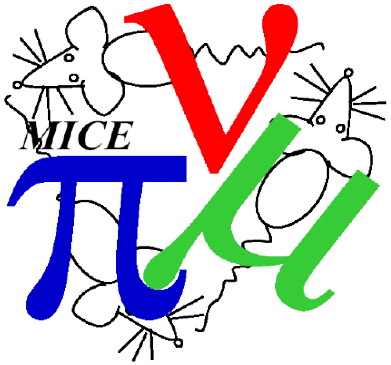
MAUS – Analysis Issues



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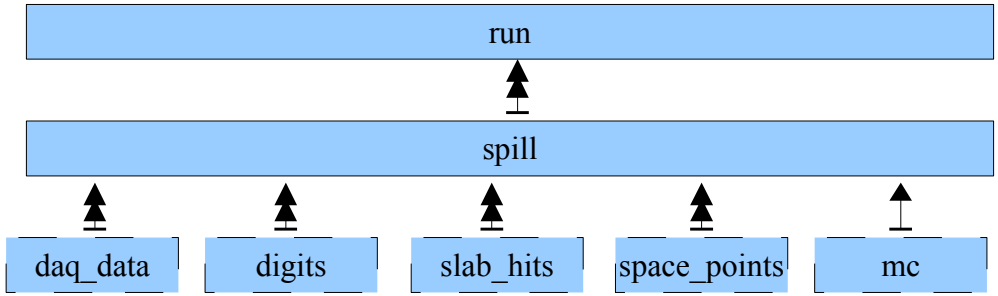
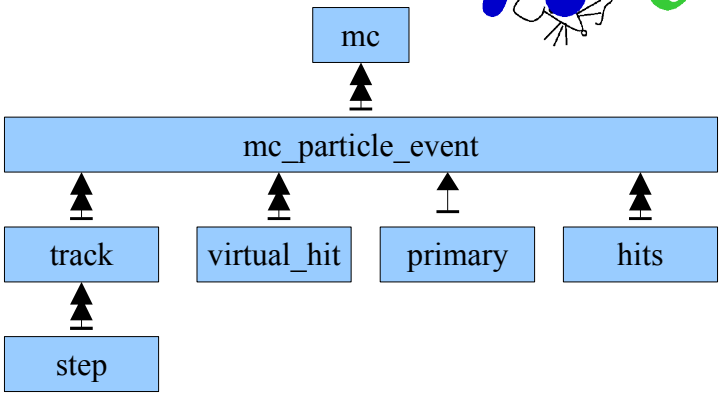
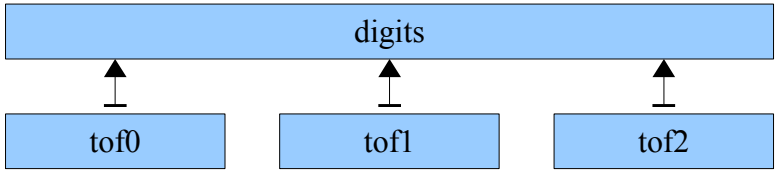
Overview

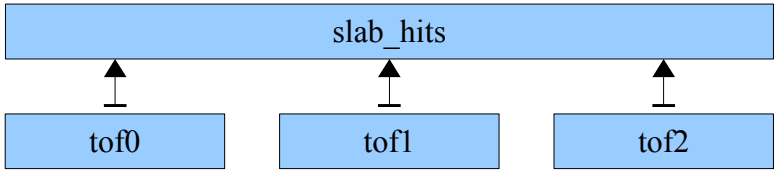
- Trying to specify the “detector integration” task
- Short term
  - Data structure
  - Data representation
  - Batch production
  - Beam input via G4BL
  - Geometry responsibility
- Longer term
  - Global Recon
  - Optics Tool

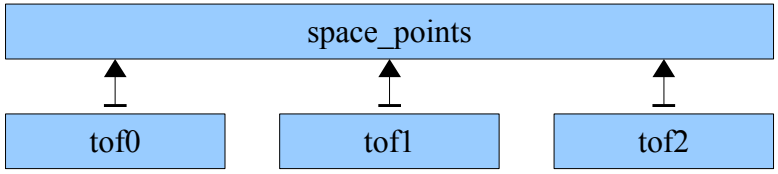
Current data structure

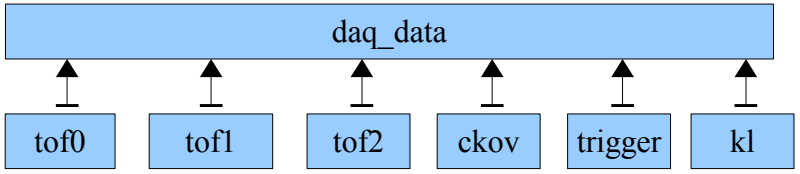




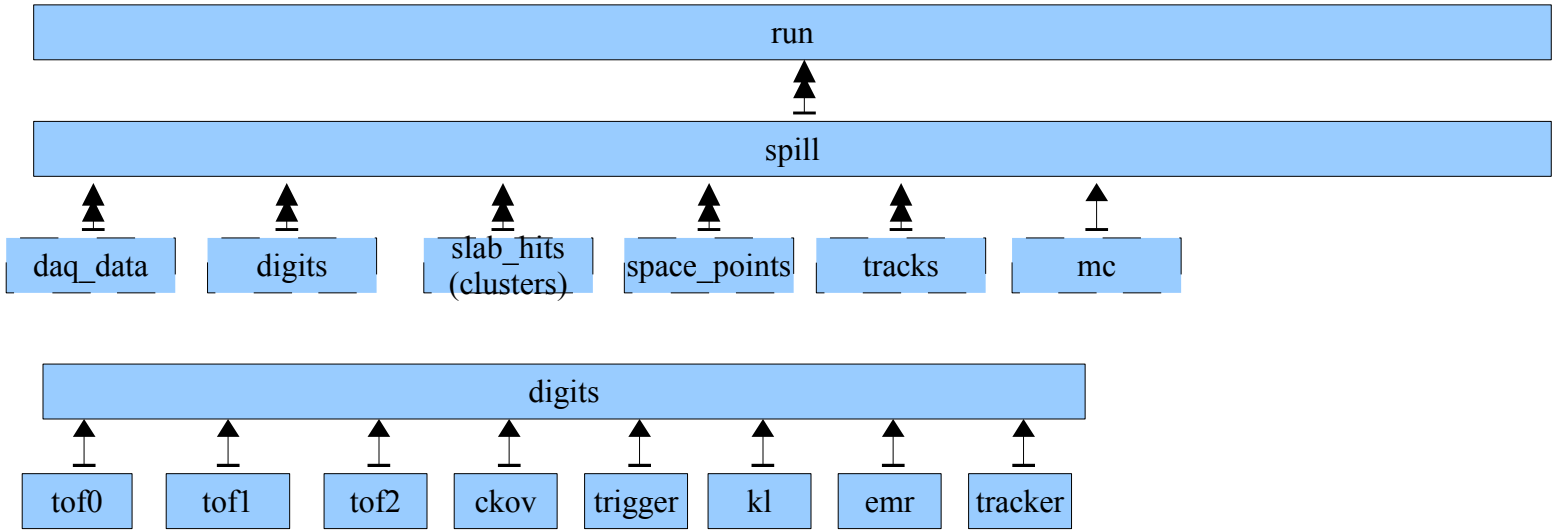








Final data structure

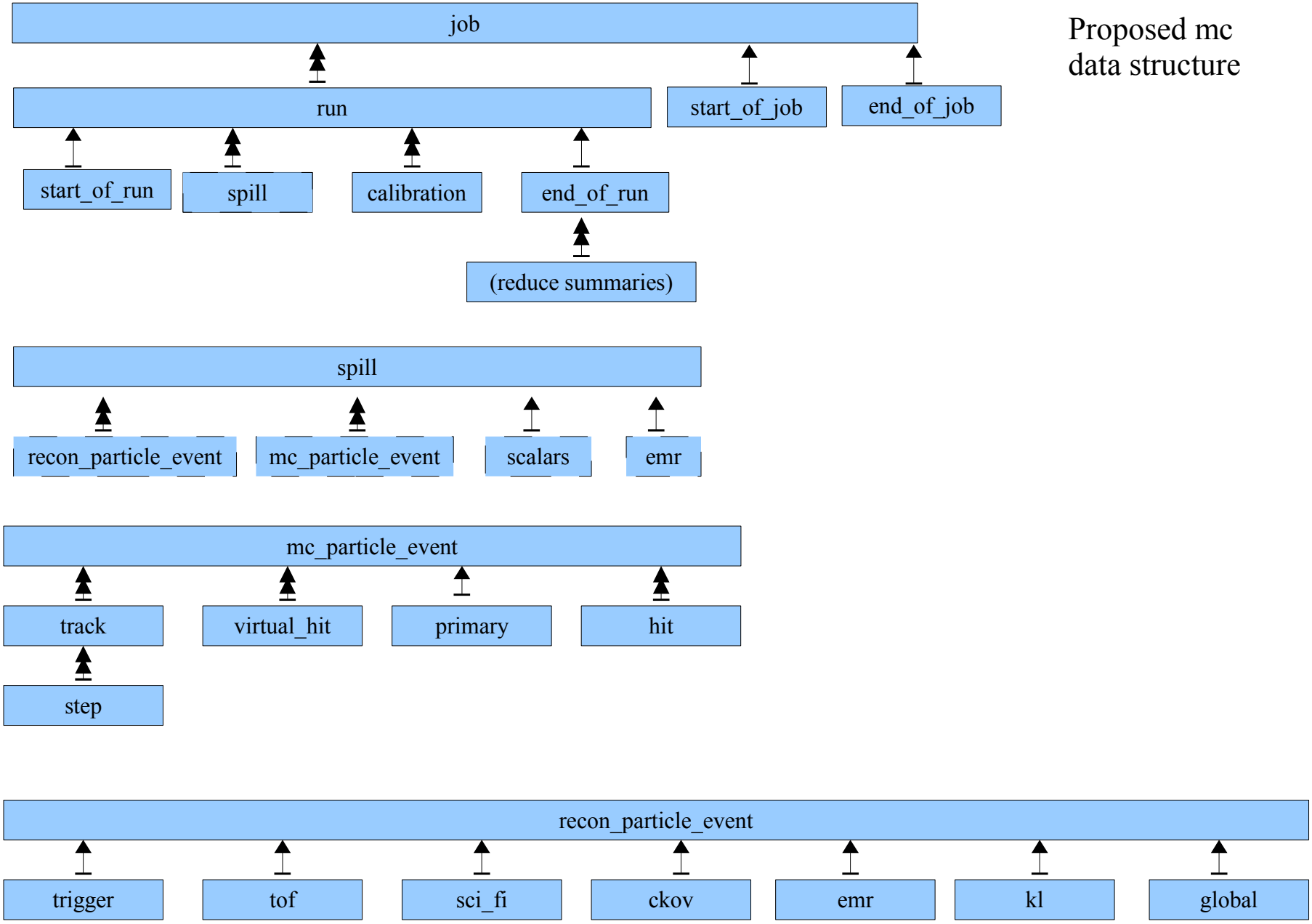


Etc...

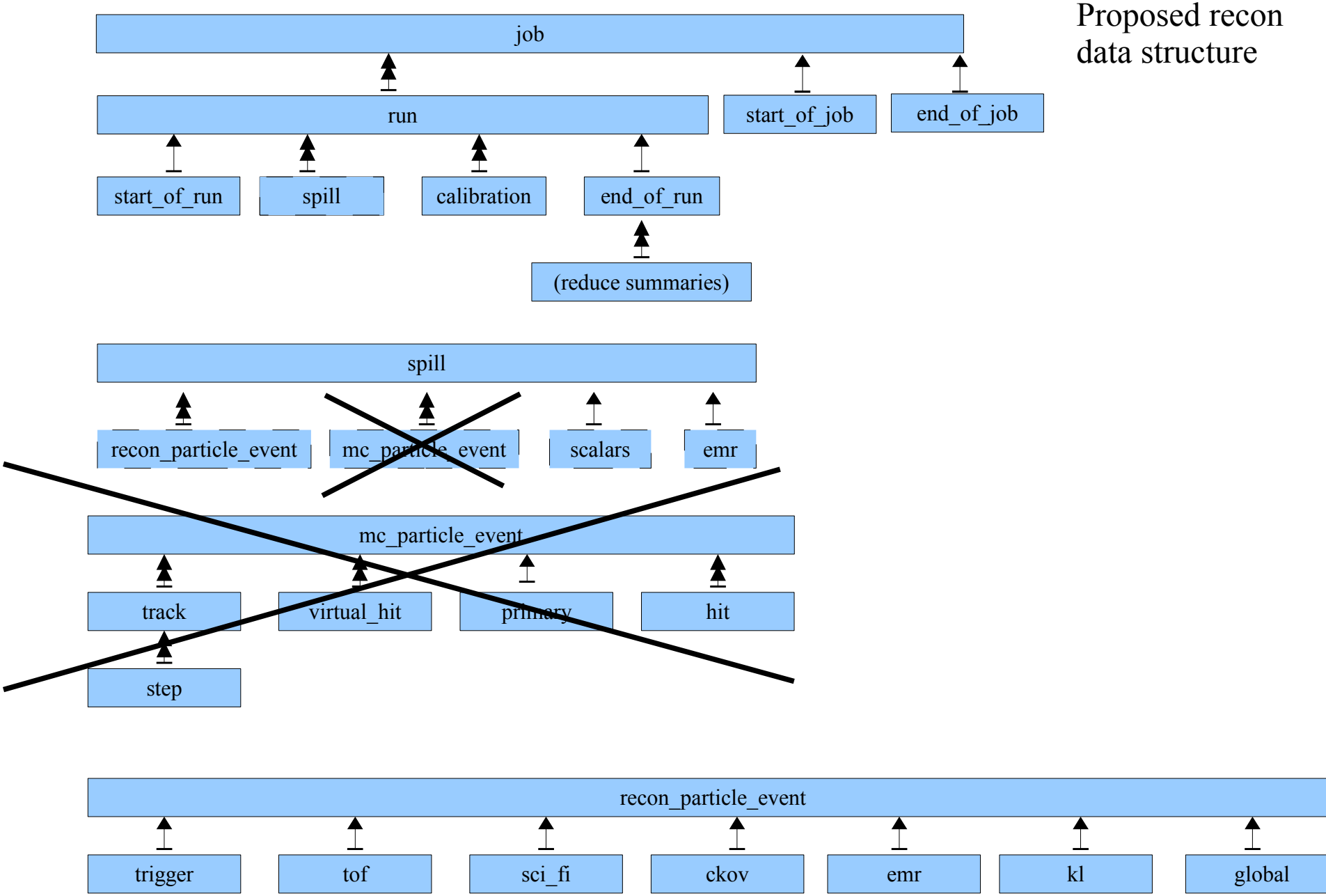
Comments

- Tough to extract the digits/slab hits/cluster for *this* particle event
  - Need to do a search and construct a particle event every time we want to do any reconstruction - madness
- We struggle to know e.g. what digits were used to reconstruct a particular slab hit
  - Can't do noise studies easily
- We have no way to handle per-run calibration data (DAQ calibration event)
- We have no way to store run metadata
- But:
  - Nice for global recon – we can e.g. trivially extract all space points
  - Some existing code in this data structure

Proposed mc data structure



Proposed recon data structure



Data Representation

- Data currently represented in json
  - No way to enforce any structure
  - Developers can e.g. change the data structure during reconstruction
  - No way to enforce conventions
    - Like “all Space Points should have (x,y,z,time) field”
  - Some concerns over file size, access speed
    - Can probably be addressed using native json, e.g. use some compression routine
  - Naturally leads away from good practice – encapsulation, etc
- Propose using a ROOT data tree
  - More conventional
  - Maintain json functionality

Data - Implementation

- Changing data structure needs to be done ASAP and is quite a hard change (i.e. can't phase it in easily)
  - Rogers task? In collaboration with other developers?
- Changing data representation can be phased in slowly – thanks to nice modular structure in MAUS
- At the moment data serialisation goes like
  - PyJson -> Reconstruction module -> PyJson -> string -> JsonCpp -> Reconstruction module -> JsonCpp -> string -> JsonCpp -> Reconstruction module -> ...
  - Choose to use JsonCpp or PyJson by developer preference
  - Conversion to string is just a lazy
- Generalise this serialisation to allow different types
  - Converter(..., DataTypeA) -> Reconstruction module -> Converter(DataTypeA, DataTypeB) -> Reconstruction module -> Converter(DataTypeB, DataTypeC) -> ...
- Then implement Converters for ROOT, JsonCpp, PyJson
  - If DataTypeA == DataTypeB we have a null operation
  - No longer need to go back to strings all the time so should result in code speed up

Batch Production

- Propose a batch production job for MC and Reconstruction
  - After a stage of settling analysis users won't be interested in details of this or that reconstruction routine
  - Nice to have “official” recon data sets for analysis
- Will be done on GRID
  - Automatically trigger as data is taken
  - Use a reference version which may not be the latest – chosen by analysis group
  - Rerun over data sets for new code version/calibration/etc can be requested by analysis group
- Needs:
  - GRID setup
  - Input beam (next slide)
  - Geometry import
  - Digitisation of TOF and other detectors
  - ROOT IO (propose write ROOT data trees)
- Aim was mid-February
  - All looks quite tight

Input Beam (g4bl)

- I think we use G4BL for input beam to batch production
  - Need reasonable rate and time distribution
    - For multiparticle effects (pile up, dead time)
    - For tracker dead time model
  - Extract rate from GVA1
    - Fit to binomial distribution?
  - Extract time distribution in each spill from fit to TOF0 t
    - Fit to some exponential distribution? Saw tooth?
  - Means we need to do reconstruction job and then use reconstructed GVA1 and TOF0 to do the Monte Carlo
    - Circular dependency is unpleasant
      - Use recon as input to MC which is used to understand recon... urg...
    - Is there a better way?

Geometry Responsibility

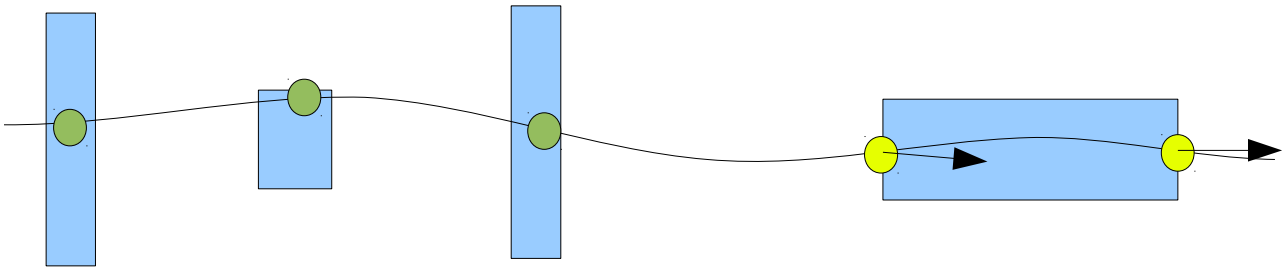
- We have a set of routines for pulling geometry from a reduced CAD model of MICE
- It needs someone to check that the geometry is correct
  - Detectors are responsible for checking that their geometry is correct
  - Beamline expert is responsible for checking geometry and fields in beamline is correct
  - Analysis group is responsible for checking cooling channel geometry and fields are correct
- Geometry release cycle goes like
  - CAD release from Jason Tarrant
  - Converted into Geant4 readable and uploaded to ConfigDB
  - Checked by experts
  - Tagged as a release of new geometry
- First attempt will follow survey being taken right now

Longer Term Items

- Global Recon
- Optics tool

Global Recon

- We have some set of measured space points (TOF), tracks (tracker), Light yields (EMR, KL, Ckov) with some set of errors
- How do we tie these things together?
- Two somewhat separate things:
  - Track fitting
  - PID



Example Uses

- Calculate change in 4D emittance, amplitude
- Calculate change in longitudinal (energy-time) emittance, amplitude
- Detector alignment in the presence of fields
- Physics process studies in the presence of fields (e.g. multiple scattering in the absorber)
- PID (esp tracker vs TOF)

Basic specification

- We seek to get the following variables
  - x, y, z, time
  - px, py, pz, energy
  - Preferred pid (gives charge, mass, etc)
  - On user-defined planes – typically spacial planes, probably not z-planes
    - Engineering geometry has ***x*** as the beam axis
- We seek errors
  - Covariance matrix of errors in (x, y, time, px, py, energy)
    - E.g. say we know x exactly but px we have some error
    - Propagate that measurement and we find we introduce uncertainty in x
    - In fact there is a correlation between the x-px uncertainty
    - Encode as a “covariance matrix”
  - p(electron), p(muon), p(pion)? sigma(mass)? Not sure how to write down error in pid

Aim of track fitting

- Basic aim is to minimise χ^2 of the measurement errors
  - So in 1D minimise sum$[(X_i - x_i)^2 / Var(dx_i)]$ where
    - x_i is a measurement made at detector i,
    - X_i is the globally reconstructed measurement at detector i
    - $Var(dx)_i$ is the error on x_i
  - In ND this becomes
    - sum$[(U_i - u_i) V^{-1} (U_i - u_i)^T]$
    - u_i is a vector of measurements made at detector i,
    - U_i is a vector of globally reconstructed measurements at detector i
    - V_i^{-1} is the error covariance matrix at detector i
- Might alternatively try to minimise determinant of the error covariance matrix

Tools

- Need to propagate tracks through our equipment
  - Runge Kutta
  - Accelerator transport matrix for online
- Need to propagate errors through our equipment
  - Accelerator transport matrices – this transports like a beam envelope
  - Required for some minimisation routines e.g. Kalman
- Need minimisation routines
  - Minuit is quick and dirty
  - Kalman is more elegant but needs some work
  - TOF recon algorithm is also nice
    - Need to generalise
- Some seed finding routines
  - Normally we just use the tracker
  - Might want something for if tracker is not there/cross checks

Track/Error propagation

- We can already do Runge Kutta through arbitrary field maps, either using G4 or custom tracking routines
- We can already calculate transfer matrices through arbitrary field maps
  - Numerical differentiation of the tracking
    - Generate a few different tracks
    - Do $u_{out} = M\, u_{in}$
    - We can use G4 to calculate u_{out} from u_{in}
    - We can solve as a simultaneous equation for **M**
  - Second order correction
    - Instead of solving as a simultaneous equation, can do linear least squares (it's all nice linear sums of terms)
    - Gets a more correct answer
    - Costs more processing - tracking more particles
  - Direct integration (not implemented)
- All implemented in Optics routines
  - **Needs significant clean up and testing**

Other things

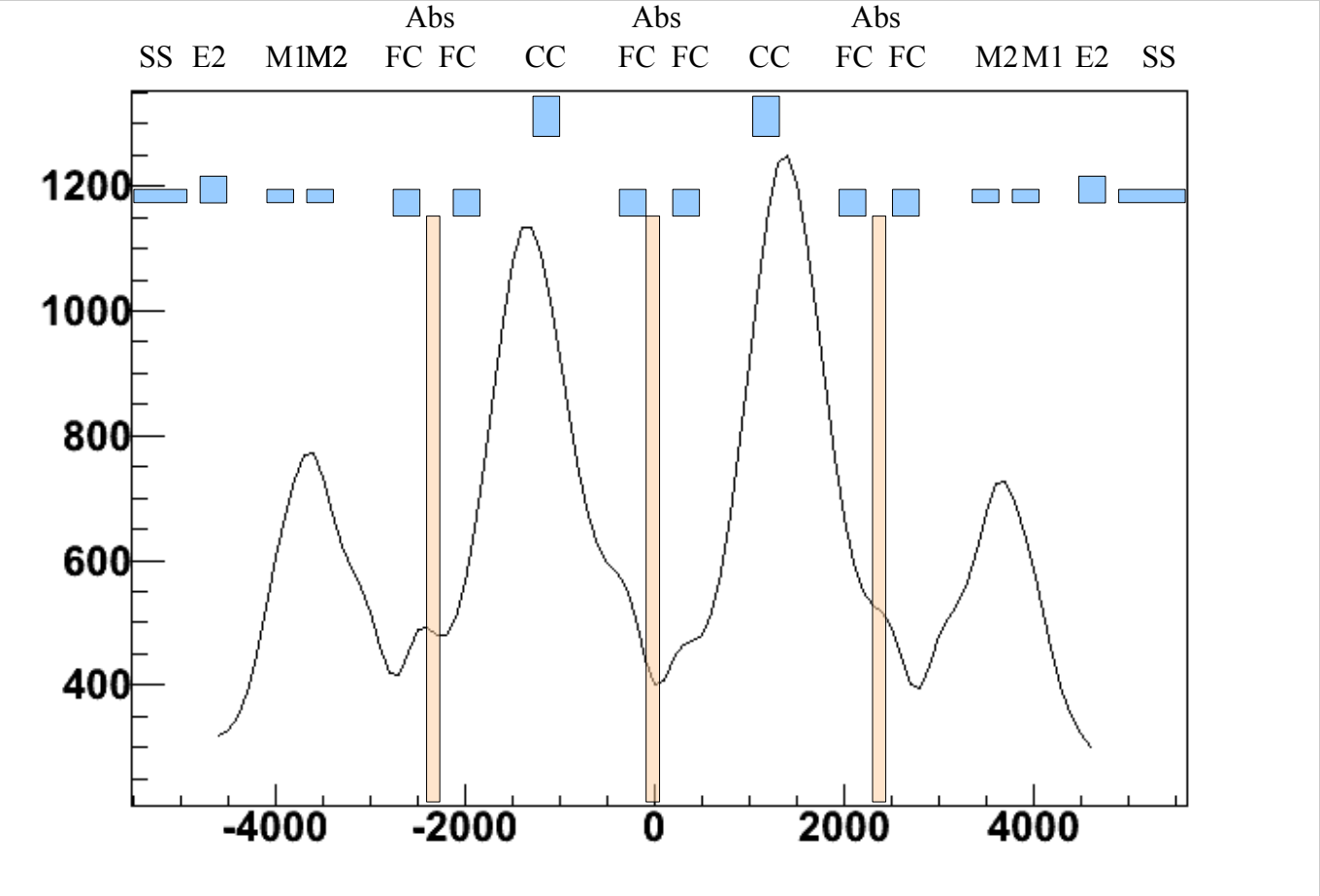
- Transport through materials
  - Tracks should lose energy
  - Error matrices should get a scattering/straggling kick
- PID
  - Basic routine I think we try candidate particles and look for well-fitted tracks
    - E.g. try to reconstruct assuming muon, electron, pion
    - Look at errors and take the best one
  - Not sure how to do something more sophisticated
    - Include mass as a tracking parameter?
    - How to include Ckov and KL/EMR?

Next Steps

- Specification document is in progress
- Definition of data structure
  - PID output might have to be vague until I understand the right way to do it
- Definition of class structure
  - We already have some optics infrastructure in place, currently in a tidy-up phase
- Seek comments early and often
  - I am a novice – detector experts in MICE have done it all before

Optics Tool

- Request was made for a light weight tool to evolve beam envelopes for use in control room
- Propose following tool
  - (powerpoint prototype of a GUI)
  - Allows to define a set of magnet currents and input beam
  - Then plot resultant beam envelope, momenta, etc down the accelerator
  - Geometry shown is Stage 6 geometry
  - In principle we should be able to handle any geometry e.g. would hope to include Q4-9, etc
- Seek comments



Beam

Z (mm) -2750

definition penn

beta (mm) 420

alpha 0

em. (mm) 6

Beamline

E1 (A) 149.05

M1 (A) 149.05

SS (A) 222.01

M2 (A) 222.01

E2 (A) 109.12

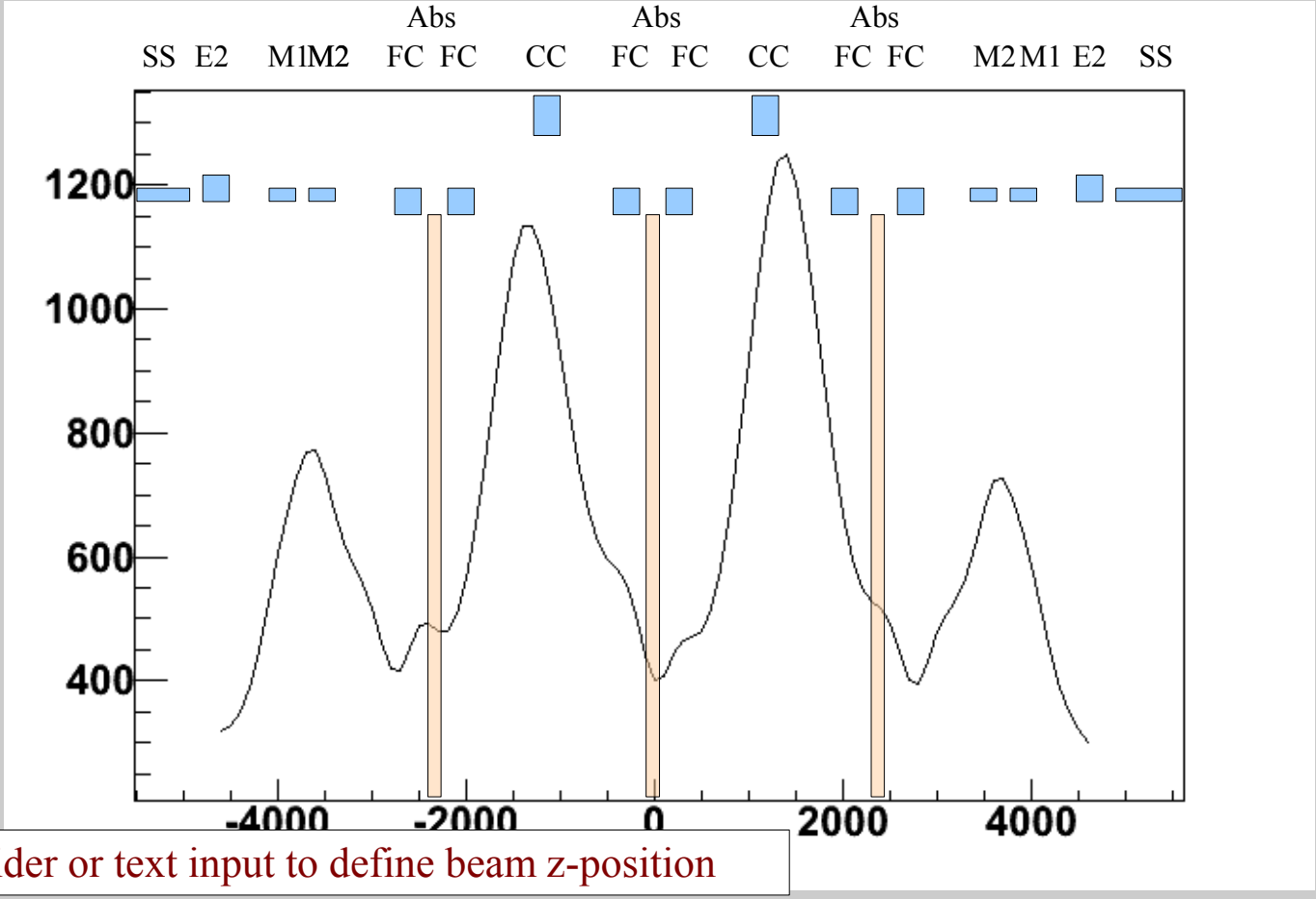
FC (A) 109.12

CC (A) 109.12

Plot

ordinate beta_perp

Show optical elements



Slider or text input to define beam z-position

Beam

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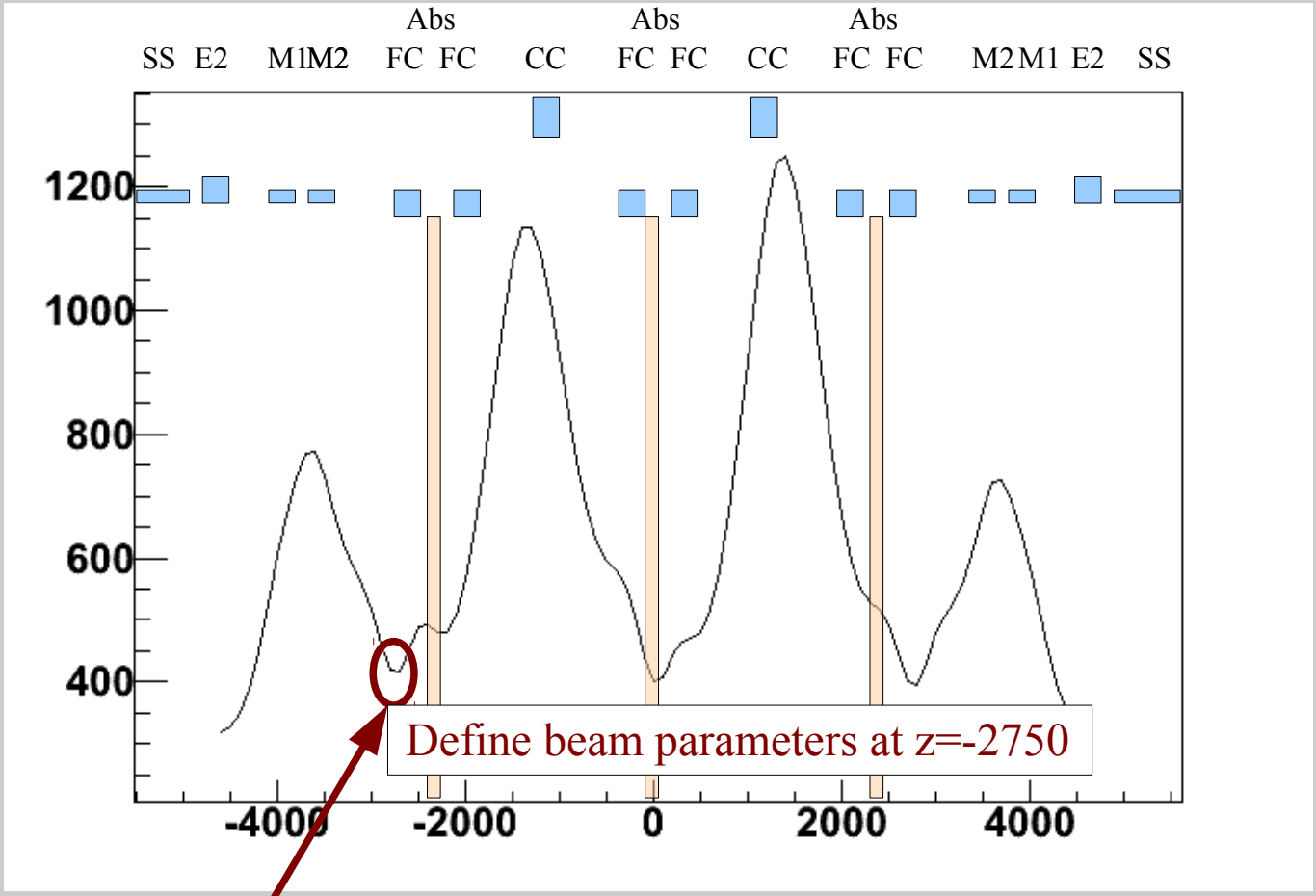

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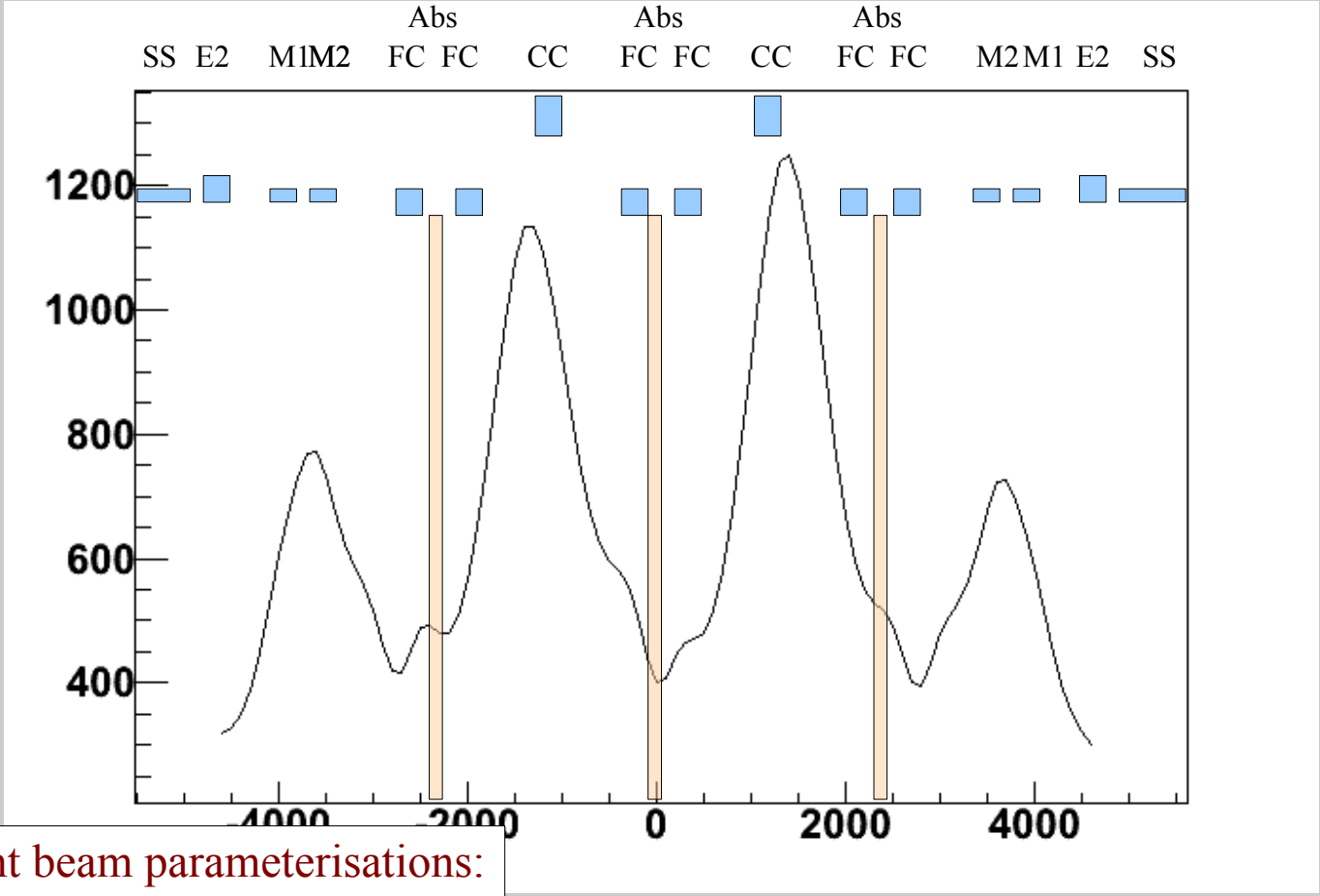

Different beam parameterisations:
penn
twiss

Z (mm) -7000 definitio twiss

beta_x (mm) 2700 beta_y (mm) 350

alpha_x 0 alpha_y 0

em_x (mm) 2 em_y (mm) 4

Beamline

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E2 (A) 109.12 FC (A) 109.12

CC (A) 109.12

Plot

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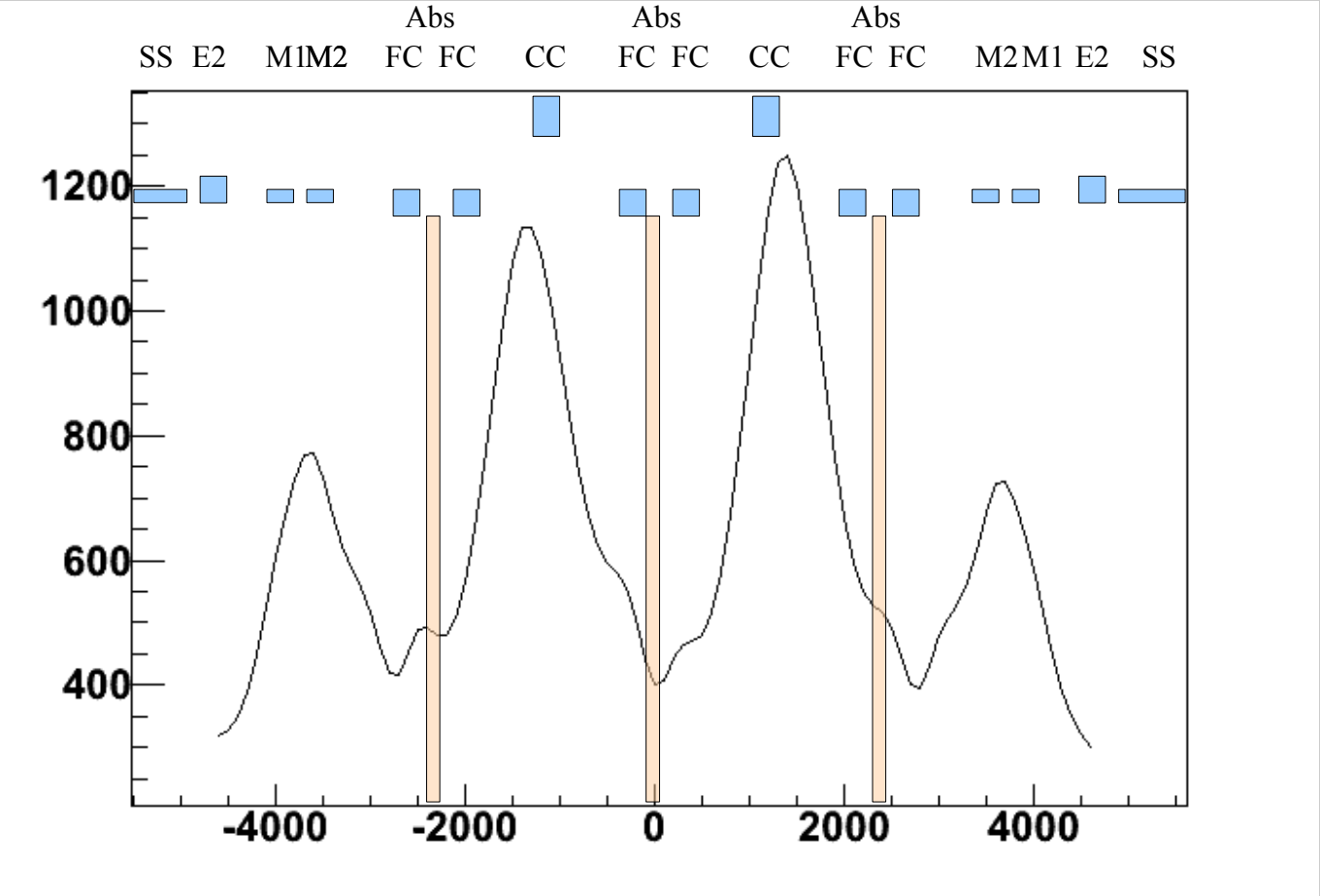
Show optical elements



Beam

Z (mm)

beta (mm)

alpha

em. (mm) 6

Control magnet currents
•Should use currents like the ones typed into controls PC

Beamline

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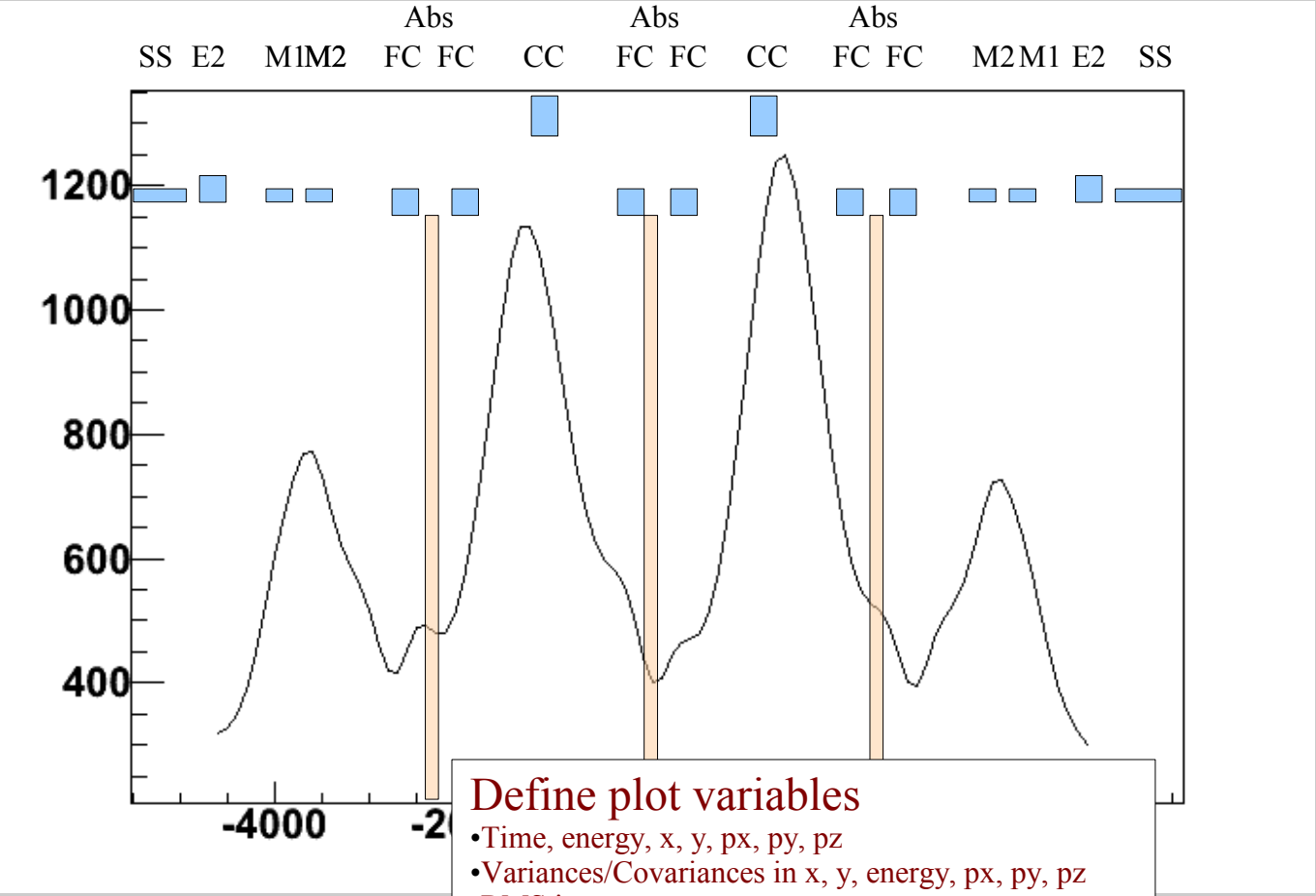

Define plot variables

- Time, energy, x, y, px, py, pz
- Variances/Covariances in x, y, energy, px, py, pz
- RMS in x, y, energy, px, py, pz
- Beta function in x, y, transverse 4D
- Alpha function in x, y, transverse 4D
- Gamma function in x, y, transverse 4D
- Emittance in x, y, transverse 4D
- Kinetic angular momentum
- Amplitude momentum correlation
- Dispersion in x, y
- Dispersion prime in x, y

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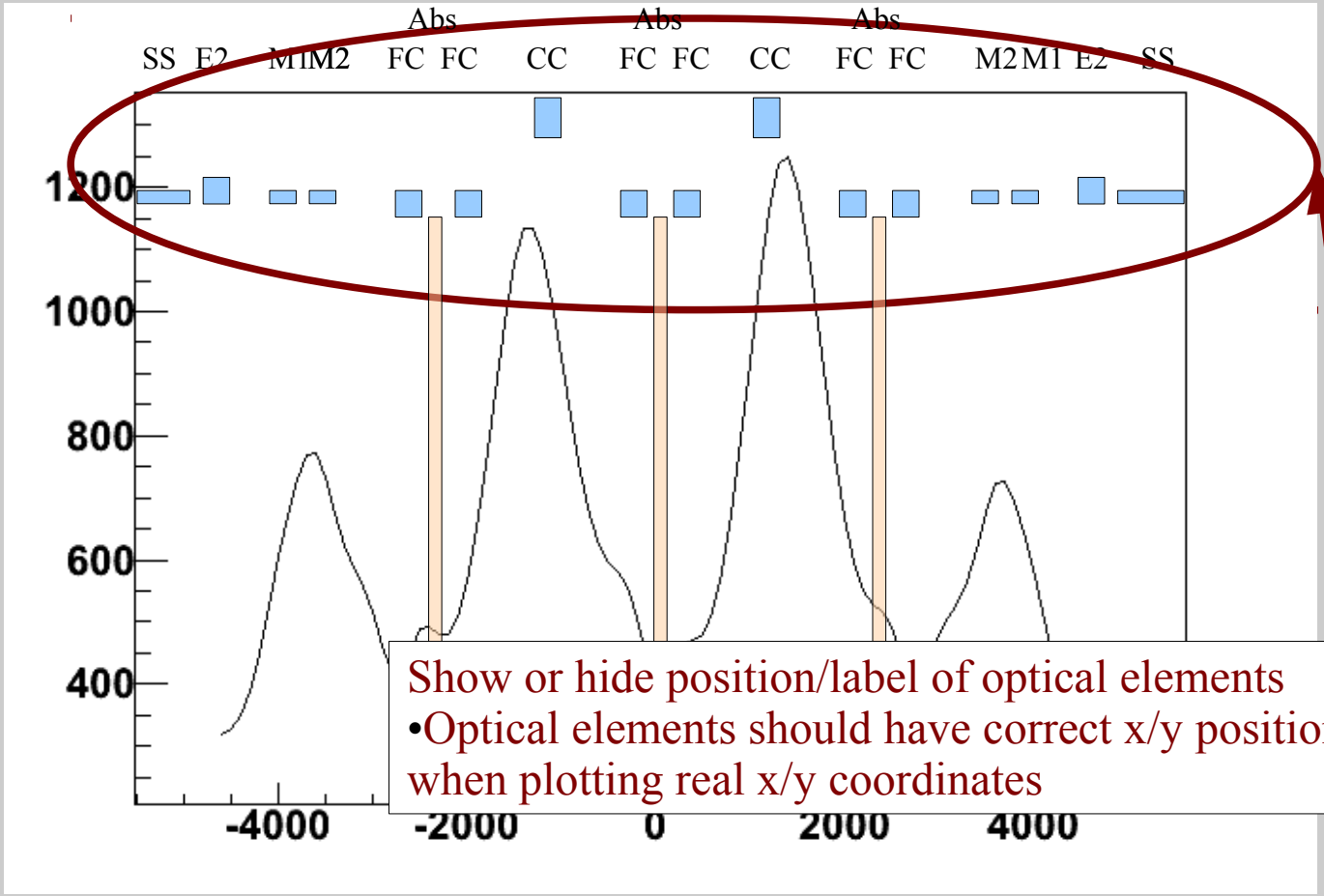

Show or hide position/label of optical elements
•Optical elements should have correct x/y position when plotting real x/y coordinates

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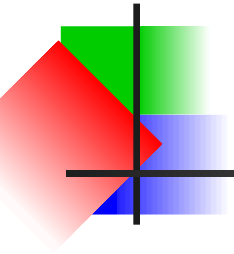

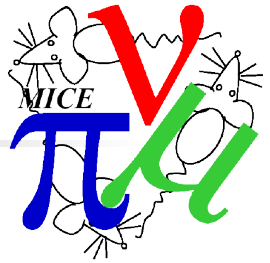

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