Survey and Alignment of the ILC

Status of the LiCAS RTRS Project

Warsaw University

LiCAS

Linear Collider Alignment & Survey

LC Survey Challenge

PROBLEMS

- Complex & irregular layout of machine:
  - Horizontally and vertically curved sections, (R_{min}>500m)
  - Some sections geometrically straight, others following geoid
  - Sections with significant slopes

- Many different sections (Linac, DR, BDS, FF, MDI)
- Possibly various beamlines in one tunnel
- Temp. & pressure gradients in tunnel
- Very tight working space (1m wide)
- Space serves as emergency escape route

Best solution is to split up the survey procedure into
- a reference survey (along the tunnel)
- and a stake out

  ➔transfers coordinates to the machine over short distances across the tunnel

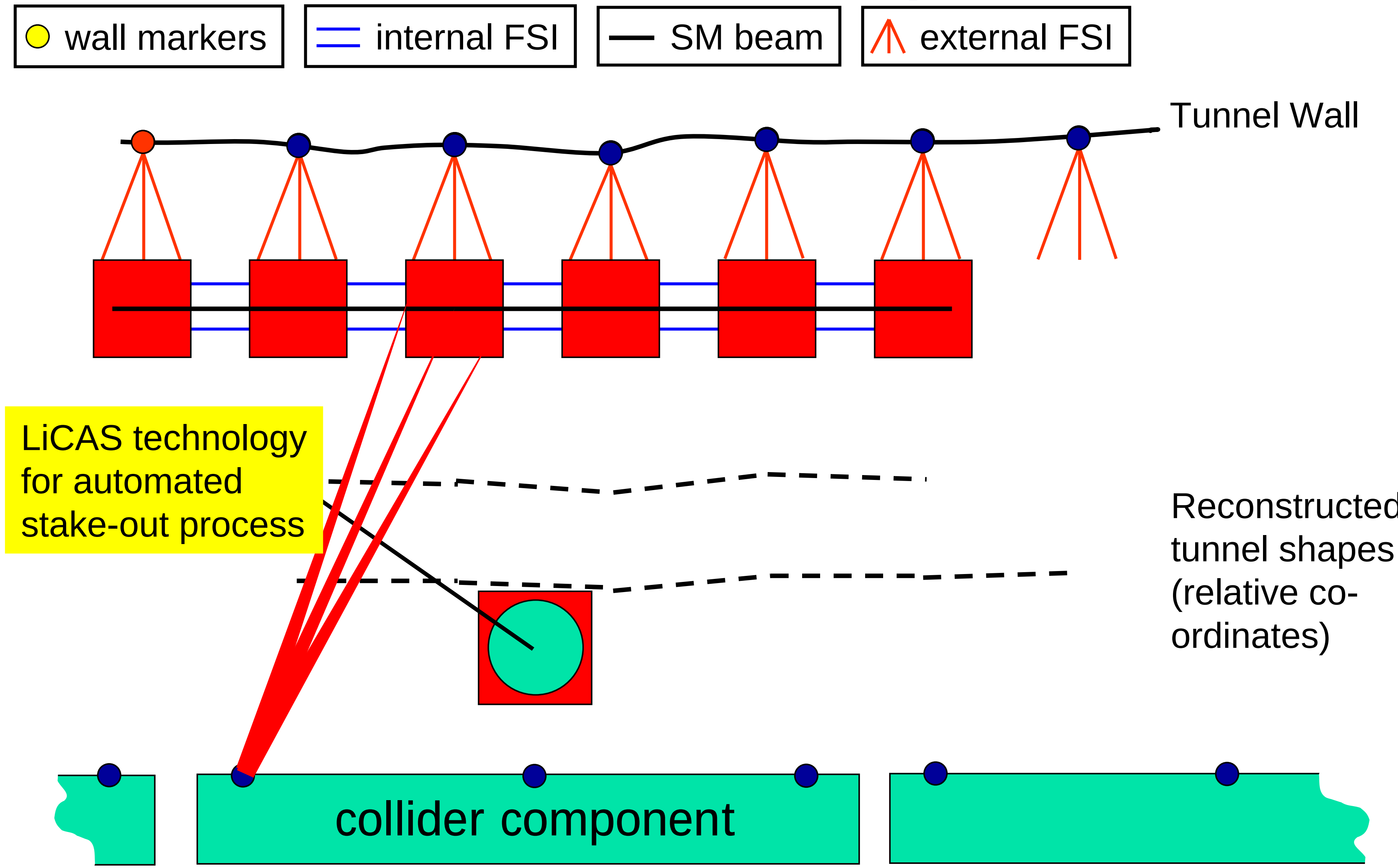
➔Optical Survey methods are not precise enough for reference structure

➔**Need new instrument ➔ RTRS (Rapid Tunnel Reference Surveyor)**

- Provides regular reference structure
- Uses regular markers at tunnel wall

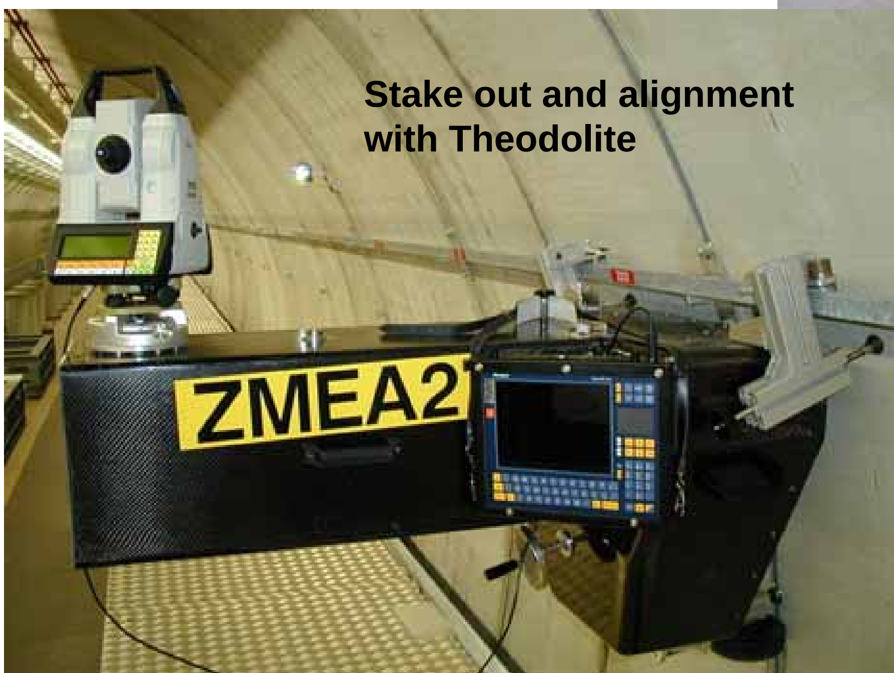
No long-term stable (>months) reference monuments at O(10

RTRS concept

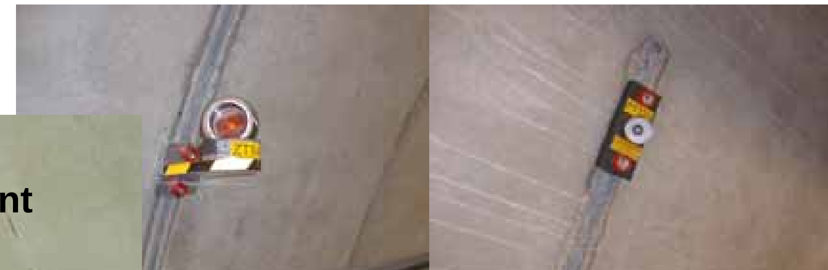


Stake out and alignment in the VUV-FEL Tunnel @ DESY

PROTOTYPES



Stake out and alignment with Theodolite



Stake out and alignment with Laser Tracker

Cost calculation (of reference system)

$$TCO_{Ref} = R_{acc}\, n_{surv}\, L_{acc}\, T_{sd}\, (k_{sd} + C_{surv}) + I_{surv} + M_{surv}$$

- R_{acc} : Lifetime of accelerator [years]
- n_{surv} : Number of surveys per year [1/year]
- L_{acc} : Length of accelerator [km]
- T_{sd} : SD-time required for 1 km survey [days/km]
- k_{sd} : cost per shutdowntime [€/day]
- C_{surv} : cost of survey team(s) [€/day]
- I_{surv} : Investment costs for survey system [€]
- M_{surv} : Maintenance costs for Survey instruments [€]

COST CALCULATION

Cost calculation

(conventional optical survey w. Lasertracker, 3 teams)

R_{acc}	:	20 years
n_{surv}	:	1.2 / year
L_{acc}	:	33 km
T_{sd}	:	5 days/km
k_{sd}	:	800.000 € / day
C_{surv}	:	1.120 € / day
I_{surv}	:	100.000 € / team
M_{surv}	:	2.500 € /instr./year

COST CALCULATION

$$TCO_{Ref} = 1.1 \text{ Bill. } € + 5.5 \text{ years downtime}$$

Cost calculation

(conventional optical survey w. Lasertracker, 10 teams)

TCO_{Ref} = 322 Mill. € + 1.7 years downtime

Cost calculation (RTRS, 1 train)

TCO_{Ref} = 0.8 Mill. € + 0.7 years shutdown

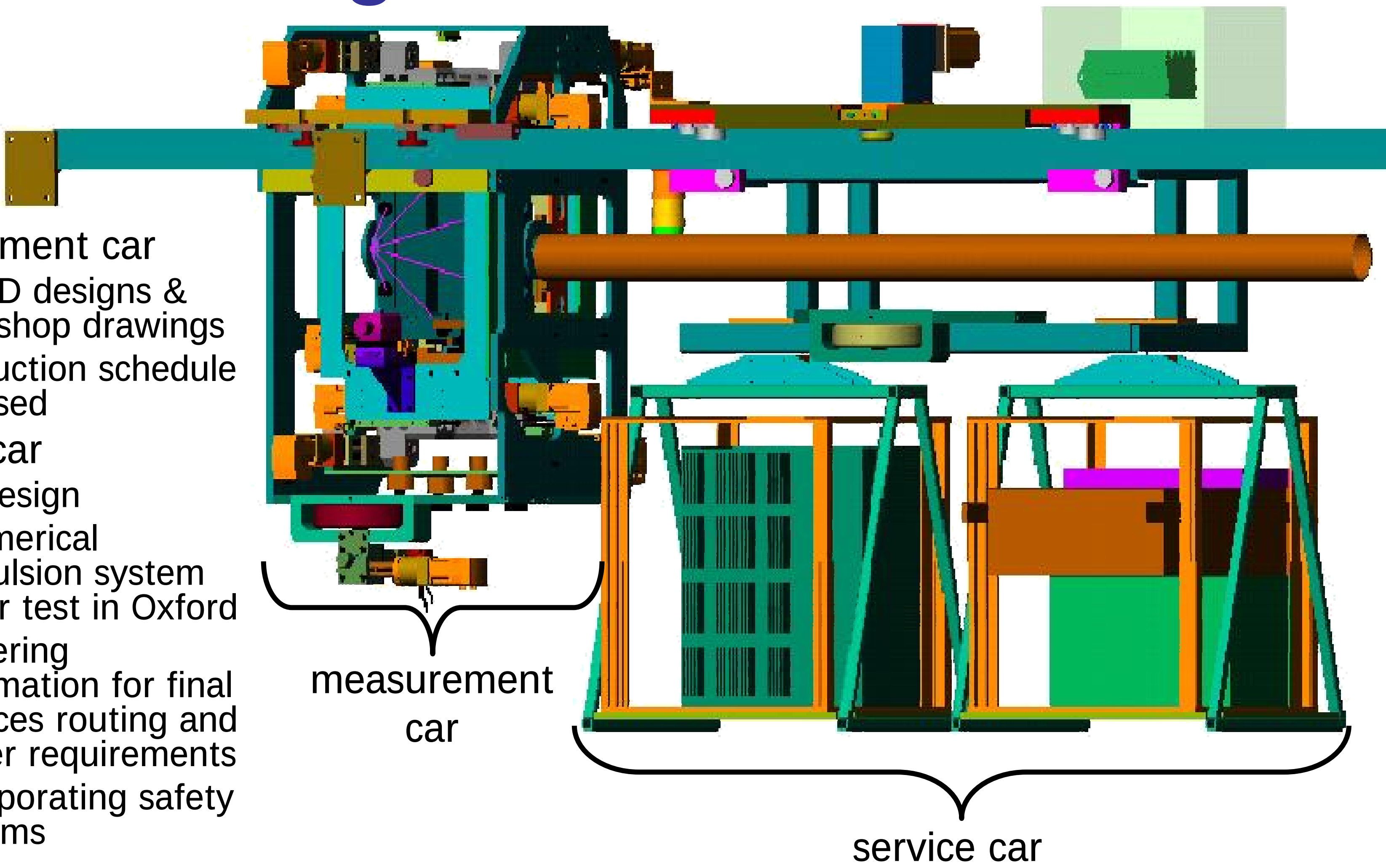
Costs include development!

COST CALCULATION

Previous Generation RTRS (Gelis, DESY)

RTRS global Mechanics

- Measurement car
  - full 3D designs & workshop drawings
  - production schedule finalised
- Service car
  - full design
  - commerical propulsion system under test in Oxford
  - gathering information for final services routing and power requirements
  - incorporating safety systems

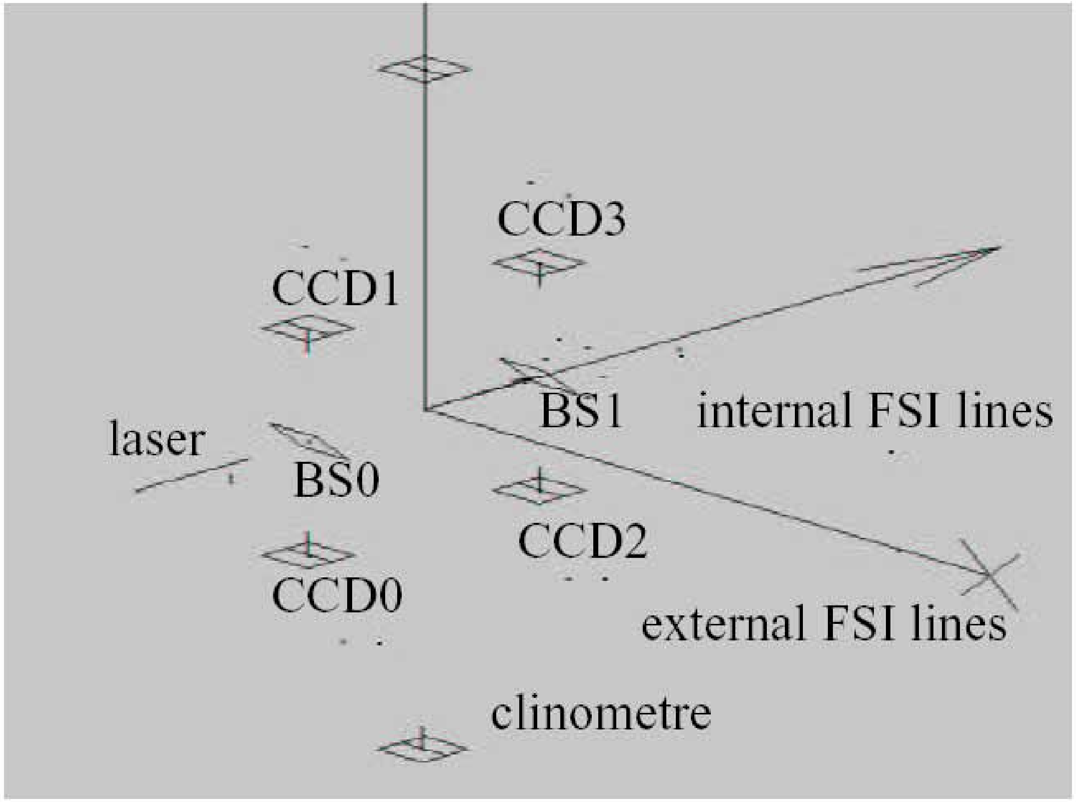


Tunnel preparation

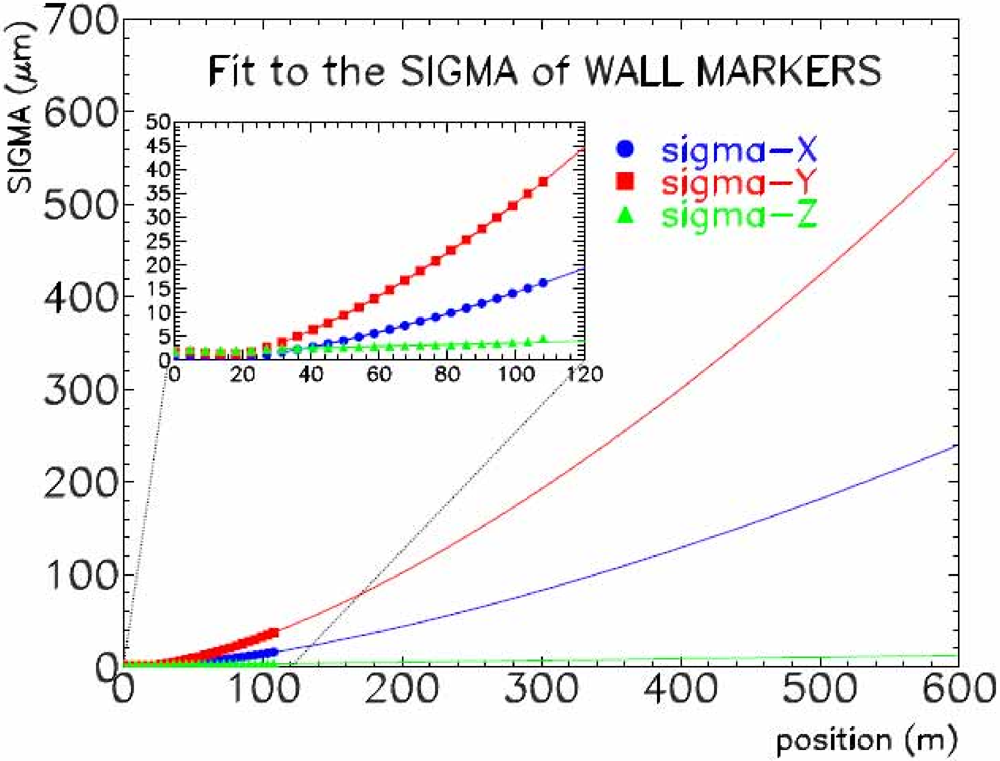
- 55m long (effective) service tunnel at DESY
- tunnel tests showed walls stable enough
- air conditioning
- installed high speed WLAN and LAN
- installing laser interlocks and safety systems
- ready for use well before RTRS prototype expected to arrive

SIMULGEO: Software used in the simulation

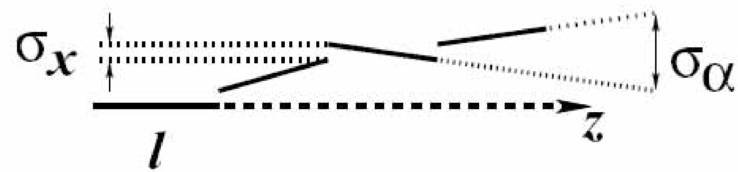
- Object oriented script language for description of opto-geometrical systems
- Mechanical correlations between objects grouped in local frames
- Performs full error propagation (N^2 matrix, very CPU consuming)



Extrapolation to $600\,m$ tunnel section



- extrapolation using random walk model:

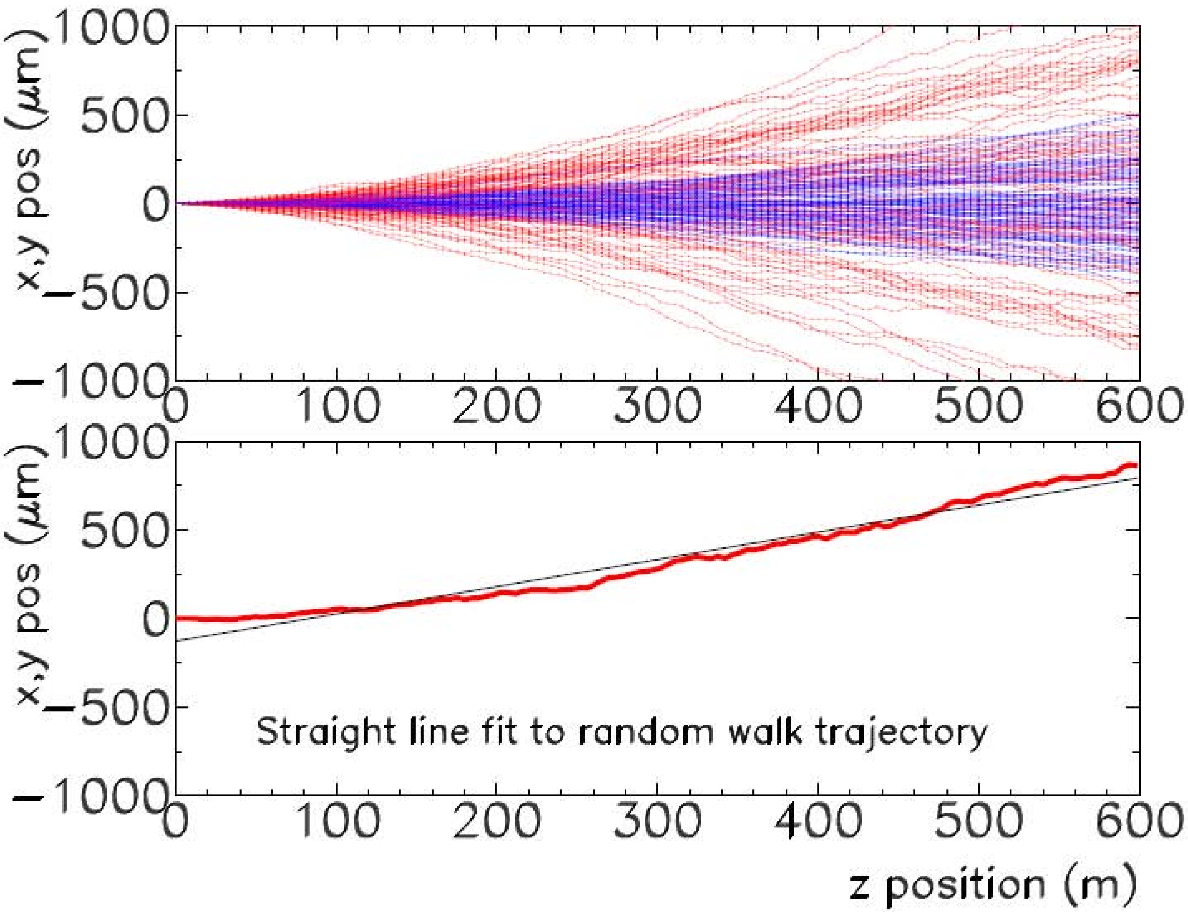


- off-sets and angles are <u>relative</u> to the previous "ruler"
- asymptotic behaviour:
  $\sigma_{xy,n} \sim n^{\frac{3}{2}}, \quad \sigma_{z,n} \sim n$

$$\sigma_{xy,n} = \sqrt{l^2 \sigma_\alpha^2 \frac{n(n+1)(2n+1)}{6} + \sigma_{xy}^2 \frac{n(n+1)}{2}}, \quad \sigma_{z,n} = \sqrt{\sigma_z^2 \frac{n(n+1)}{2}}$$

n – wall marker number, l – effective length of the ruler (here: distance between cars),
errors: σ_α – angular $(\sim 0.1\,\mu rad)$, σ_{xy} – transverse $(\sim 0.5\,\mu m)$, σ_z – longitudinal $(\sim 0.1\,\mu m)$

Random Walk Monte Carlo: trajectories, fits



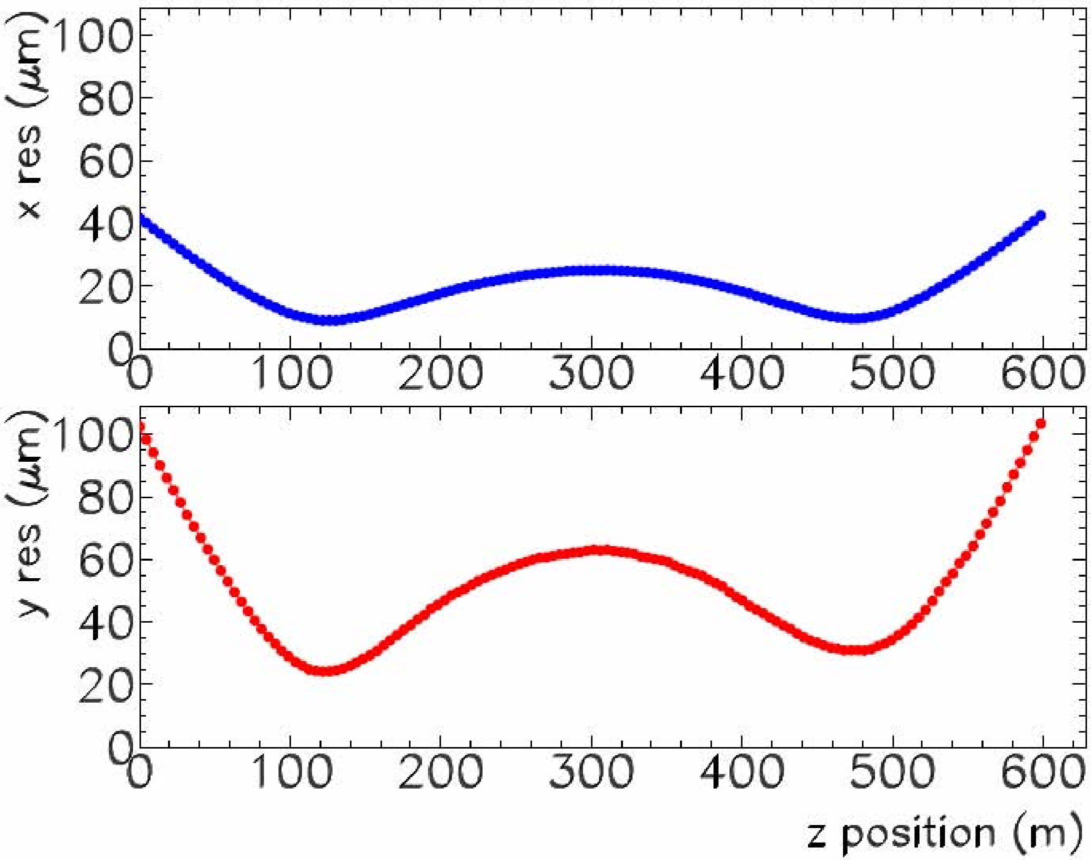
- trajectories generated from Random Walk Monte Carlo using parameters from the fit to SIMULGEO points (X, Y) direction

- good news: points along trajectories are strongly correlated (ie.: small 'oscillations' observed)

- straight line fits to the Random Walk paths for $600\,m$ tunnel section

- repeating this procedure for many "numerical experiments"...

Random Walk Monte Carlo: residua



- mean deviation from straight line fits (X, Y) direction
- realistic input to the simulations of beam dynamics

- well below specification: $\sigma_x = 500\mu m$, $\sigma_y = 200\mu m$
- however: only statistical errors included

What do we do next

Up to autumn 2005

- Completion of FSI and LSM and global analysis codes
- Production of Electronics
- Construction of 3-car prototype components
- Partial assembly of inner systems at Oxford
- Sub-system calibrations
- Installation in DESY test tunnel = 1. Nov. 05

What do we do next

Up to Spring 2006

- Operate prototype at DESY
  - commissioning
  - many calibration programs on full train
  - multiple test surveys of tunnel
  - tuning of operation and analysis algorithms
  - study of systematic errors

Up to Spring 2007

- In Oxford
  - Improvements of component calibration programs & hardware
  - Design of second generation instrument
    - much smaller ➔ could fits into i.e. X-FEL tunnel
    - much simpler ➔ reduce from R&D to production functionality
    - 6 cars
  - Design integrated stake out instrument

LiCAS pre CDR Working Document

- During this workshop we (LiCAS group) want to start writing a working document intended to be the precursor to a survey and alignment CDR section/chapter
- We think this document could be divided like this:
  - Definition of scope
  - one chapter for each collider section that needs survey and alignment (sources, DR, Linac, BDS, FF, MDI, detector, polarimeters, etc.)
  - Overall survey and alignment strategy
  - Overall cost estimates/summary
  - Overall list of open R&D issues and who could work on them
- For each such collider-section specific chapter we intend to provide
  - Requirements
    - tolerances
    - frequency/period
  - Assumptions
    - build tolerances
    - beam based method performance
  - Current “baseline” for
    - fiducialisation scheme
    - survey scheme
    - alignment (mover) scheme
  - Availability issues
  - Remaining R&D + who does it
  - Cost/Effort estimates

LiCAS pre CDR Working Document

- We need input from people who know:
  - how the collider will perform with different alignment tolerances (WG1)
  - what realistic component (module)
    - build tolerances are (WG 2)
    - fiducialisation tolerances are (WG2)
  - how we can intergrate the RTRS into the tunnel crossection (GG4&5)
  - how accurately the sources need to be aligned (WG 3a)
  - how accurately the damping ring needs to be aligned (WG 3b)
  - how accurately the BDS needs to be aligned (WG 4)
  - what special "gimics" need special alignment (polarimeter, special sextupoles, final focus, detector components, other diagnostics) (WG4 GG2)
  - What acceptable downtimes are (GG 3)