold ambiguity for most cases.
- For the events with normal and FalseX tracks (see previous section) an additional KTOF track is always generated. This track is then used to find independent β object.

Three different methods used to reconstruct rigidity, namely "Fast", based on 5x5 matrix inversion, "Kalman" based on Kalman filter using the GEANE CERN Library program and "path integral" one from J.Alcaraz.
The references for first two are in
http://ams.cern.ch/AMS/Analysis/hpl3itp1/amsnote.ps pages 4,5. See also the appendix for some discussion about features of the algorithmes. Juan wrote a note explaining his method
http://ams.cern.ch/AMS/Reports/AMSnote-2003_03_01.ps.gz

Tracker alignment is described in some details in http://ams.cern.ch/AMS/Analysis/hpl3itp1/amsalig.ps
"GlobalDB" alignment is the "normal" one : i.e. coordinates and rotations of all ladders are found by minimizing the χ^2 of the uniformly irradiated ladders sample of tracks with known momentum.
Building a histogram of the ratio of the nominal to the average measured momentum for all concerned ladder combinations gives: see page 7 of the above note.
Some of the ladder combinations have their ratio quite different from one. For them "LocalDB" alignment was additionally done, i.e. every such ladder combination has their own set of displacements and rotations, which push the average momentum measurement to a nominal one.
In this case the tracker coordinates is somehow virtual ones. Still this procedure improves the tracker resolution on beam test.

- Velocity is reconstructing by fitting Time measurements of ToF clusters found in the vicinity of Tracker Track with the assumption of constant particle speed. For the low $\beta < 0.4$ particles refit using only two inner ToF time measurements is normally done. Down going particles have + velocity sign, upgoing: -.
- Together with β a β_C is calculated (Courtesy of Yu. G.). β_C takes into account that particle speed is bounded by speed of light. The formulae is the following:

$$\beta_C = \frac{\int_{-1}^{1} x \cdot e^{-\frac{(x-\beta)^2}{2\cdot\sigma_\beta^2}}}{\int_{-1}^{1} e^{-\frac{(x-\beta)^2}{2\cdot\sigma_\beta^2}}},\ \beta \text{ is the measured velocity},\ \sigma_\beta \text{ is its error}$$

Likelihood method based on predefined samples of de/dx for tof and tracker after velocity and $\cos(\theta)$ corrections. for charge up to 3 tof and tracker combined used, above only tracker.

- Mass is calculating over standard formulae. In case of $1/\beta < 1$ a new $1/\beta' = 2 - 1/\beta$ is calculated, and mass is redefined according it plus gets an additional - sign. The idea of this substitution is to be able to estimate ToF time measurement tail distributions, using $\beta < 1$ constraint.
- Momentum and/or velocity measurement may be "improved" using the fact that particle mass is in fact precisely known. "Fitted" momentum and velocity is taken from minimization of

$$\frac{(\mathrm{x} - 1/\mathrm{p})^2}{\sigma^2_{1/\mathrm{p}}} + \frac{(\sqrt{\mathrm{m}^2 \cdot \mathrm{x}^2 + 1} - 1/\beta)^2}{\sigma^2_{1/\beta}}$$

where p is measured momentum, β velocity, σ's are their corresponding errors and m is the (known) particle mass.
- Repeating this procedure for all known particle masses with

the given charge and choosing one with minimal χ^2 results in getting of the particle ID (pid) value.

- There were 16 Anti Counters in AMS01 detector, read out from up and bottom sides separately.
- The hardware readout threshold was $0.1 - 0.2$ MeV, efficiency for detecting a MIP particle being $> 99.9\%$
- Thanks to short attenuation length (120 cm) the vertical (Z) coordinate of reconstructed ACC hit, the latter are simply sum of up and down readout signals of a particular Anti Counter, was reconstructed, though with quite big error of about 8 cm.
- ATC (CTC) detector consisted of two layers of aerogel cerenkov blocks read out by pmts positioned in the center of the blocks. See http://ams.cern.ch/AMS/Reports/AMSnote-99_10_01.ps.gz for details. There were two features one have to pay attention on:
  - "AfterPulses": Sometimes the event get a huge CTC signal in one of the cells. This is normally a tail from previous event

and should be ignored.

– Low β p and especially He have quite high probability of having CTC signal due to scintillation of the teflon CTC cell wrapper.

"Normal" particle in the ntuple has all the pointers to charge, velocity and track objects set up. Sometimes however a particle without track may be created. The direction of such particles is getting from ToF (AMS01) ToF,TRD or ECAL (AMS02). Such particle normally has *ptrackp* pointer negative and rigidity undefined.

Relevant Datacards (see also /offline/vdev/doc/datacards.doc):

- TRIG always shows the total number events generated. Angular, momenta and other restrictions via MCGEN datacards are always applying after generation. The only exception is MCGEN 15 (fixedplane) datacard. Putting MCGEN 15=1 will lead generation of particles only from top plane.
- MCGEN 20=5 should be used for all acceptance related calculations to avoid confusion. It corresponds uniform log(Momentum) input spectrum.

MC Generation Specifics, or How to Calculate an Acceptance

Examples on how to generate events to estimate an acceptance:

- /offline/v3.00/prod/mc/trigmc01str.job Stranglet gen example
- /offline/vdev/prod/mc/trigmc02xx.job AMS02 gen examples

To properly calculate an acceptance one has to:

- Select one of the AMS0x generation examples
- Generate TRIG events
- Apply user defined cuts.

$$A(E, \cos\theta, \phi)(m^2) = \pi \cdot 3.9^2 \cdot NP \frac{N^{\mathrm{BinnedSurvivedEvents}}}{\mathrm{TRIG}} \cdot \frac{1}{\Delta_{\mathrm{Log(Mom)}} \cdot \Delta_{\cos\theta} \cdot \Delta$$

, there NP = 6 if MCGEN 15=0 and 1 otherwise