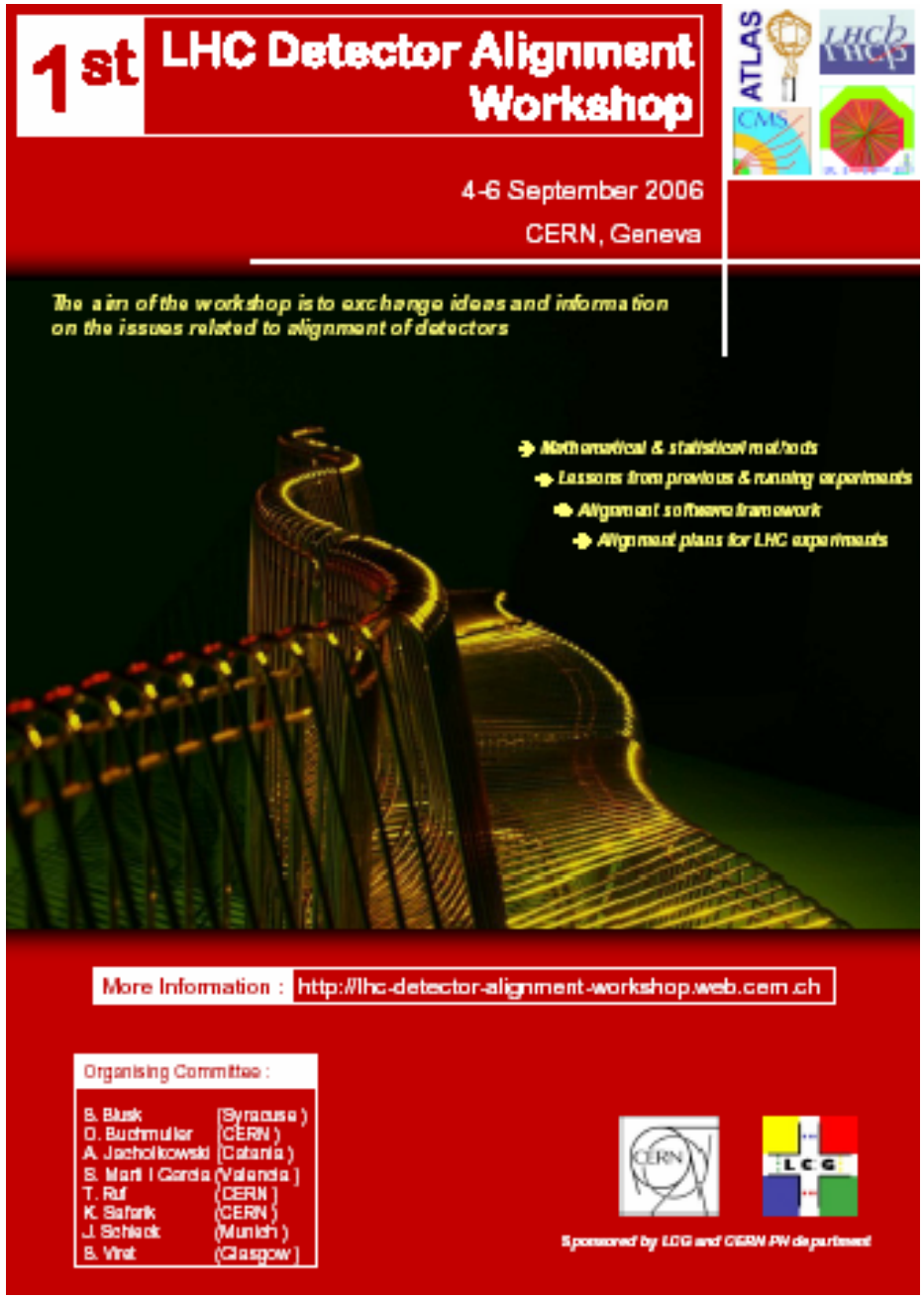


LHC Detector Alignment Workshop Summary

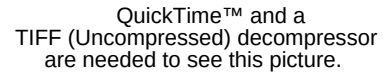
David Brown, LBNL

Generalities

- **Thanks to the organizers for inviting me**
- **I have learned at lot in 2 days, but**
  - **You are the experts in LHC detector alignment**
  - **I cannot do justice to everything I've heard**
  - **I will not waste your time by repeating back your own work**
- **I will provide a biased, eclectic outsiders view**
  - **I will not address 'settled' issues**
    - Use of track 'reduced' residuals, Kalman fit tracks
    - Importance of complementary data
    - Utility of a-priori metrology
  - **Intentionally provocative**
  - **No disrespect is intended!**
  - **Feel free to challenge me!**

Summary Theme: Finding Balance

Division



Integration

‘Iterative’ vs ‘closed form’ optimization

- **Also known as**
  - ☞ **U ncorrelated vs correlated**
  - ☞ **Global chisq vs local chisq**
  - ☞ **Biased vs unbiased**
- **Both algorithms are really iterative**
  - ☞ **Nonlinearities, outlier rejection, …**
- **Both algorithms can treat correlations**
  - ☞ **One explicitly, one implicitly**
- **Both algorithms are complex, elegant**
- **Both algorithms are only as accurate as the information that you feed them**
  - ☞ **There is no substitute for careful data preparation!**

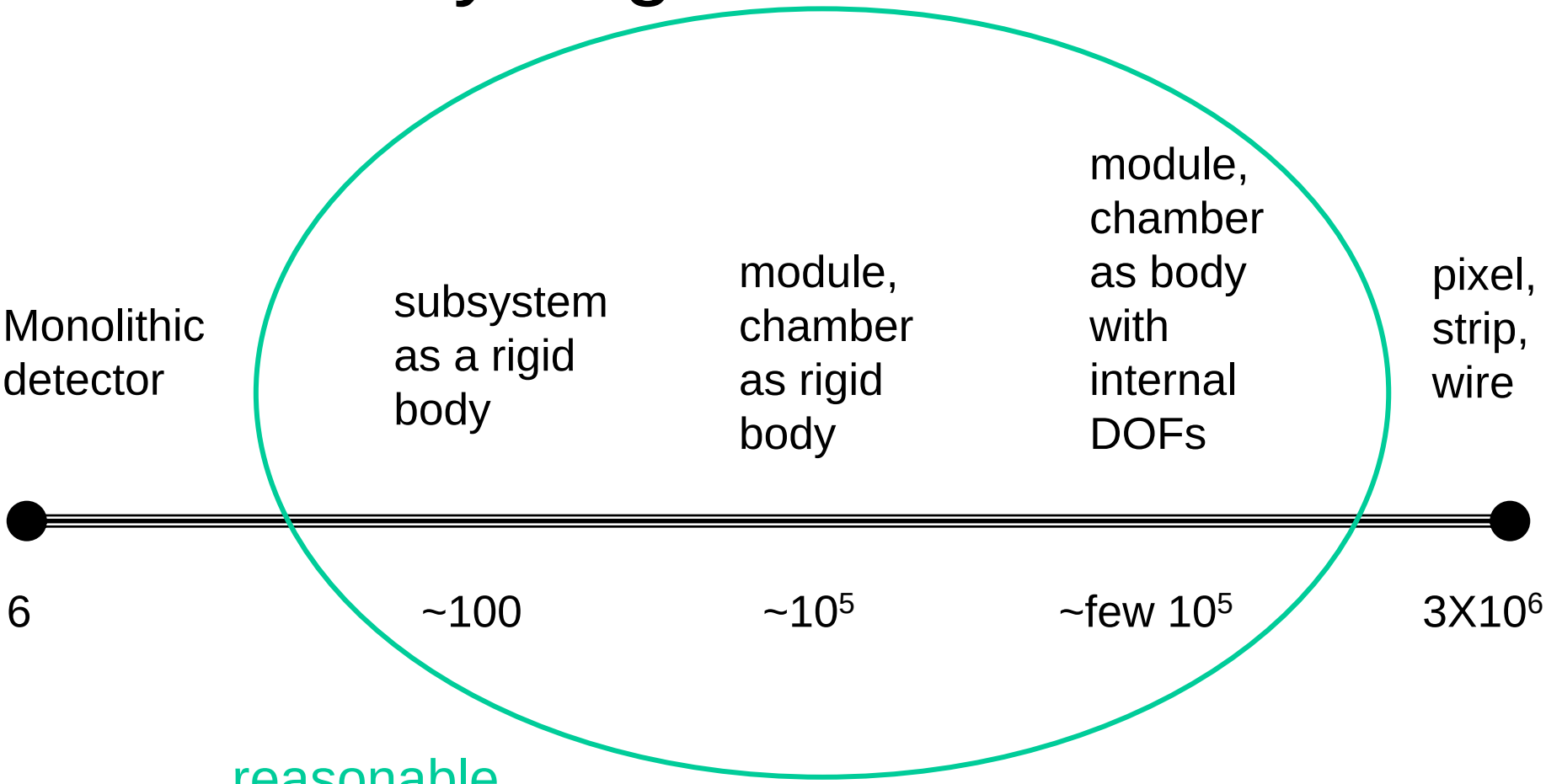
Optimization Algorithm Usage

- **Iterative (residual chisq)**
  - ☞ **BaBar, CDF, STAR, Atlas, CMS, ALICE(?)**
- **Closed-form**
  - ☞ **SLD (SVD)**
  - ☞ **Zeus, H1, Atlas, CMS, LHCB, ALICE (Millepede)**
  - ☞ **CMS (Kalman)**

Optimization Algorithm Comparison

	Iterative	Closed-form
# iterations to convergence	10→100	3→10
CPU cost/iteration	Refit tracks + N wafers 6X6 matrix inversions	Refit tracks + derivatives + matrix eqtn. soln.
Resolves global distortions?	Yes, by iteration (unknown scaling with NDOF)	untested
Monitoring access?	Simple	?
# processors that can be used	N wafers	1
Memory	α NDOF	α NDOF^X (~2)
Statistical precision	Biased (all residuals) or reduced (prescaling)	Optimal

How Many Alignment Parameters?



‘How I Would Align an LHC Detector’

- **Assemble a complementary set of event**
  - **Muons, pairs, cosmics, survey, …**
- **Align the innermost (most sensitive) detector first**
  - **Align internal DOFs with complimentary data**
    - Rigid body parameters plus non-planar distortions
    - Use sanitized outer-tracking constraint (on curvature, …)
- **Align the next detector outwards next**
  - **Include (aligned) innermost detector in track fit**
  - **Align using standard techniques**
    - Track self-consistency, survey, …
- **Continue outwards**
  - **Include calorimeter, muon chambers**
- **Repeat (if necessary)**

Software Redundancy

- **Overlapping software development is good**
  - ☞ **Allows development of novel, risky solutions**
  - ☞ **Provides a more complete exploration of problem space**
  - ☞ **Competition encourages development and improvement**
- **Too much software overlap is bad**
  - ☞ **Manpower is wasted**
  - ☞ **Fragments groups by preventing standardization**
- **4 different geometry packages for 4 experiments**
  - ☞ **Common functionality, common names**
- **4(?) different conditions databases, descriptions of alignment parameters**
- **2 different C++ implementations of Millepede**
- **3 track-based alignment procedures in CMS**

I would have liked to hear more about..

- **Integrating hardware and track-based alignments**
- **Preparing a reasonable alignment for first physics**
  - ☞ **Technique, resources needed, timescale**
- **Untangling overlapping effects (Tobias)**
  - ☞ **Material,B field,Alignment,Detector malfunction**
- **Outlier rejection**
- **Alignment procedure instrumentation (self-monitoring)**
- **Use of vertices in alignment**
  - ☞ **Ks, gamma conversions (off-axis tracks) as constraints**
  - ☞ **Monitoring using vertex mass, consistency**
- **Event model, reco interaction with alignment**
  - ☞ **Are alignment needs satisfied?**

Final Questions

- **Are alignment parameter statistical errors (covariance) useful?**
  - ☞ **Procedure goal is to make them insignificant**
  - ☞ **They are not usable in tracking (correlated between tracks)**
- **Could 11cm beam spread in commissioning run be enough for to measure disk Z positions?**
- **Could albedo particles be used as a source of off-axis tracks for alignment?**
- **Are low-Pt (curling) tracks useful in alignment?**
  - ☞ **Complementary constraint compared to straight tracks**
  - ☞ **Large scattering**

Conclusions

- **This workshop was a success**
  - ☞ **Lots of participation**
  - ☞ **Communication of new ideas**
  - ☞ **Sharing of techniques between LHC experiments**
  - ☞ **Comparison of existing (and former) experiments' methods against LHC experiments' plans**
- **With 1st data ~1 year away, LHC detector alignment preparation is in good shape**
  - ☞ **Alignment infrastructure incorporated into all experiments**
  - ☞ **(multiple) alignment techniques in place at all experiments**
  - ☞ **Realistic scenarios starting to be considered**
  - ☞ **Test beam and cosmic data being examined**
- **The scale of the problem is daunting**
  - ☞ **Time remaining must be spent wisely to insure success**

QuickTime™ and a (Uncompressed) decompressor are needed to see this picture.