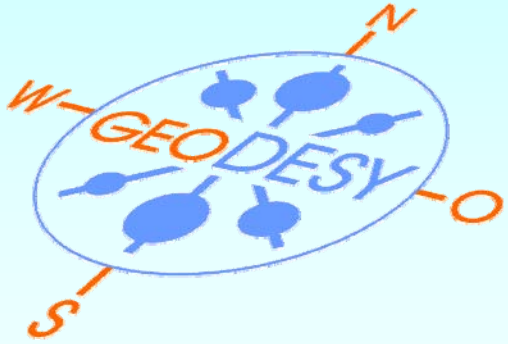
Survey and Alignment of the ILC

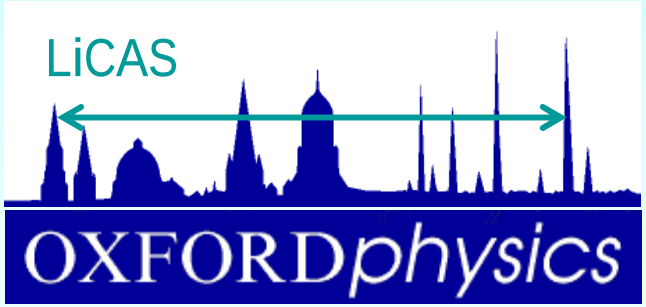
An introduction to the concept and open questions

Johannes Prenting, DESY, Survey & alignment,
for the LiCAS collaboration

Warsaw University

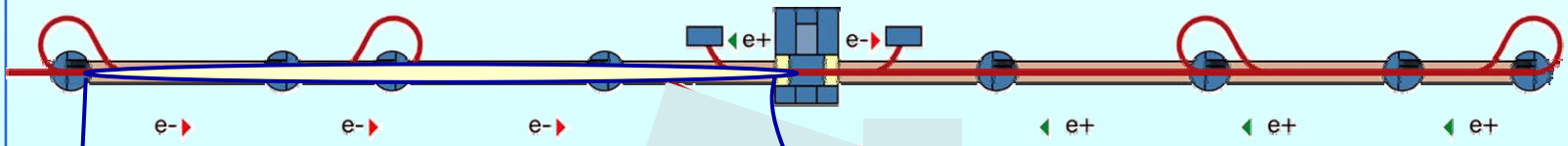


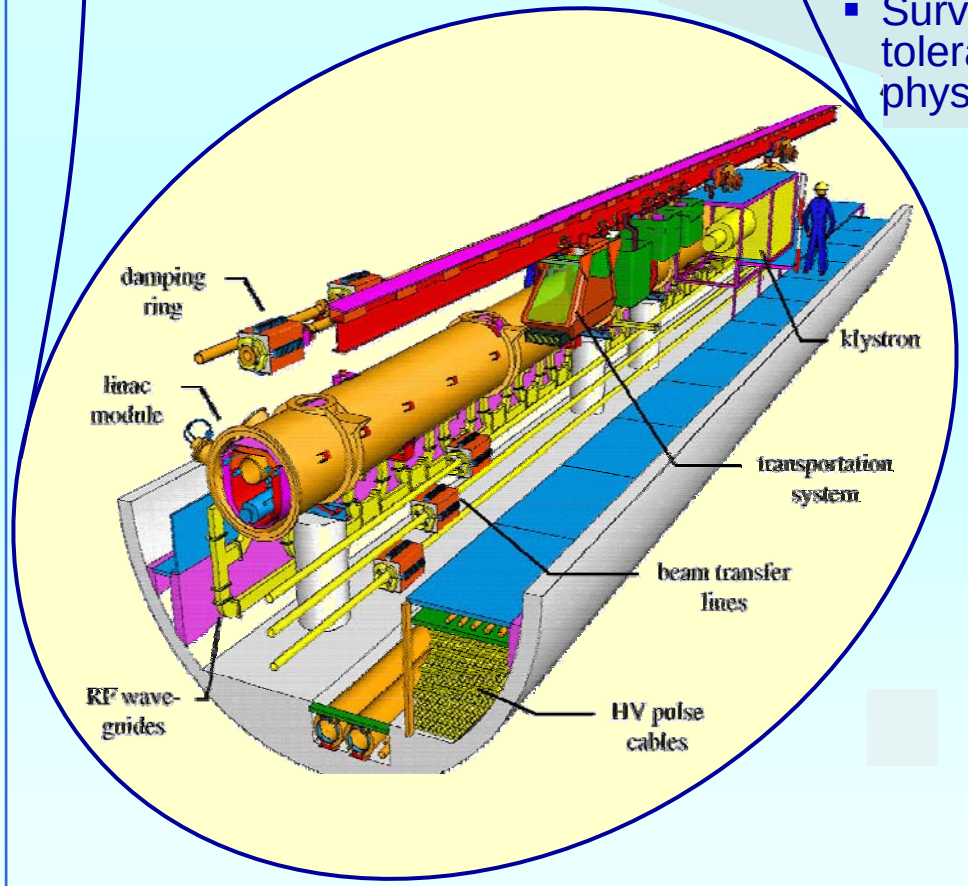
Applied Geodesy Group



Linear Collider Alignment & Survey

LC Survey Challenge



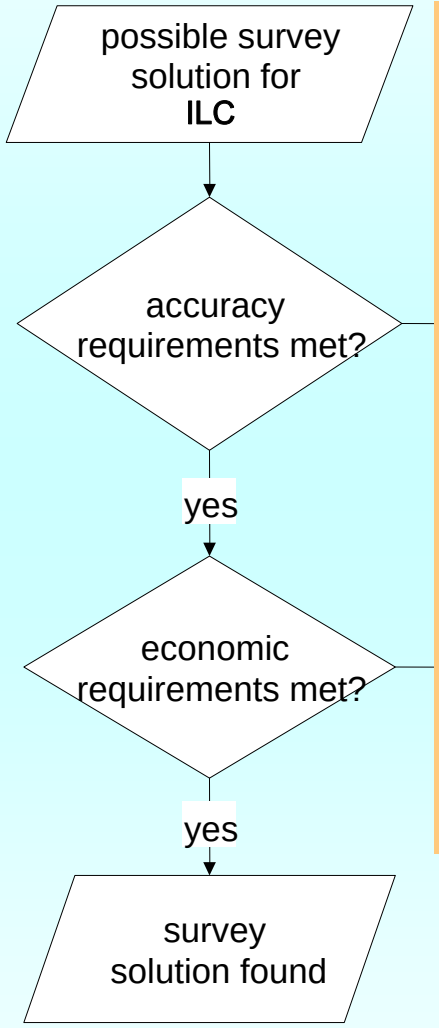


- Survey = multi step process with single tolerance budget driven by accelerator physics:
  - component construction
  - component fiducialisation
  - component survey
  - machine alignment

Components Survey:

- 200µm vertical, 500µm horizontal = our slice of tolerance budget
- over some 100m = O (betatron) wavelenght

SURVEY & ALIGNMENT ISSUES FOR ILC



Accuracy demands:

Linac:

transversal : s_{module} =0.5mm, s_{cavity} =s_{quad}=0.3mm, s_{BPM} = 0.3mm

vertical : s_{module} =0.2mm, s_{cavity} =s_{quad}=0.2mm, s_{BPM} = 0.2mm

over a range of some 100m length.

Injector: ??

damping rings: ??

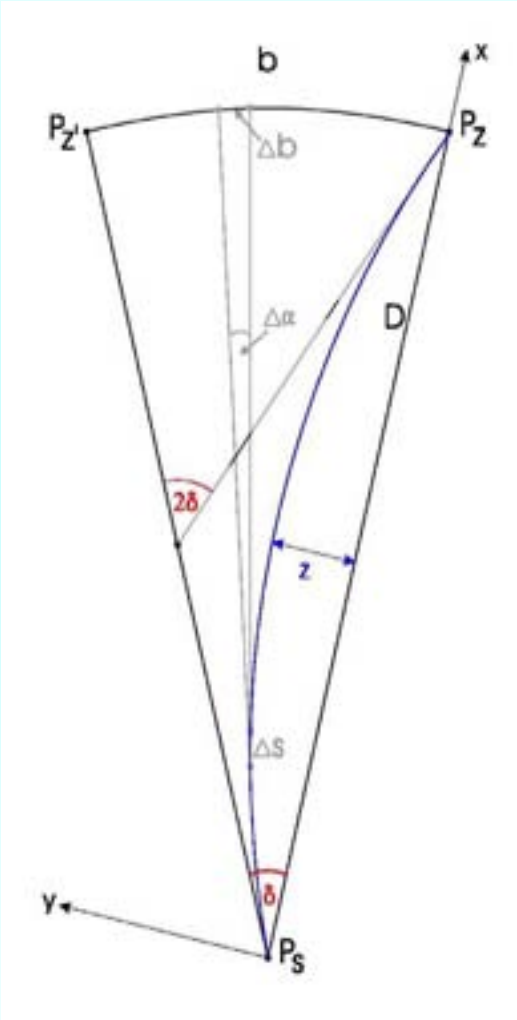
beam delivery system: ??

final focus: ??

machine detector interface: ??

What can we achieve with classical survey methods?

Achievable accuracy with conventional methods



in this application mainly depends on the angle of refraction

$$\delta_{[rad]} = \frac{\kappa}{R \cdot D} \int_{P_s}^{P_z} (D - s) ds$$

mit $\delta n / \delta y$ = a = konstant

n = refractive index

κ = local refractive coefficient

$\kappa = f(P, T, \delta T / \delta y) \approx f(\delta T / \delta y)$

approximation equations

$$2\delta_{[rad]} = \int_{P_s}^{P_z} \frac{\delta n}{\delta y} ds = \int_{0}^{D} \frac{\delta n}{\delta y} ds$$

thus $\delta_{[rad]} = a \cdot \frac{D}{2}$ and $z = a \cdot \frac{D^2}{8}$

Numerical examples for various $\delta T / \delta y$

	lateral refraction $\delta T/\delta y = +0{,}1\ K/m$		Comparison with altimetry $\delta T/\delta y = -0{,}065\ K/m$	
distance [m]	angular error [mgon]	lateral error [mm]	angular error [mgon]	lateral error [mm]
50	0,16	0,031	-0,10	-0,020
100	0,32	0,125	-0,21	-0,081
150	0,48	0,281	-0,31	-0,183
200	0,64	0,500	-0,41	-0,325
250	0,80	0,781	-0,52	-0,508
300	0,95	1,125	-0,62	-0,731
600	1,91	4,500	-1,24	-2,925
1200	3,82	18,000	-2,48	-11,700

Standard solution to minimize effects of refraction:
monitoring pillars alternating on either side of the tunnel.
Conventional optical method not suitable here.

LC Survey Challenge

- 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

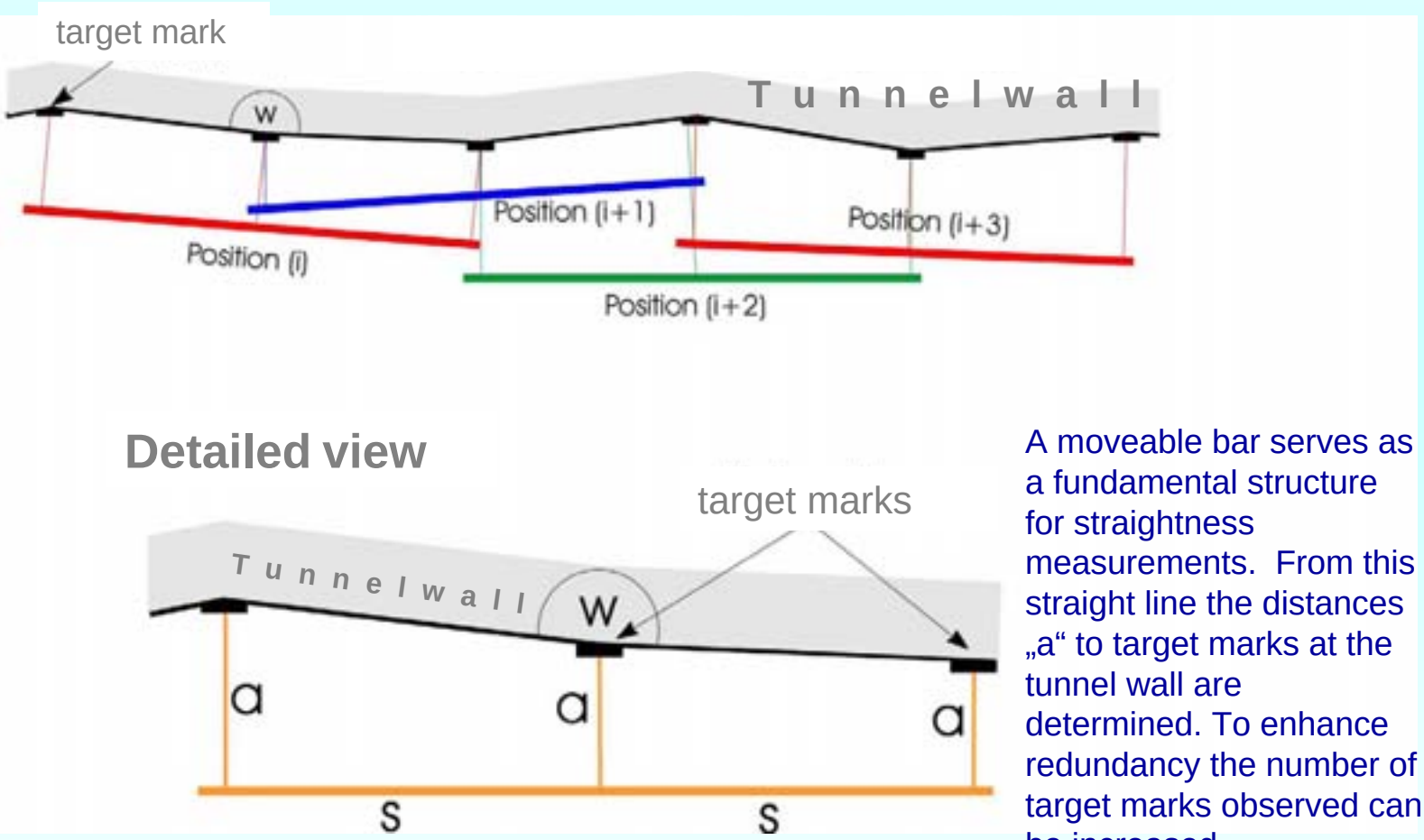
➔Optical Survey methods are not precise enough for reference structure
➔**Need new instrument ➔ RTRS (Rapid Tunnel Reference Surveyor)**

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

- No long-term stable (>months) reference monuments at O(10 μm) level
- Need frequent surveys
- Need automated process

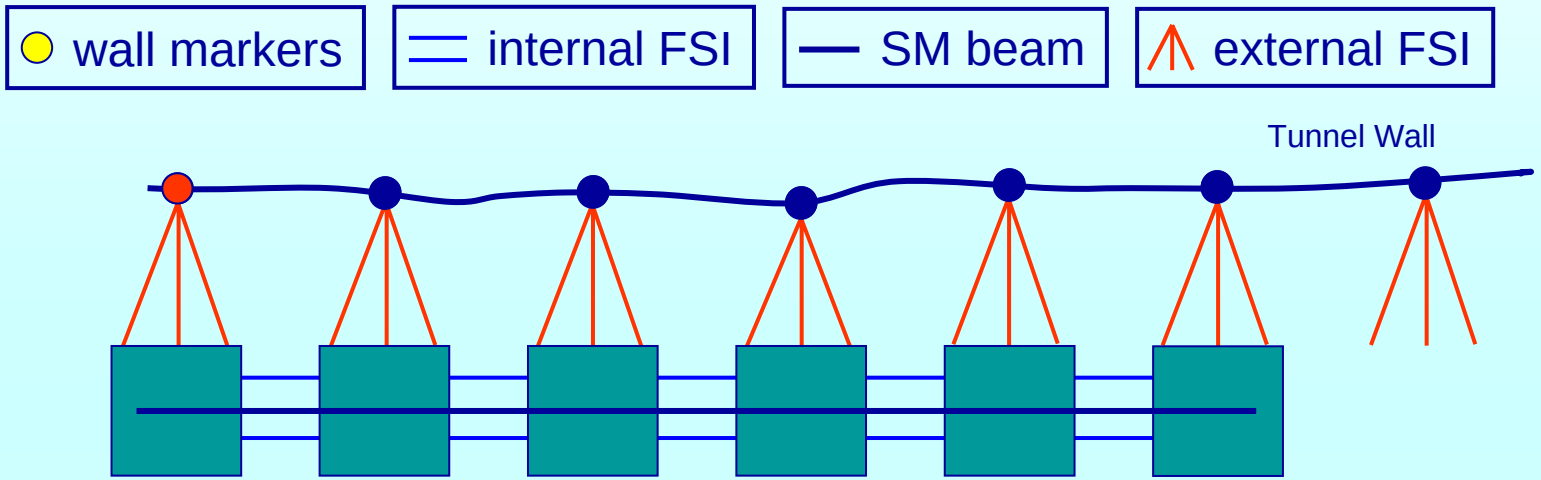
Straightness measurements with RTRS (multipoint alignment)

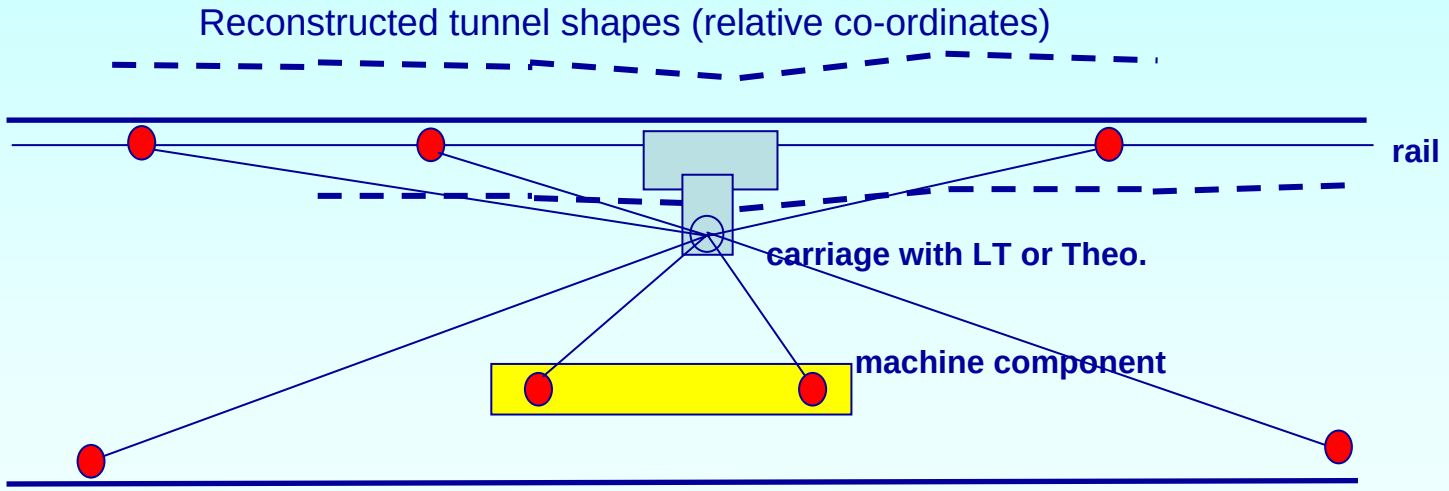
A technique to avoid the effects of refraction is given by the multi-point alignment. This method replaces angle measurements by distance measurements to at least three points.



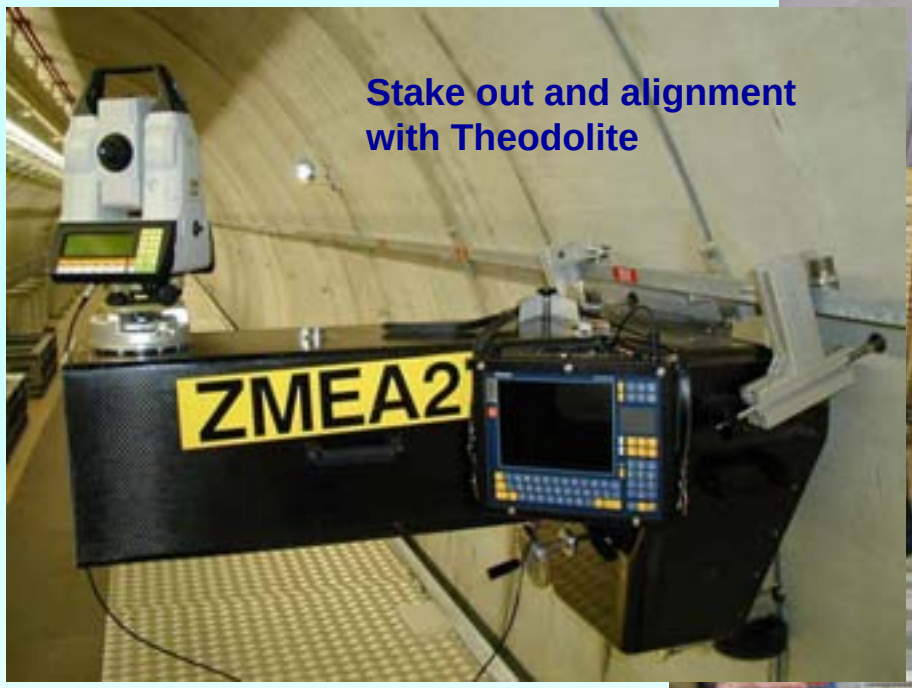
A moveable bar serves as a fundamental structure for straightness measurements. From this straight line the distances „a“ to target marks at the tunnel wall are determined. To enhance redundancy the number of target marks observed can be increased.

RTRS concept





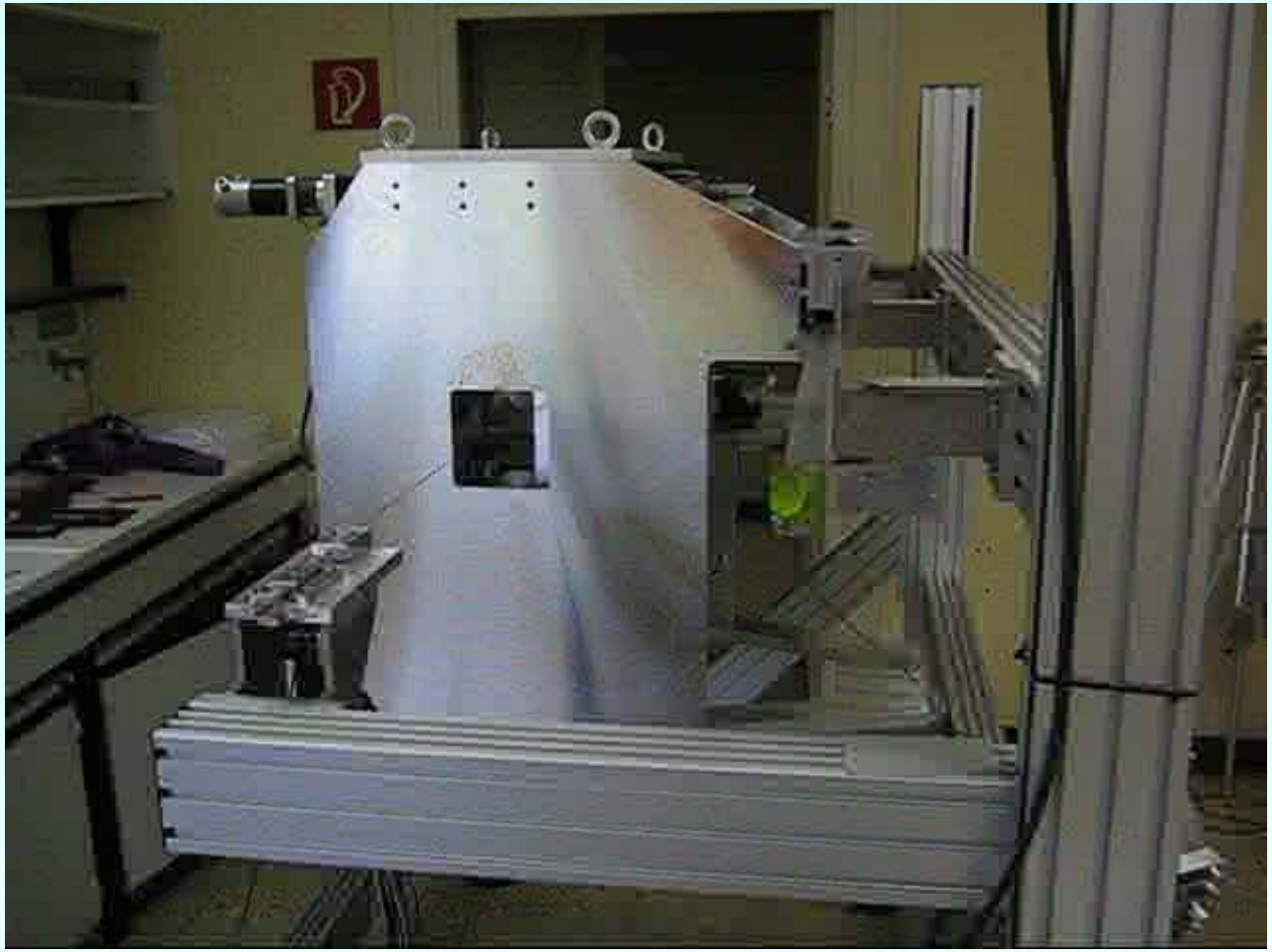
Stake out and alignment in the VUV-FEL Tunnel @ DESY



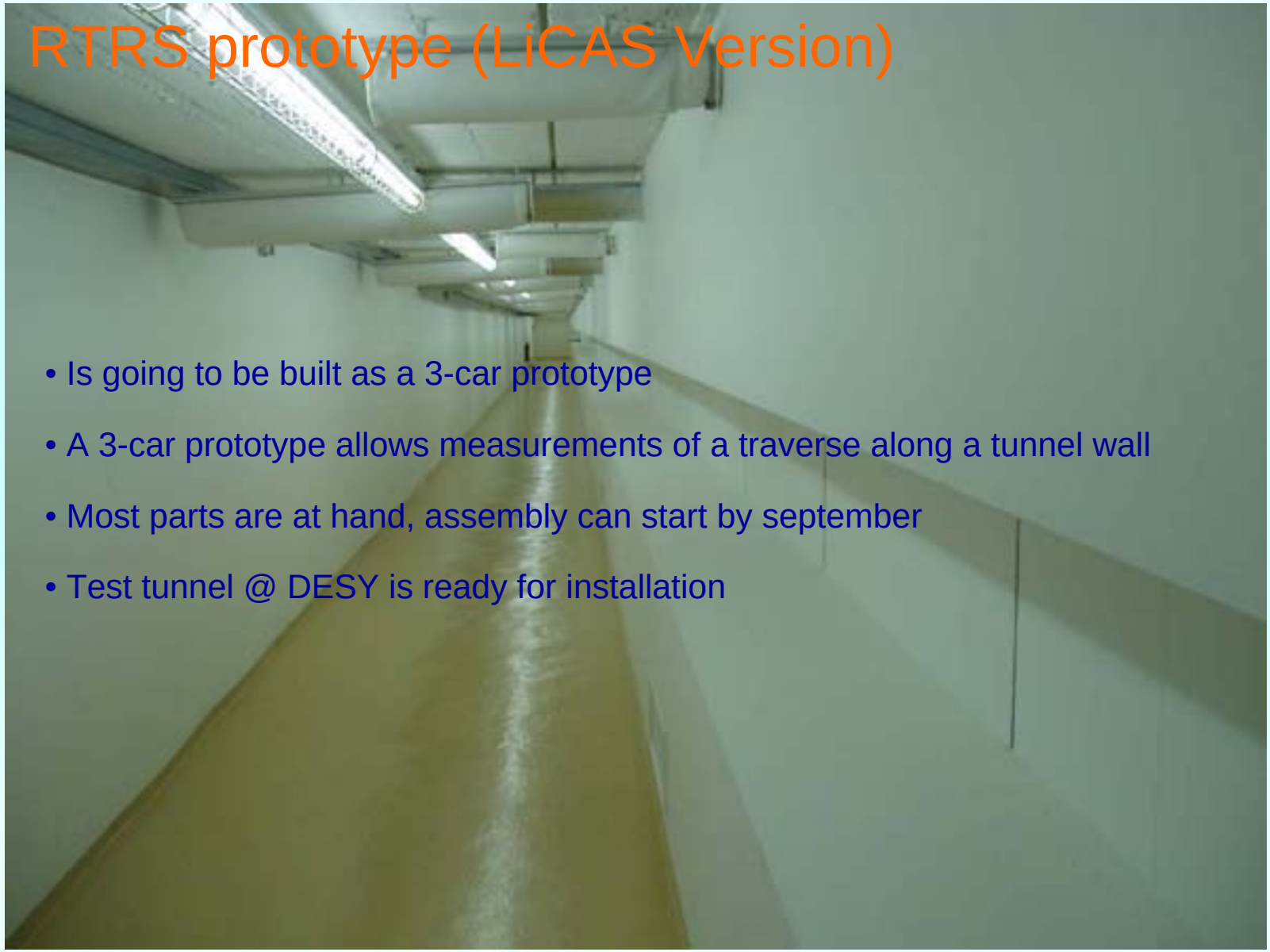
Stake out and alignment with Theodolite

Stake out and alignment with Laser Tracker

RTRS: single car prototype (from 6 car train, DESY Version, (GeLiS))

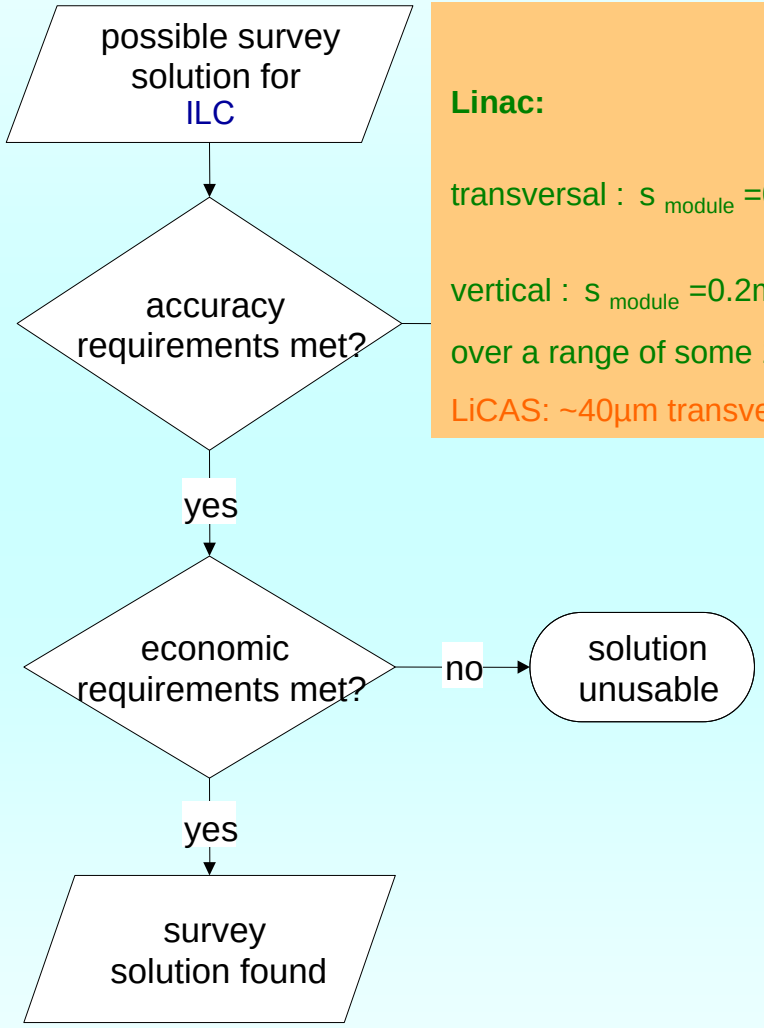


RTRS prototype (LiCAS Version)



- Is going to be built as a 3-car prototype
- A 3-car prototype allows measurements of a traverse along a tunnel wall
- Most parts are at hand, assembly can start by september
- Test tunnel @ DESY is ready for installation

SURVEY & ALIGNMENT ISSUES FOR ILC



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over a range of some 100m length.

LiCAS: ~40µm transversal, ~100µm vertical -> see talk of G.Grzelak

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

(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

TCO_{Ref} = 1.1 Bill. € + 5.5 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!

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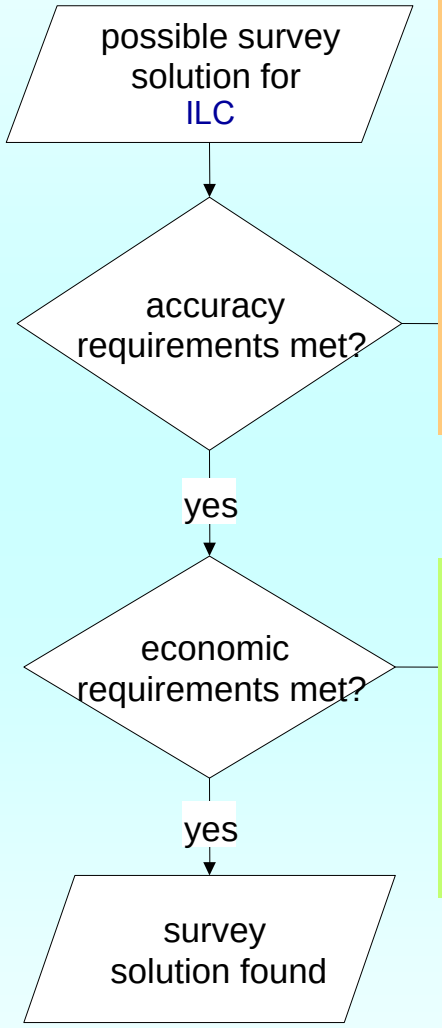

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Economic requirements:

RTRS

LiCAS pre CDR Working Document

- During this workshop we want to start writing a working document intended to be the precursor to a survey and alignment CDR section.

- We think this document could be divided like this:
  - Definition of scope
  - Overall survey and alignment strategy
  - Overall cost estimates
  - one chapter for each collider section that needs survey and alignment (sources, DR, Linac, BDS, FF, MDI, detector, polarimeters, etc.)
  - 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 -
    - - build tolerances are (WG 2)
    - - fiducialisation tolerances are (WG2)
  - how we can integrate the RTRS into the tunnel crossection (GG4&5)
  - how accurately the sources need to be aligned (WG 3a)
  - how accurately the damping rings need 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 are acceptable downtimes ? (GG 3)

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Thnx for your attention !

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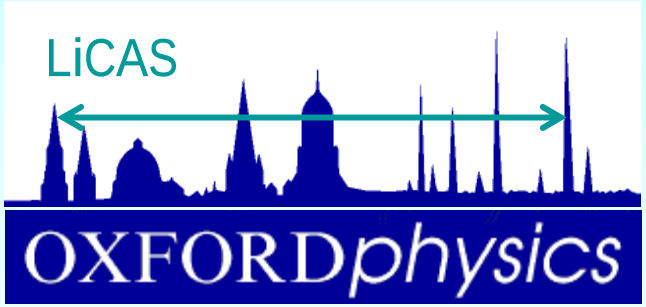

Linear Collider Alignment & Survey