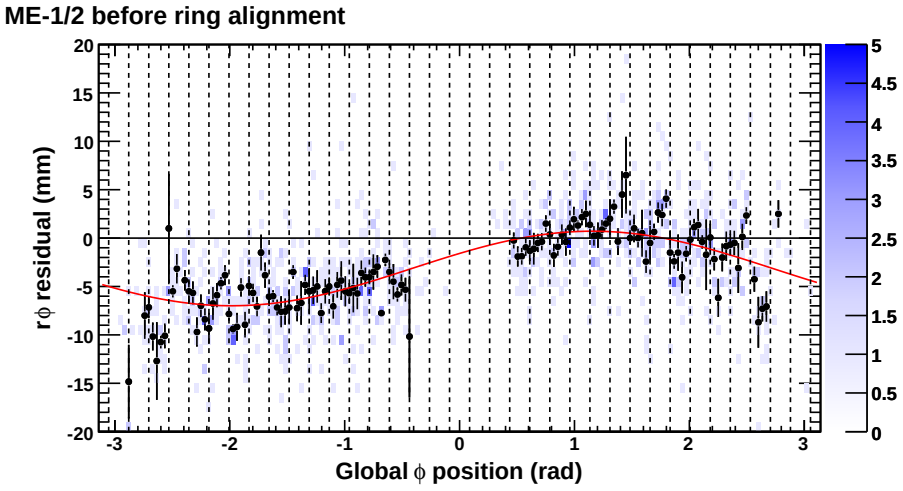
Muon alignment planning

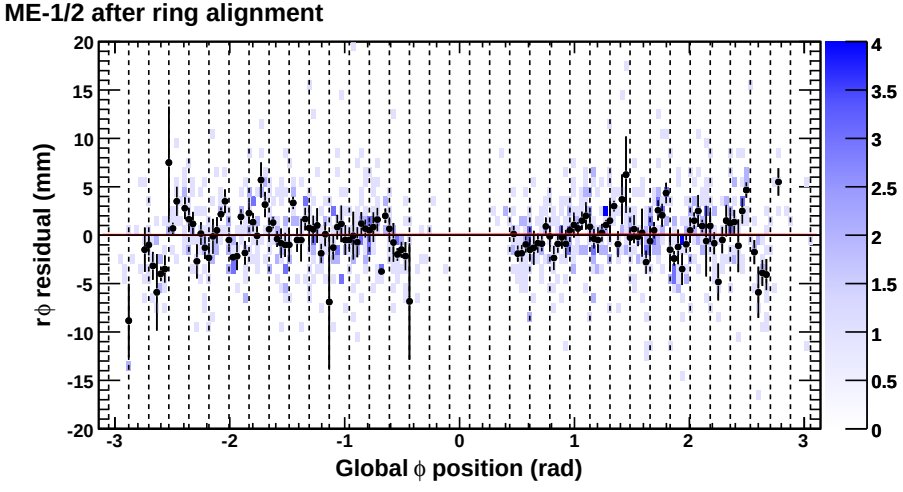
Jim	done	▶ produced algorithm and software for R-T alignment
		▶ demonstrated ring-alignment (using monitoring plots only)
		▶ demonstrated beam-halo alignment (unmaintainable code)
		▶ documented almost everything in twiki format
		▶ got people interested in tracker global distortion issue
	to-do	▶ generalize and re-write beam-halo alignment procedure
		▶ document everything in the form of permanant notes
Aysen	done	▶ learned and improved R-T code
	to-do	▶ optimize R-T procedure for few pb^{-1}
		▶ start delivering constants: 2010 cosmic rays $\longrightarrow$ aligned barrel chambers and endcap ring-positions
Vadim	done	▶ findQualityFiles, Alignment Quality Monitor
	to-do	▶ hardware alignment case (?), more quality tests
		▶ formalize CSC ring-position procedure

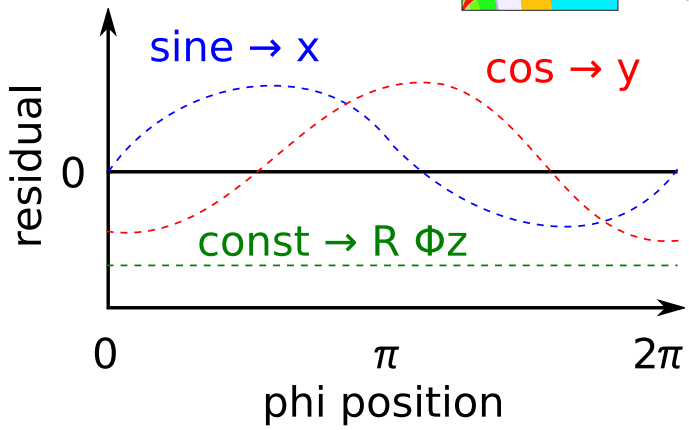
2010 cosmic rays

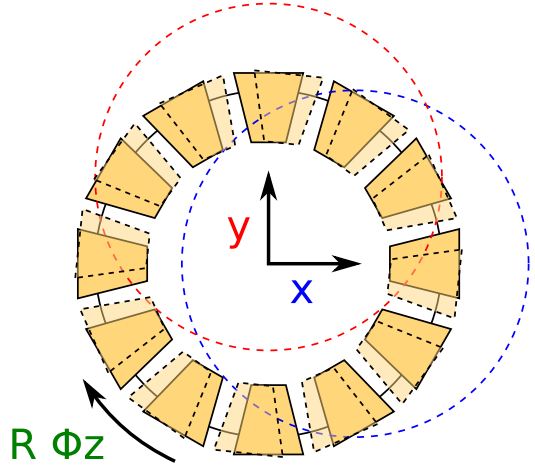
- Already collected: "1 million cosmics" (what that means depends on p_T cut) "with all subsystems participating" (essential). Sometimes called "CRAFT-10" because it is similar in scope to CRAFT-09 and CRAFT-08.
  - tracker alignment (prerequisite) already performed
- First real alignment problem for Aysen: people need this for reconstruction of first TeV collisions data
- Exact repeat of CRAFT-09 procedures: we've done it before, we can do it again, depending on statistics
- Timescale: a few weeks
- I'm planning a visit to A&M next week, so that we can get started on this (should discuss optimal dates)

Ring-position alignment



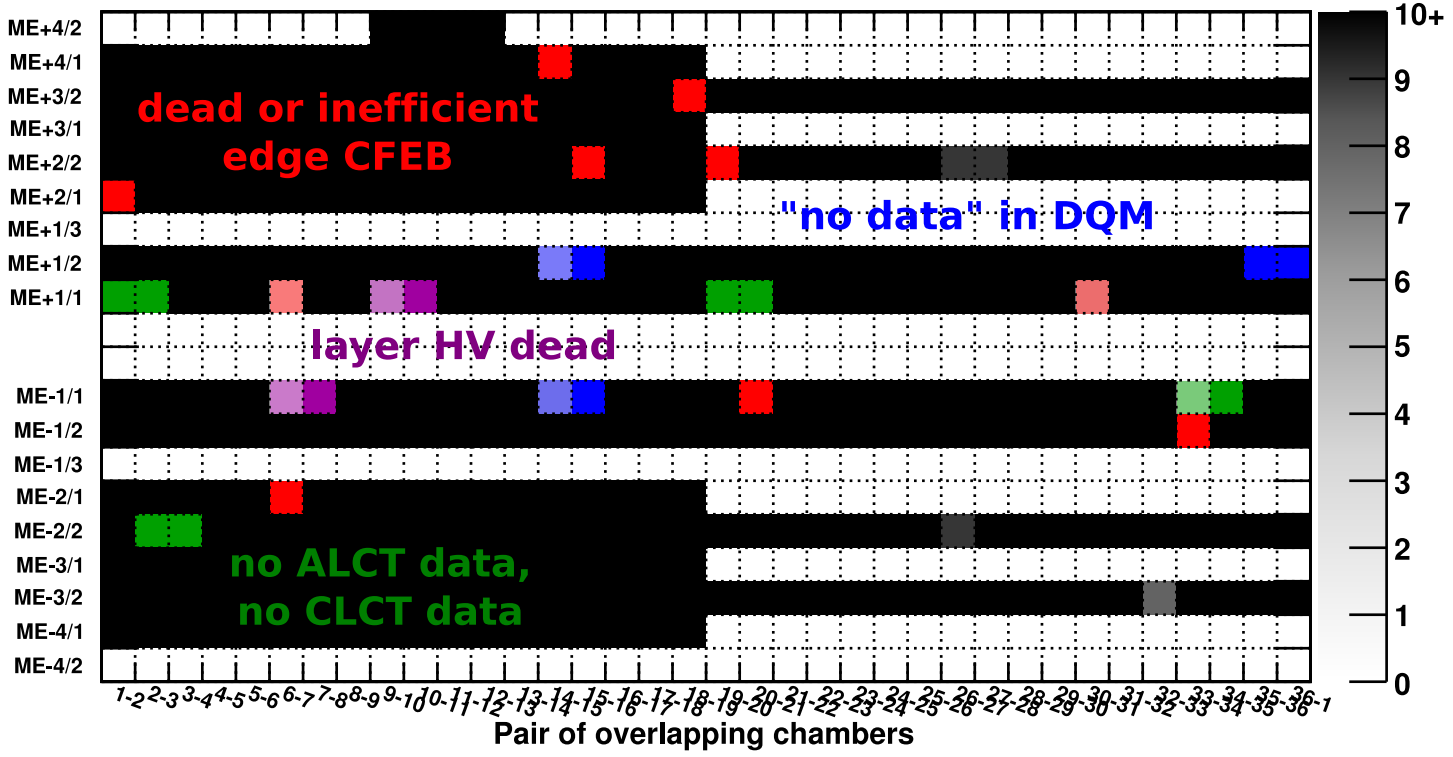






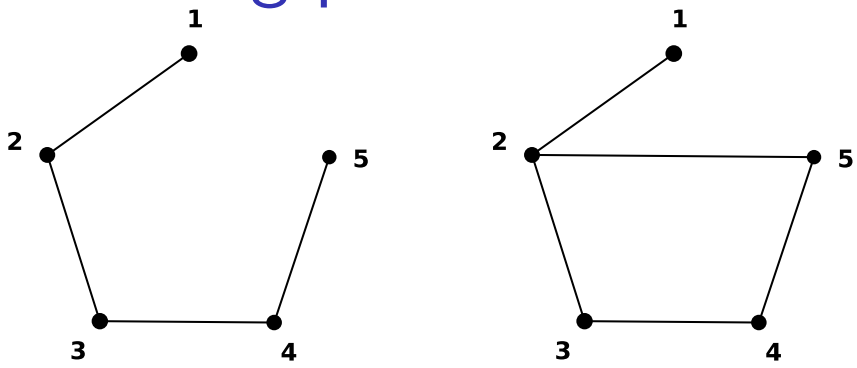
- Performed on monitoring plots (not in R-T framework), put positions in XML, produce SQLite file, and that becomes the alignment
- Previously done by hand, but it can be naturally added to Vadim's diagnostics (easy to automate)

What to do about CSC-Overlaps



- CSC-Overlaps procedure depends on complete rings
- Missing chamber/CFEB problems are not going to be resolved soon
- Applying closure as a constraint only helps rings with one gap and is very sensitive to small problems (e.g. 8 mm error accumulated from 18×500 μm effect)

Generalizing procedure



- Old procedure (left): nearest-neighbor constraints $m_{i,i+1}$ defines a static matrix whose inverse solves the alignment problem for all chambers simultaneously
  - if not all connections are present, matrix would be non-invertable
  - filling in gaps by "faking" the missing residuals such that closure $= 0$
- New procedure (right): constraints from any pair of chambers m_{ij}, matrix is built up dynamically from the constraints
  - can treat constraints from residuals, photogrammetry, and maybe hardware alignment on an equal footing
  - requires a re-write of the module, which was needed anyway

Testing with 5-chamber example

$$\chi^2 = \sum_{\text{constraints}} \frac{(m_{ij} - A_i + A_j)^2}{{\sigma_{ij}}^2} + \lambda \left(\sum_i A_i \right)^2$$

# format: $(i, j, m_{ij}, \sigma_{ij})$
constraints = [(0, 1, 0.3, 1.), (1, 2, 0.1, 1.), (2, 3, -0.3, 1.), (3, 4, 0., 1.), (4, 0, -0.1, 1.),]

result: $A_0 = 0.18$, $A_1 = -0.12$, $A_2 = -0.22$, $A_3 = 0.08$, $A_4 = 0.08$

covariance:
$$\begin{pmatrix} 0.44 & 0.04 & -0.16 & -0.16 & 0.04 \\ 0.04 & 0.44 & 0.04 & -0.16 & -0.16 \\ -0.16 & 0.04 & 0.44 & 0.04 & -0.16 \\ -0.16 & -0.16 & 0.04 & 0.44 & 0.04 \\ 0.04 & -0.16 & -0.16 & 0.04 & 0.44 \end{pmatrix}$$

modes with uncorrelated uncertainties:

$-0.45A_0 + -0.45A_1 + -0.45A_2 + -0.45A_3 + -0.45A_4$	$\propto \sqrt{1/\lambda}$ (meaningless)
$0.63A_0 + 0.25A_1 + -0.48A_2 + -0.54A_3 + 0.14A_4$	0.60 (weaker modes)
$0.6A_1 + 0.37A_2 + -0.37A_3 + -0.6A_4$	0.60
$0.63A_0 + -0.38A_1 + -0.01A_2 + 0.4A_3 + -0.64A_4$	0.37 (stronger modes)
$-0.39A_1 + 0.64A_2 + -0.64A_3 + 0.39A_4$	0.37

Minuit gives the same results as linear algebra under many different configurations (but sometimes only in the first 3–4 digits for complicated cases)

Planned documents

- CSC Overlaps alignment procedure
  - written at the same time as the new code
  - touches on every aspect of alignment theory in a simple example; will be a great introduction...
- Reference-Target alignment procedure and infrastructure
  - including the XML tools, ring-alignment procedure

Summary of procedures and software products

- Reference-Target algorithm: chamber-by-chamber alignment for DTs and CSCs (AlignmentProducer module)
- CSC-Overlaps algorithm: chambers-within-rings for CSCs (AlignmentProducer)
- Scripts for submitting and collecting data from both of the above
- CSC Ring alignment: ring positions relative to tracker (simple procedure performed on monitoring plots)
- Monitoring plots in CommonAlignmentMonitor
- XML tools for creating and analyzing muon system geometries
- Alignment Quality Monitor browser for organizing study of monitoring plots (and eventually) differences between muon system geometries