Seminar BE

From point cloud acquisition to 3D model

As Built and Reverse Engineering at CERN using 3D laser scanning technologies

29.11.2011 room 864-1-D02

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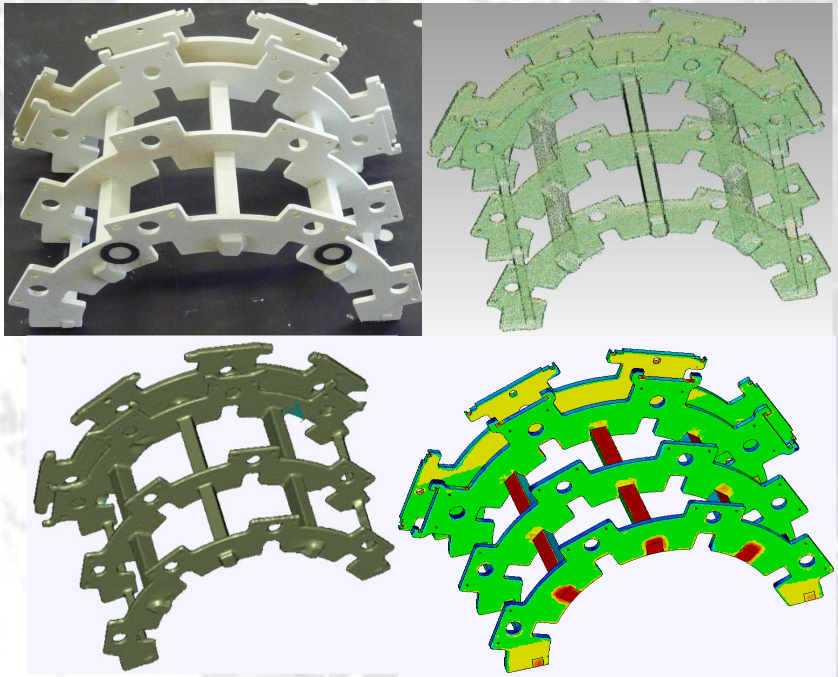
Contents

Why is scanning interesting for CERN?

- **Provides as-built data with possible use to:**
  - **Check envelopes, interfaces, services for integration and assembly phase**
  - **Improve/create documentation for future interventions and modifications**
  - **In combination with radiometric information create virtual reality (texture projection) as mock-up for automated interventions**
  - **Optimize efficiency in shut down periods and limit exposure to radiation**
  - **Inspect elements (tolerances and specifications)**

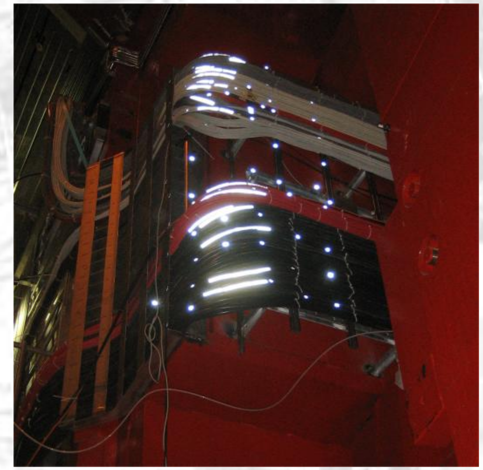
- **Possible Outputs**
  - **Point clouds (xyz coordinates)**
  - **Triangulation mesh, surfaces, solid**

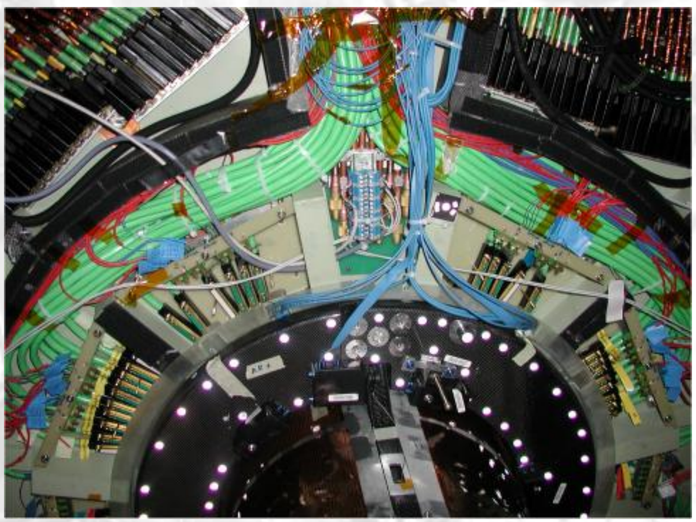
- **Advantages**
  - **Fast and accurate acquisition of details**
  - **Limited preparation on object**

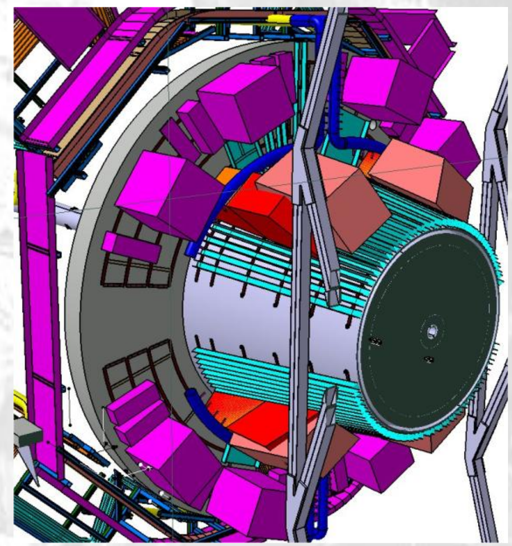


Examples for missing scans (ALICE+CMS)

- **Scanning system has been missed for ALICE and CMS:**
  - **CMS YE3 feet**
  - **Service package in L3 door**
  - **ITS services**
  - **ALICE FASS**
  - **Envelope ALICE TPC inner cylinder**
  - **CMS YE3 chambers envelope**
  - **CMS Bulkhead (for LS1)**

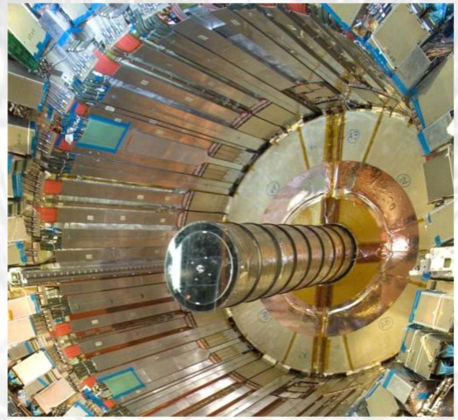


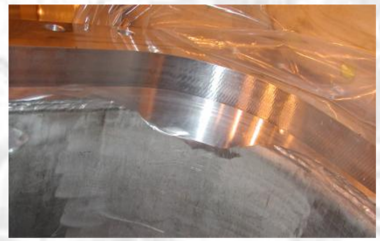




Examples for missing scans (ATLAS)

- Scanning system has been missed for ATLAS:
  - Spreader plate for TRT Endcap insertion
  - ECT turret
  - Envelope measurement of TRT barrel for insertions
  - Envelopes on BT cryostats
  - Welds and pipes on LArg cryostat
  - Determine non-conformities on bedplates, feet (welds)
  - Form of JD-disks





- **Mainly envelope problems for integration**
- **Non-conformities on arriving pieces with comparison to CAD**

Collaboration 3D scanning

- Following the experience from the construction of LHC experiments and the start for design changes like in LS1 and LS2
- Collaboration on 3D scanning PH/DT-PO and BE/ABP-SU started in 2008
- The main motivation of this ‘project’ is to bring as-built dimensions of detector components into the 3D CAD modelling environment as early as possible so that the engineering design teams are working on the most accurate of CAD models for interventions on the present LHC detectors or during the design, construction, assembly and installation phases of future projects.
- Main collaborators:
  - PH/DT-PO → A. Catinaccio, C. Bault, A. Maurisset
  - BE/ABP-SU → C. Lasseur, D. Mergelkuhl, A. Behrens
  - GS/ASE → B. Lepoittevin link to CAD/CATIA
  - Also links to CAEC/GUCS, EN/MEF, project offices

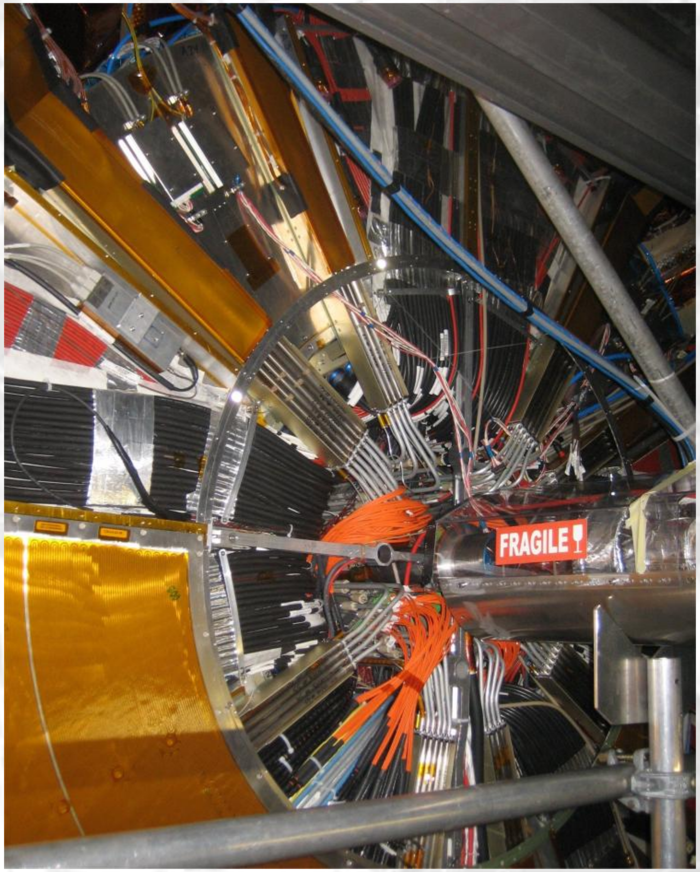
Collaboration 3D scanning

- **Phase 1: Search of most appropriate methods, tools and software**
  … available software for the conversion of geometrical data into very accurate 3D computer/image files and convert them into accurate 3D CATIA files
  –> demo - tests

- **Phase 2: Refinement, short listing of potential solution … investigating in more detail the short listed systems and methods from phase 1 and exploring the potential for the common development with other partners.**

- **Phase 3: Selection and application of the method … purchase … one set of equipment → may need more than one set of equipment if method proves popular**

- **First application February 2009**
- **Scan of ID services in UX15**
- **External company for 2 days**
- **Size 9 m diameter (2x)**



Technical details about scanning

- Special properties for surfaces to get good quality:
  - not transparent (glass, resin)
  - not completely black or complementary colour of scanner laser
  - not too reflective (no mirrors, polished or shiny surfaces)

  => Surface could be prepared with spray, adhesive tape, paint etc.

- Geo-referencing necessary to link the scan to coordinate system of object or to global reference system (traditional survey)
  - by known targets distributed in object space
  - link between scans by measurement arm, tracker, CMM
  - transformation of point clouds (only relative)

Time of flight scanner

Time of flight scanner → Laser impulse technology (10 picoseconds = 3 mm)

- **Sequential measurement of points**
- **Rotation of instrument (vertical axis)**
- **Rotation of mirror (horizontal axis)**
- **1000 up to > 50000 pts/s, maximum range up to few km, +- 3 mm to +- 20 mm**
- **Use for civil engineering, architecture, archaeology etc.**

Optimum Range	1 – 50 m
Maximum Range	100 m
Scan Field of View: Horizontal X Vertical	360° X 270°
Data Acquisition Rate per second:	1000-1800
Minimum Scan Increment, Horizontal:	0.0038 gon
Minimum Scan Increment, Vertical:	0.0038 gon
Point Position Accuracy at 50 m, at 1σ:	±6mm
Distance Accuracy at 50 m at 1σ:	±4mm
Laser Spot size from 0-50m:	≤ 6mm

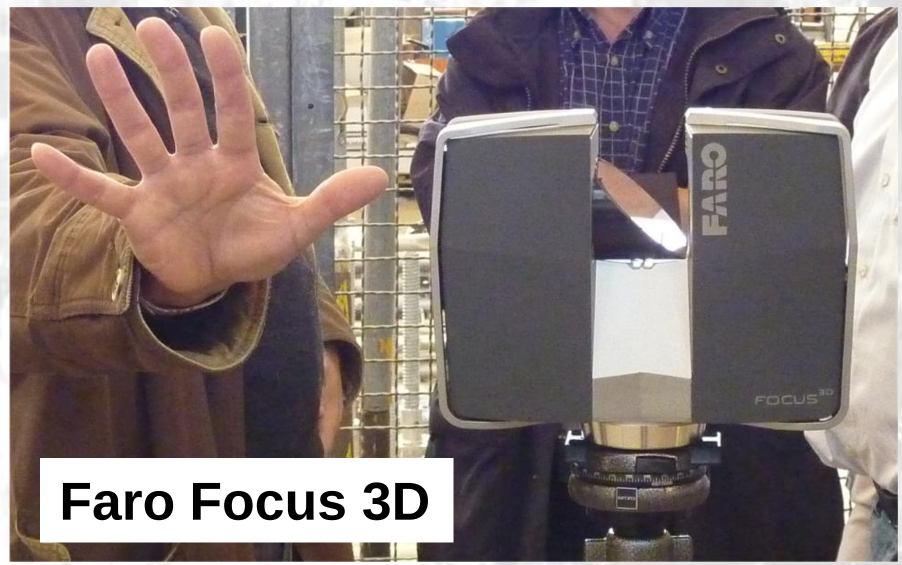
- **Leica HDS3000**
- **Since 2004 at CERN**
- **Intensive use for machine scans**

Phase Shift Scanner

- Geo-referencing by external targets
- Range precision +/- 2mm
- Acquisition rate 1 mio pts/s
- Field of view ~360° x 310°
- Quick measurements
- Spot = 5 mm @ 10 m
- Max range ~ 79 m
- Angular increment 0.009°
  - Grid 1.6 mm x 1.6 mm at 10 m
- Price system ~ 100 kCHF

Leica HDS 6200

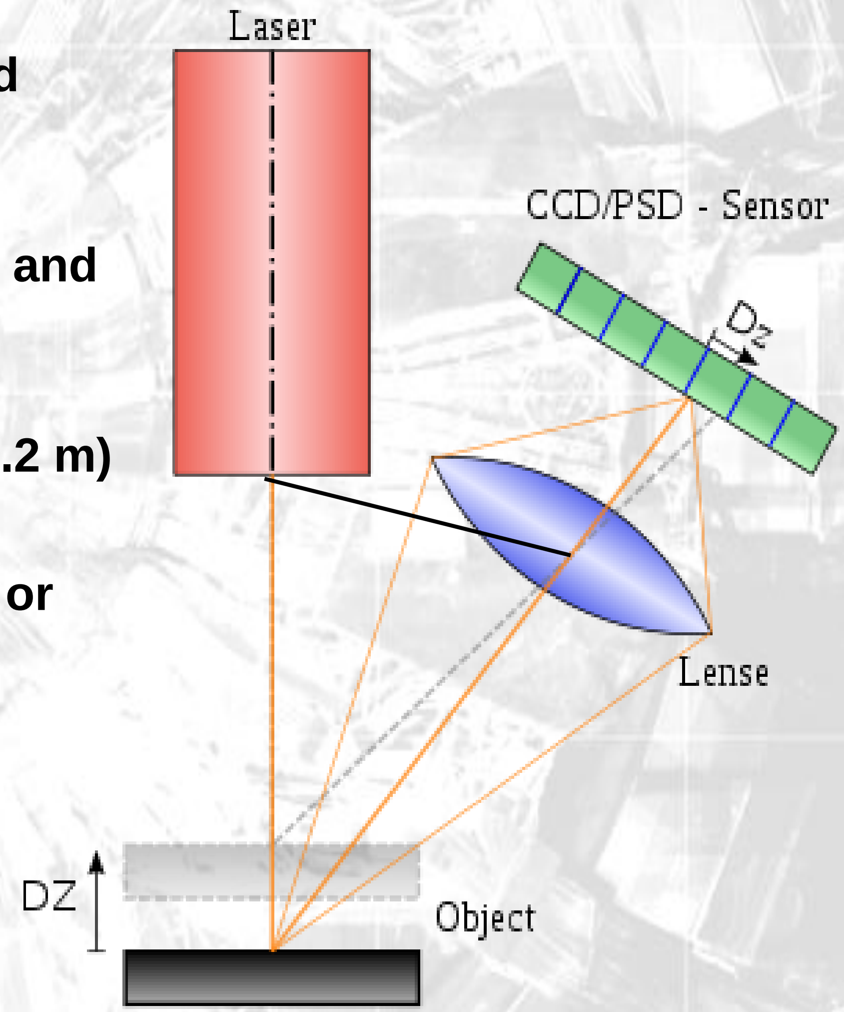
Surphaser



Faro Focus 3D

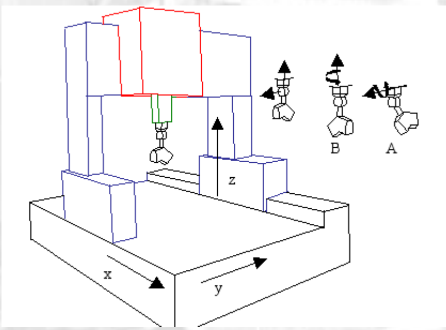
Laser Triangulation

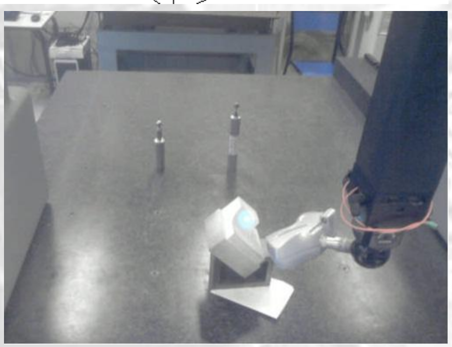
- A laser source and a camera in calibrated housing
- Calculation of relative 3D coordinates
- Sensitive to different reflectivity, colours and surface
- Short range, high precision
- Limited depth of field for scanner (0.05-0.2 m)
- Link scans by external reference
- Used as head for fixed or portable CMM, or CNC
- ~10000 - 30000 pts/s

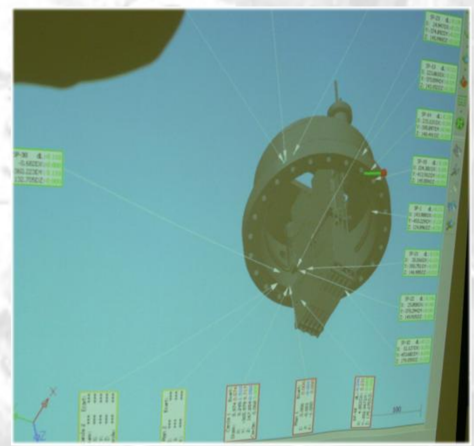


Examples for Laser Triangulation Scanner

- Scanner head mountable on CMM or portable CMM (measurement arm)
- Different filters depending on the colour, eventually spray for reflective surfaces
- Scanner at ~0.1 m to object with achievable precision 0.03 - 0.20 mm
- Scanning on part of interest only in controlled environment
- Soft G-Scan Romer is well adapted to lab environment



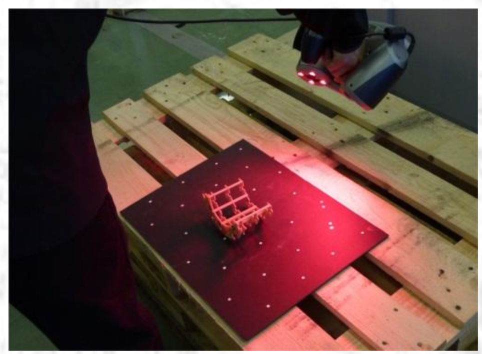


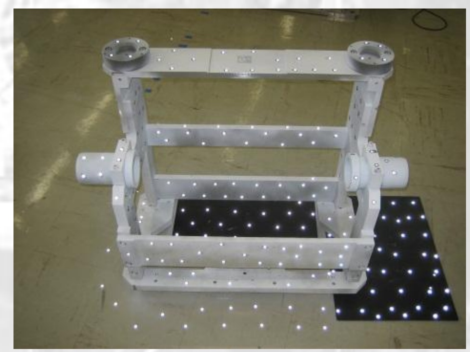


Creaform MAXscan

- Combination of photogrammetry and triangulation scanner
- Determination of retro-sticker coordinates by photogrammetry
- Positioning of scanner by spatial resection w.r.to stickers

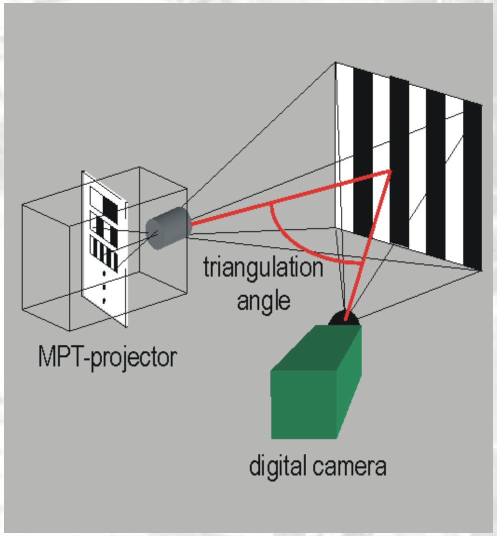
- Portable, objects of different size
- Density of stickers 0.05-0.10 m
- Depth of field 0.3 m
- Spray needed to cope with reflectivity
- Output in voxel (no point cloud but directly mesh)
- Precision up to 50 μm
- 18000 pts/s
- Control of reference points confirms precision of 30 μm





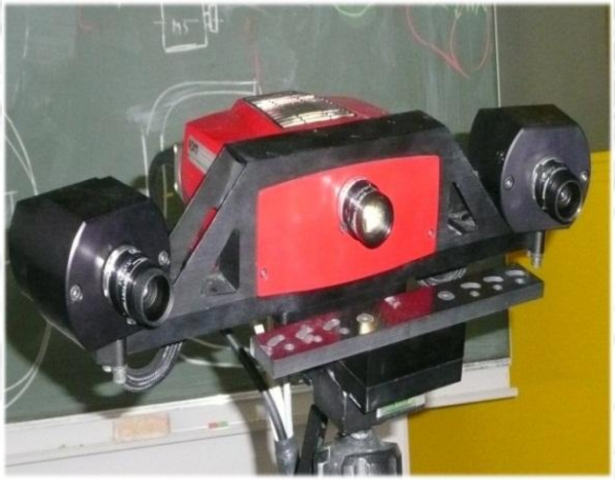
Structured Light 3D Scanners

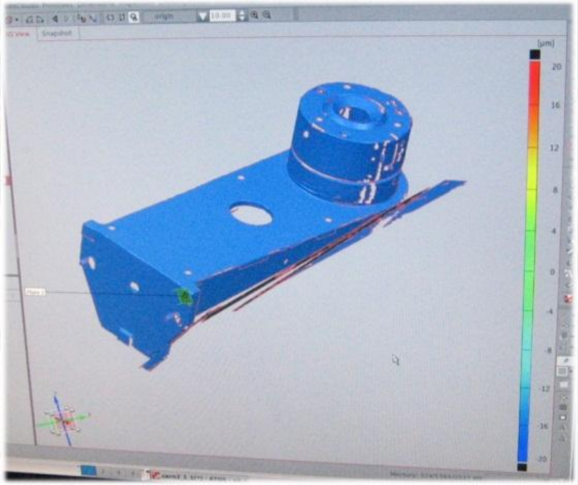
- Calibrated setup of 1 or more cameras and a light projector
- Sequential projection of binary codes to produce texture on object
- Phase-shift to increase resolution
- Different stations linked by adhesive stickers, cloud transformation or external reference (laser tracker, photogrammetric system)



- Used for limited size object (~1.0 m³)
- Acquisition time is a few seconds for single setup
- Accuracy can reach 0.01-0.05 mm

Examples for Structured Light 3D Scanners





- Use of photogrammetry for link of scanner setups
- High precision on small pieces
- Glue retro-stickers on object
- Demo at EIG

- Use of infrared projector
- Larger volume and precision (up to 0.5 mm)
- Same principle as Microsoft Kinect
- Very flexible and rapid in the field (10Hz)
- Single frame acquisition
- Interesting videos (1min each)
- http://www.mantis-vision.com/

Hand-held Scanners (external reference)

- External system as reference like optical bar, laser tracker, stickers
- Active LEDs and/or reflector on portable part to define rotations translations
- High quality with limited noise
- Time consuming in field

- Depth range, field of view ~0.1 m
- Measurement radius up to 15 m
- Precision <100 µm
- Precision Leica T-Scan 60 µm respectively 7µm/m

Hand-held Scanner

- Working with point cloud trans-formation to link stations
  - Not adapted to some geometries
  - Precision loss on large objects
  - No preparation, fast
- Working distance 0.2-1.0 m
- Limited object size
- 3D resolution up to 0.3-0.5 mm
- 3D point accuracy up to 0.5 mm
- Weight < 2 kg

Artec 3D
~15kEUR

NOOMEO

Laser Radar

- Laser radar based on Patented frequency-modulated coherent laser radar technology
- Low scan rate
- Highest precision in large volume
- Range up to 50 m
- Real non-contact measurement
- Concurrent to laser tracker
- High price > 300 kEUR

NIKON Metrology

Angle Resolution
Azimuth: 0.018 mm
Elevation: 0.039 arcsec
Uncertainty (U=2) 6.8 µm/m
Measurement range
Azimuth: 360 deg
Elevation: +/-45 deg

Distance
Sample rate 4000 pts/s
Resolution 1µm
Uncertainty (U=2) 10 µm+2.5 µm/m

Resolution for scanners

- Different parameters define the resolution for scanners
  - Laser spot at exit
  - Laser divergence
  - Precision of distance measurement
  - Quality of angular encoders
- Example laser of Leica HDS7000
  - 3.8 mm + 0.3 mrad => 10mm@10m
  - Corresponds to a surface of 80mm^2

- Resolution depends on the integration surface used for the definition of the return signal. A measured point is not a mathematical point!

- No sharp angles any more (smoothing at edges) and largest errors at discontinuities

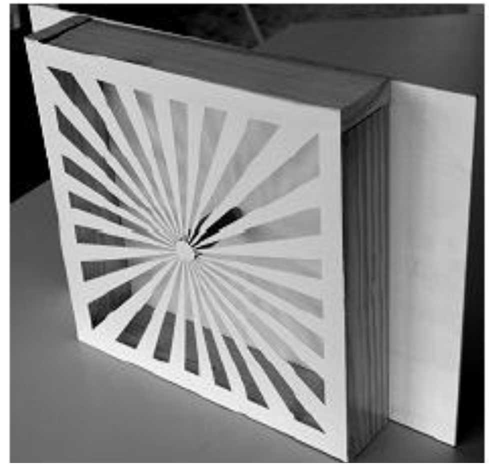
- Distance precision +- 1mm rms is equivalent to noise of 4 mm!

Measurement errors at discontinuities

- Visible noise in scan data
- Test with Böhler Star as spatial equivalent to Siemens Star
- Resolution depends on distance
- Problems in general at discontinuities
  - general noise
  - parasite points
  - relation integration surface to object details

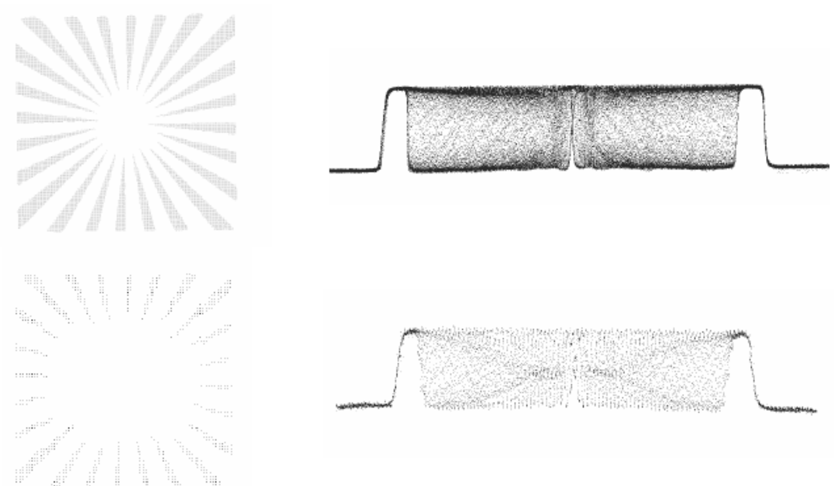
Procedure:

- Test object (see image below) scanned at 6m and 22m
- Plot of point cloud

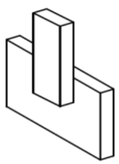


approx. 30 x 30 x 6 cm^3

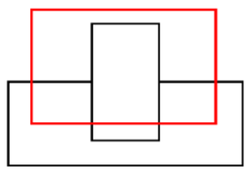
Plot of point cloud:



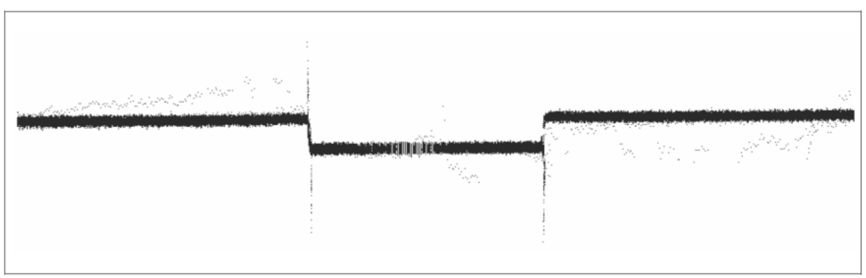
Top: test object at 6m (background and top view). Below: test object at 22m



approx. 80 x 40 cm^2



Plot of point cloud (top view):



Scanning Software

- Different software for acquisition, first preparation as geo-referencing, detailed cleaning/modelling, in parallel we have the CAD software
- Large data files for work on standard PCs (scan 1 hour = 3.6 billion points xyz) CAD programs are not made for this!
  - Confirmed by Dassault Systems in 2009.
  - Filters functions available in CATIA are limited.
- Treatment of large point clouds with efficient filters and noise reduction tools (down-sampling) this includes creating of mesh, surface etc.
- Reverse engineering to create 3D model from point clouds
- Point cloud software and CAD software have bi-directional link and are complementary and it's not a competition!

Commercial packages

Several specialised packages for treatment of 3D point clouds exist on the market:

- **3D Reshaper (France)**
- **Rapidform (Korea)**
- **Polyworks (Canada)**
- **Geomagic (USA)**

Industrial prices 10kCHF-30kCHF following number of modules

5 licenses of geomagic Studio are available (see part B)

Developments

- Users in more and more disciplines (mines, archaeology, medicine, civil engineering, forensics, military, petro-chemical industry etc.)
- IT development, computer vision (Microsoft Kinect)
- Use for navigation (autonomous cars, robots, gestural commands)
- Higher acquisition rate, longer acquisition range, (higher precision)
- Tendency to real time modelling/treatment
- Perhaps one day positioning of elements without fiducialisation in field and updating of 3D mock-up in parallel

- We follow the development in industry
- Regular new products are reaching the market
- Further tests are planned

Conclusions Part A

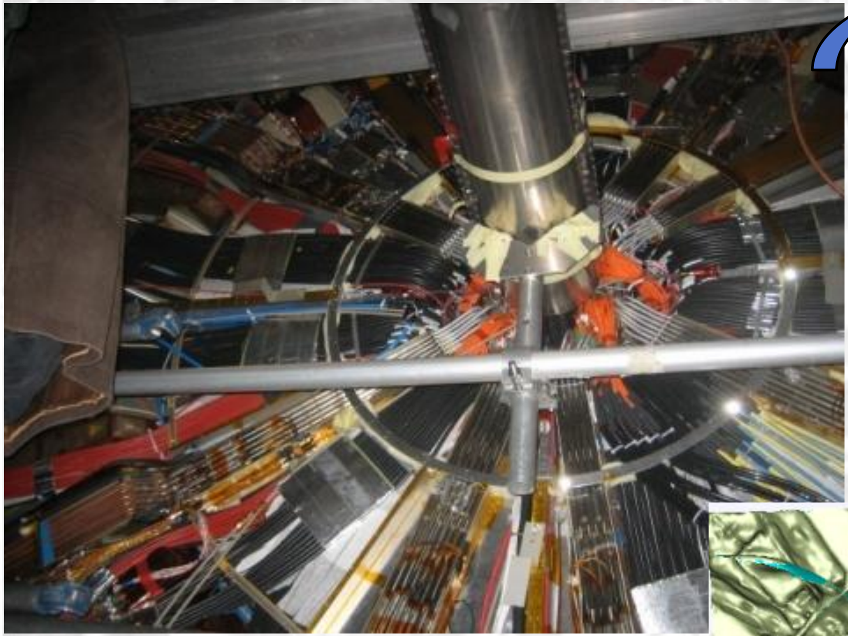
- Scanning is a proven, powerful technique
- Scanners exist for different precisions from µm to cm level
  - Level for integration at 1-3 mm
- Scanning for integration <=> Scanning for quality control

  Quite different if you look at equipment, data treatment, size, clients!
- Development of scans at CERN depends on clients, their needs, their use and imagination for data (acquisition, pre-treatment, modelling etc.)

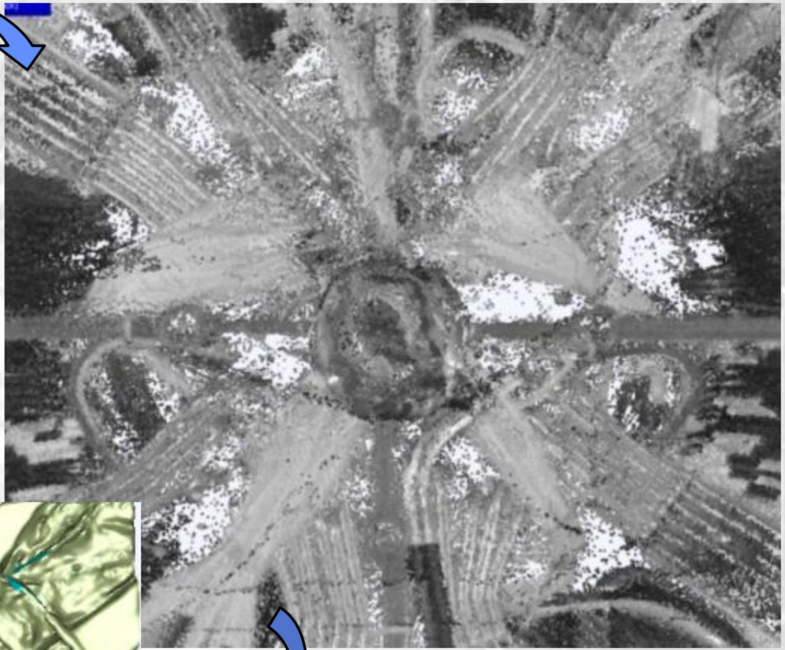
- You can find point clouds everywhere BUT very few final models!!! There is a reason why…

FROM POINT CLOUD TO 3D MODEL

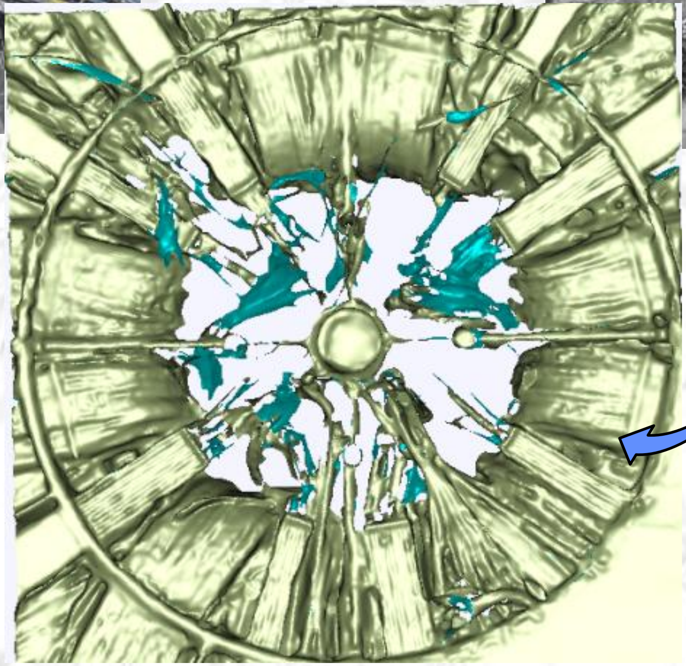
FROM OBJECT…



…TO POINT CLOUD…



…TO 3D MODEL



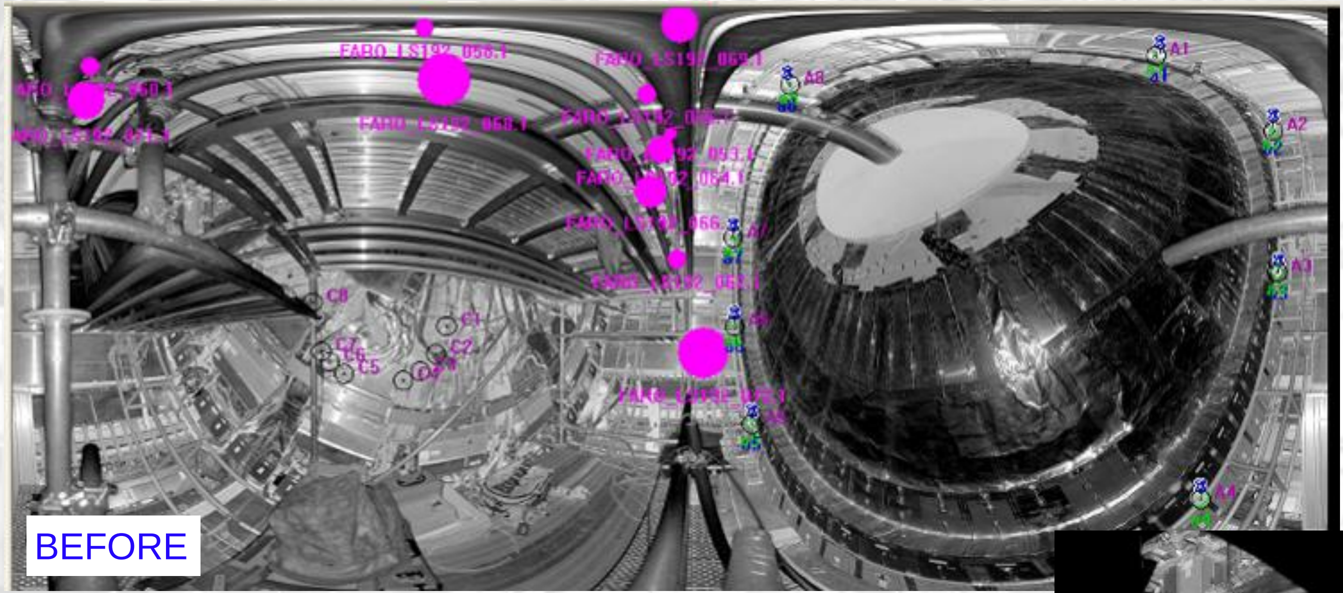
SUMMARY

1. **Part A (Dirk MERGELKUHL, BE/ABP-SU)**
2. **Part B (Aurélie MAURISSET, PH/DT-PO)**

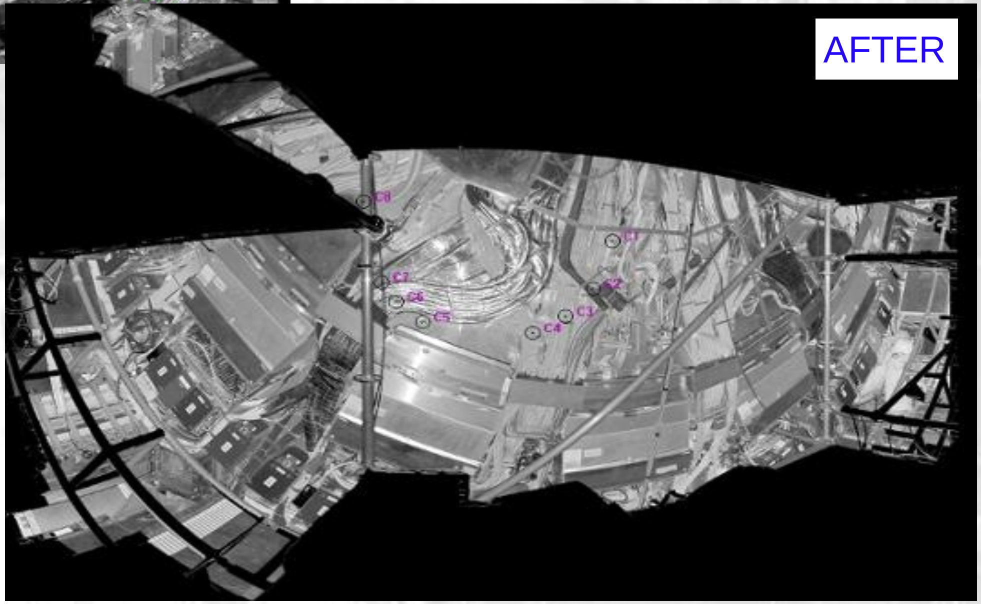
- Data Processing
  - Pre processing
  - CATIA capabilities
  - Adapted software capabilities
  - Surfaces
- Measurements
- Examples of Reconstructions
  - ATLAS
  - Zone AEGIS
  - LHCb
- Difficulties
  - Measurement
  - Reconstruction
- Conclusion

DATA PROCESSING
PRE-PROCESSING

Using specific program associated to the instrument



Data from 1 station of ATLAS ID services on LAr Barrel Face measured with laser scanner FARO Photon 80



<u>Pre-processing steps :</u>

REMOVAL of parasite measurements

ASSEMBLY of scan station

REFERENCING to survey coordinate system

REDUCE POINT DATA to keep parts of interest

EXPORT point cloud (xyz files)

Contains functions for measurements and to create geometrical sets

DATA PROCESSING
CATIA CAPABILITIES

Processing steps :

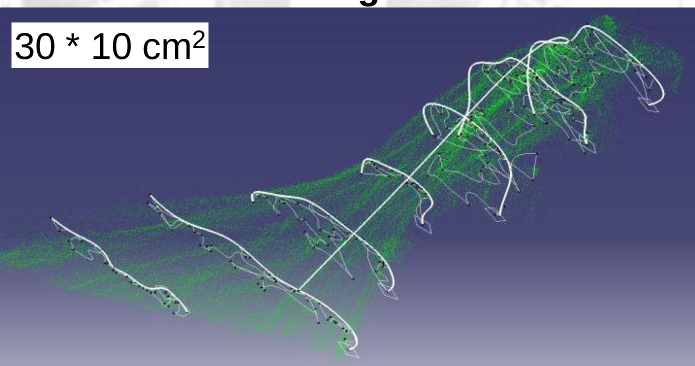
REDUCE POINT DATA (2 sample filters)

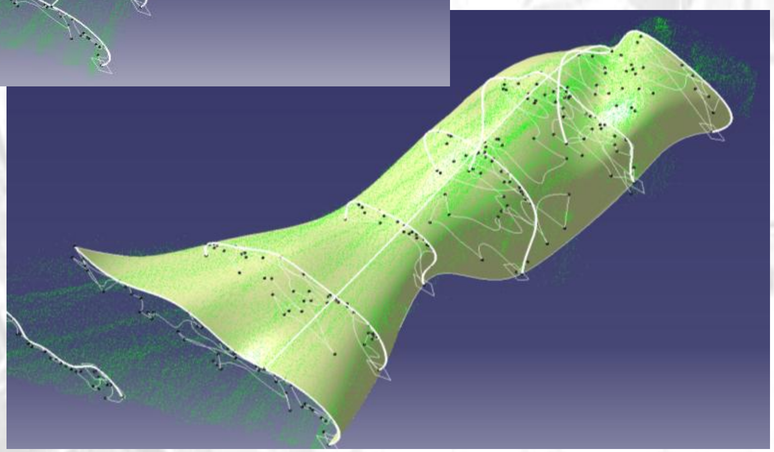
Create MESH

INTEGRATION in CAD existing model

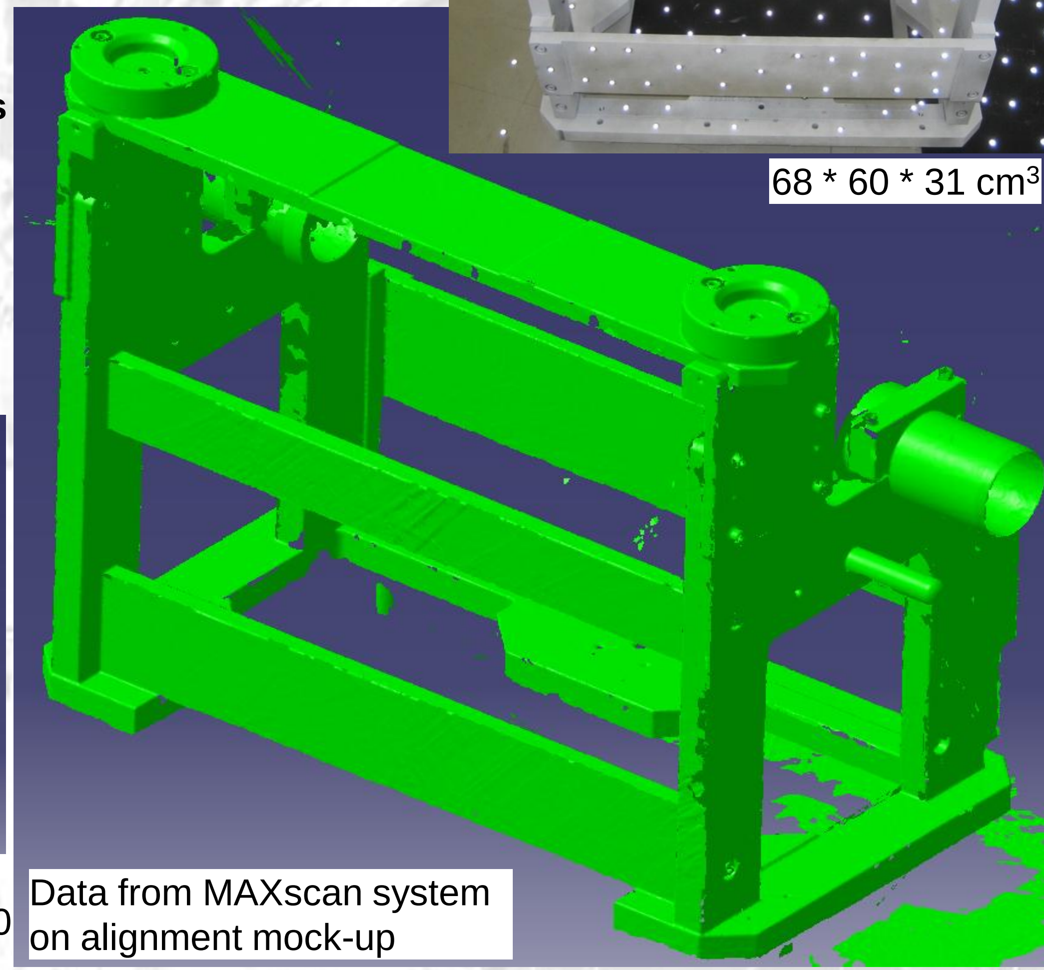
EXTRACT INFORMATION

Curves : to create lighter 3D surface from cross-sections





Extract of ATLAS ID services data
measured with laser scanner FARO Photon 80



Data from MAXscan system
on alignment mock-up

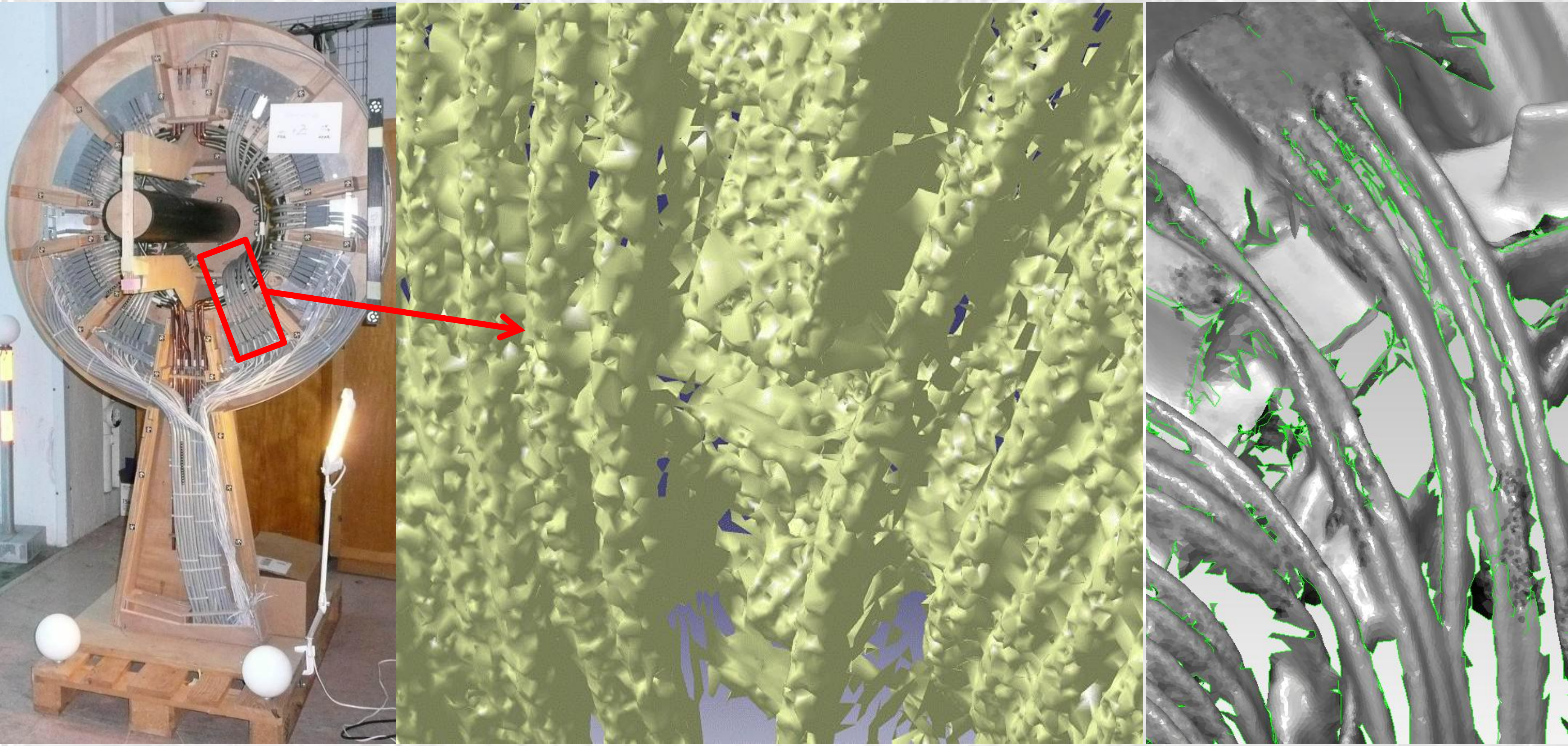
CATIA work: Christophe BAULT (PH/DT-PO), Benoit LEPOITTEVIN (GS/ASE)

DATA PROCESSING
CATIA CAPABILITIES

CATIA not adapted to all cases to mesh point clouds (Confirmed by DASSAULT)

→ **ADAPTED SOFTWARE** (Geomagic, 3D Reshaper, Polyworks, RapidForm)

CATIA **ADAPTED SOFTWARE**



Demonstration data with laser scanner FARO Photon 80 on CMS tracker mock-up

DATA PROCESSING
ADAPTED SOFTWARE CAPABILITIES

Processing steps :

REDUCE POINT DATA (2 functions to delete isolated points + 4 sample filters) – MOST IMPORTANT STEP

Mesh result depends of the filtering. Filtering is mandatory and manual.

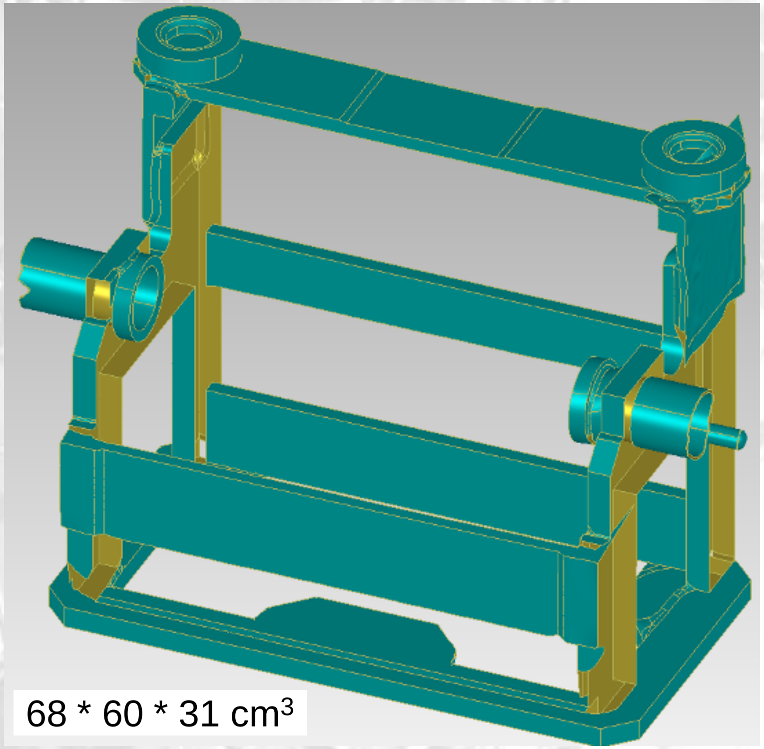
Create MESH and check, correct mesh errors, fill holes

EXTRACT INFORMATION (distances, diameters, 3D comparison)

Create SURFACE (parametric or NURBS)

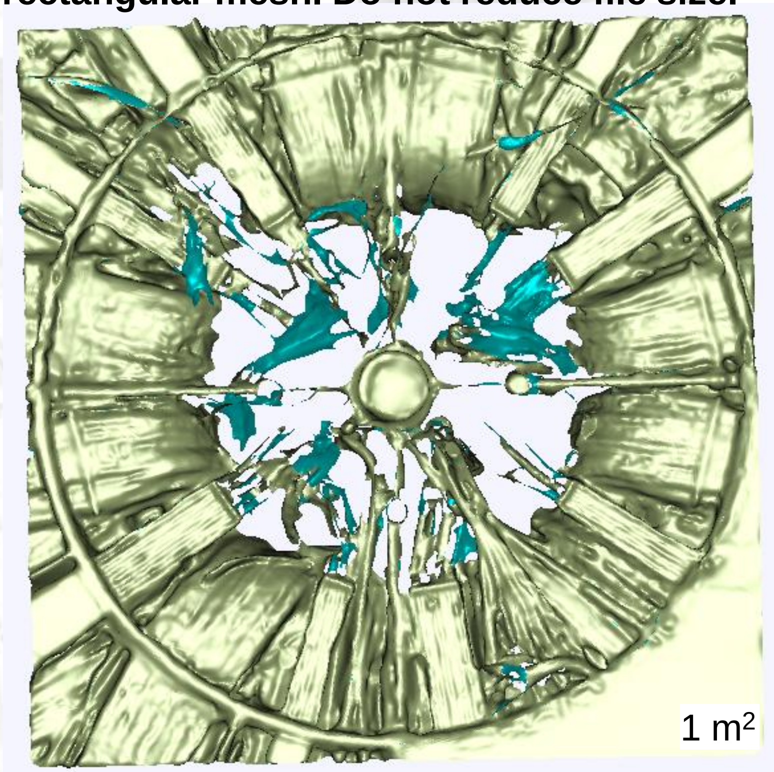
EXPORT in CATIA (stl or igs files)

Parametric surfaces : for mechanical objects, reduce file size → Easiest integration in CATIA



Data from MAXscan system on alignment mock-up

NURBS Surfaces : replace triangulated mesh by rectangular mesh. Do not reduce file size.

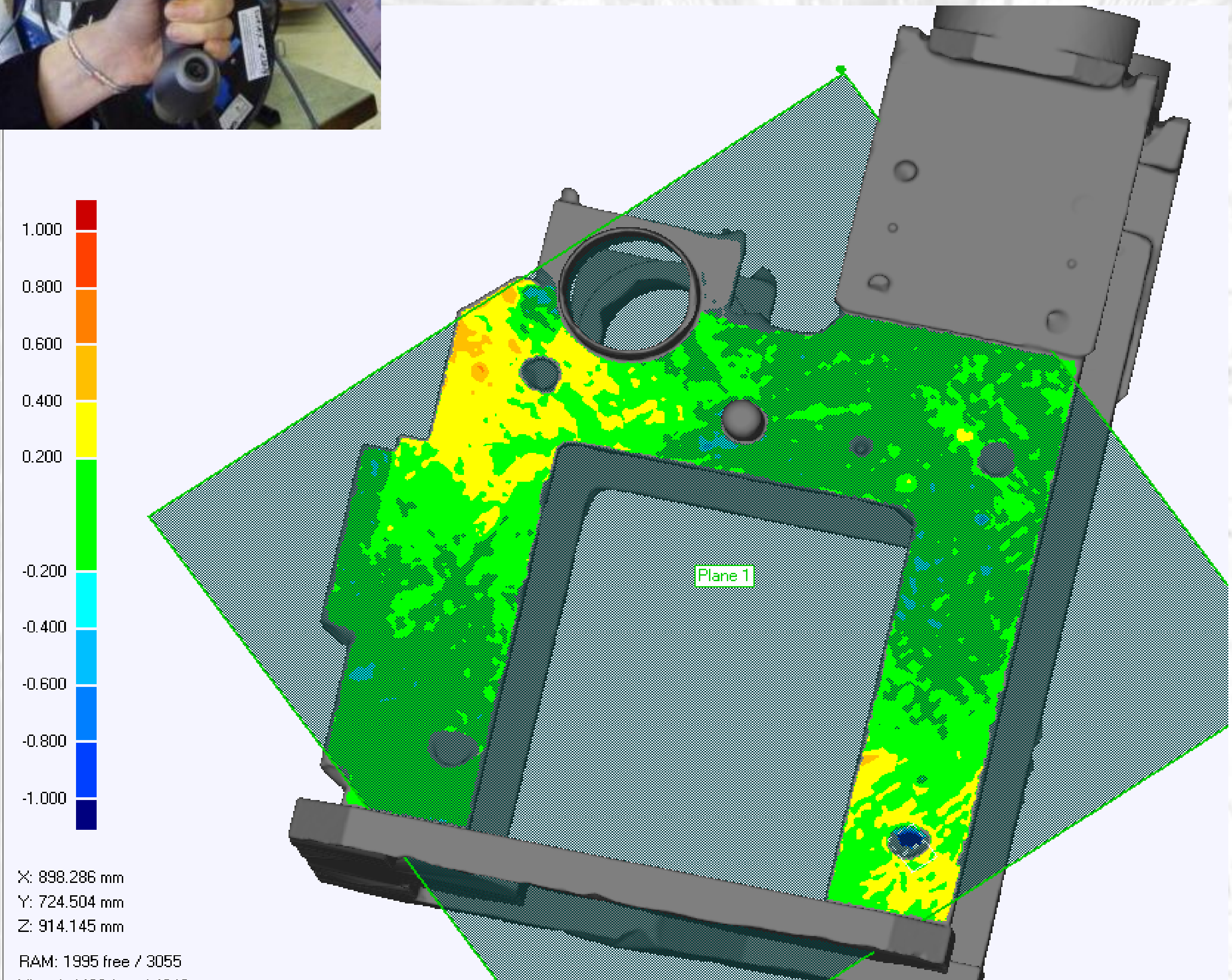


Extract of ATLAS data from laser scanner FARO Photon 80

POINT CLOUD QUALITY DEPENDS ON THE SCANNING SYSTEM

MEASUREMENTS

PLANE CALCULATION



Data from MAXscan system on alignment mock-up

Plane parameters

Parameters

Center: -274.8699, 48.0926, -78.5659 mm

Normal: -0.709, -0.001, -0.705

Principal: 0.000, -1.000, 0.001

Length: 508.1214 mm

Width: 482.199 mm

Statistic data

Deviations

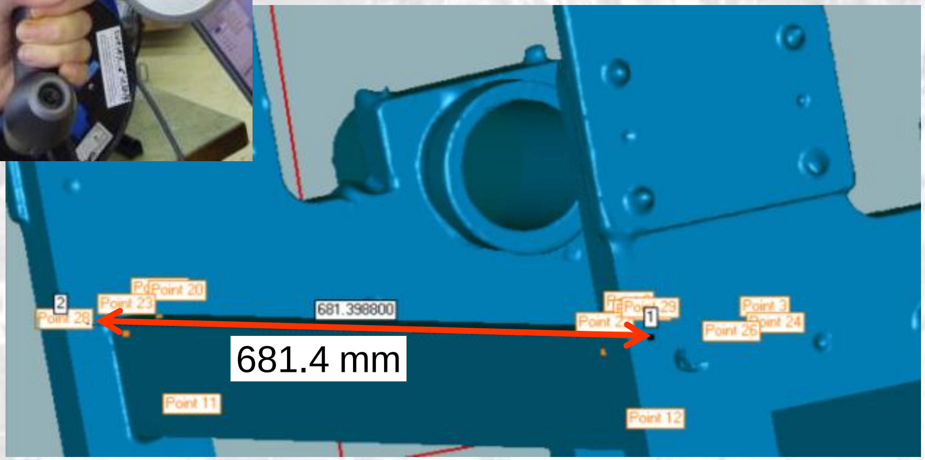
Maximum Distance:
- positive: 0.633624 mm
- negative: -4.068721 mm

Average Distance: 0.021846 mm
- positive: 0.149155 mm
- negative: -0.083743 mm

Standard Deviation: 0.170254 mm

MEASUREMENTS

POINT TO PLANE DISTANCE MEASUREMENT



Data from MAXscan system on alignment mock-up

Distance	
Distance:	681.398800 mm
X-Distance:	482.938216 mm
Y-Distance:	0.380438 mm
Z-Distance:	480.702465 mm

Calliper measurement : 681.8 mm

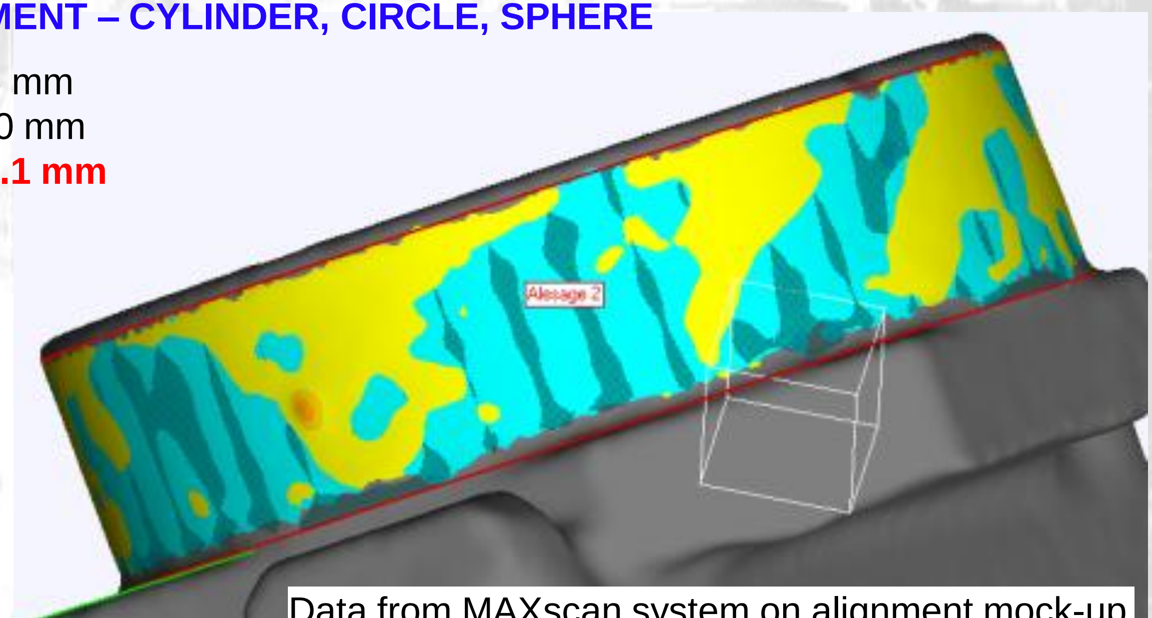
Difference = 0.4 mm

DIAMETER MEASUREMENT – CYLINDER, CIRCLE, SPHERE

Parameters

Base Point	-409.2438, -329.0609, 87.3646 mm
Direction	0.482, 0.729, -0.486
Height	29.1189 mm
Diameter	121.7221 mm

Max = 0.5 mm
Min = - 1.0 mm
STDV = 0.1 mm



Data from MAXscan system on alignment mock-up

Calliper measurement : 121.9 mm

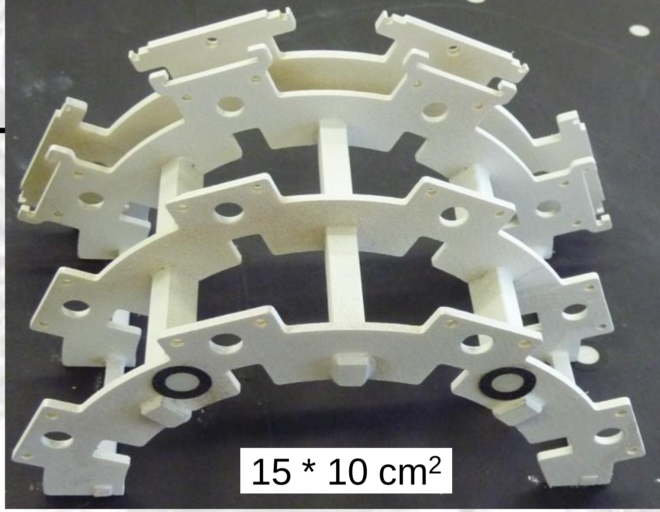
Difference = 0.2 mm

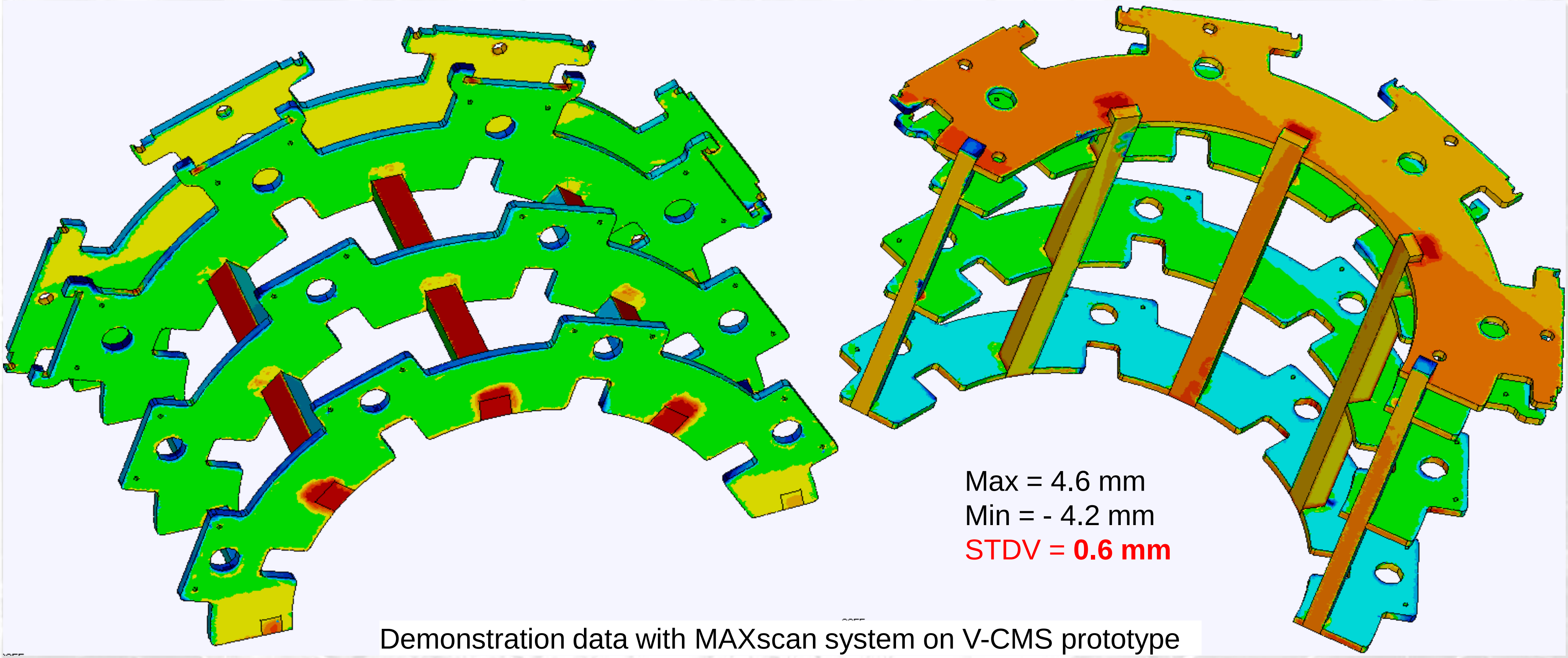
MEASUREMENTS

COMPARISON OF 3D MODELS

QUALITY CHECK AND EVALUATION OF NON-CONFORMITIES

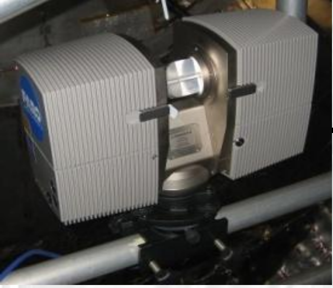
CHECK FOR CONFLICTS





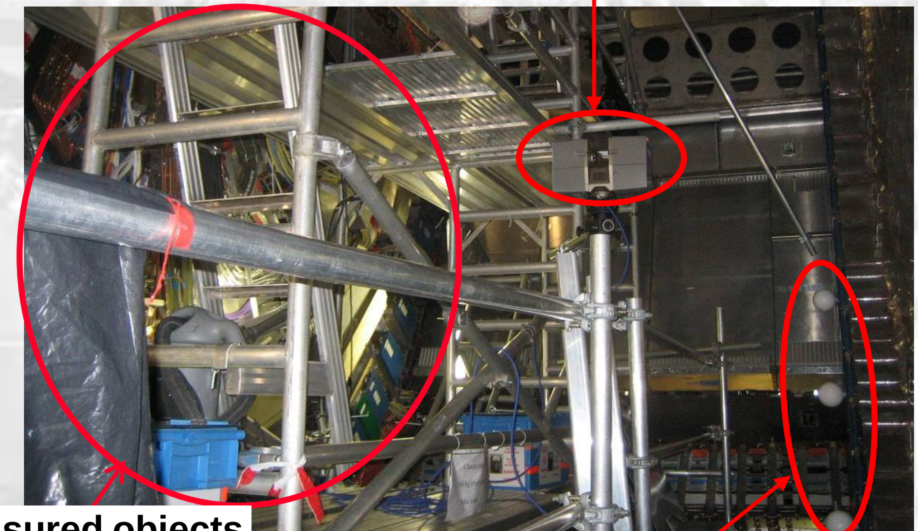
Demonstration data with MAXscan system on V-CMS prototype

EXAMPLES OF RECONSTRUCTIONS
ATLAS – ID Services on LAr Barrel Face



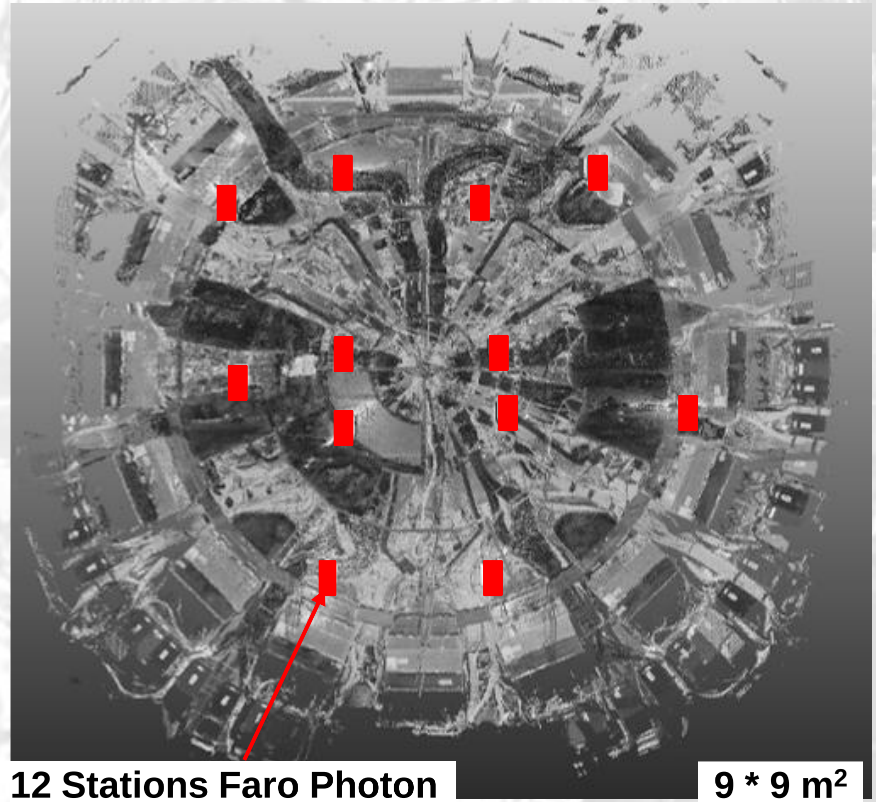
Laser scanner FARO PHOTON 80
Data acquisition : 120 000 pts/s

Point cloud on A Side after pre-treatment - 38 million points

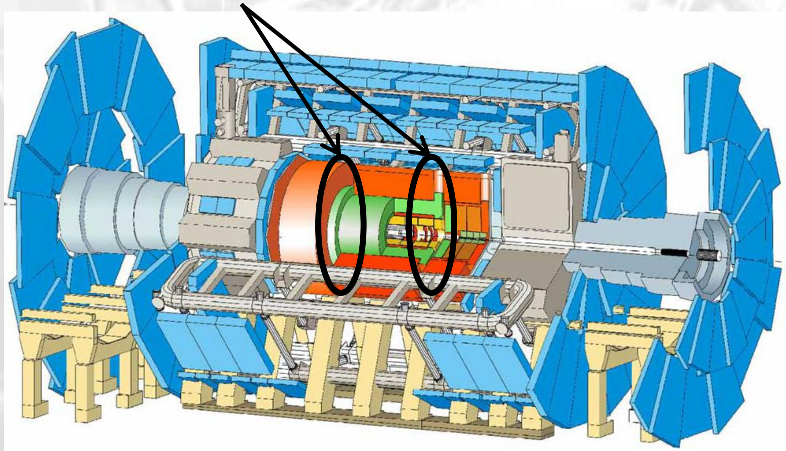


Measured objects
Very complex object and environment

Spheres: for scan assembly and geo-referencing. Results : +/- 2mm



12 Stations Faro Photon **9 * 9 m^2**

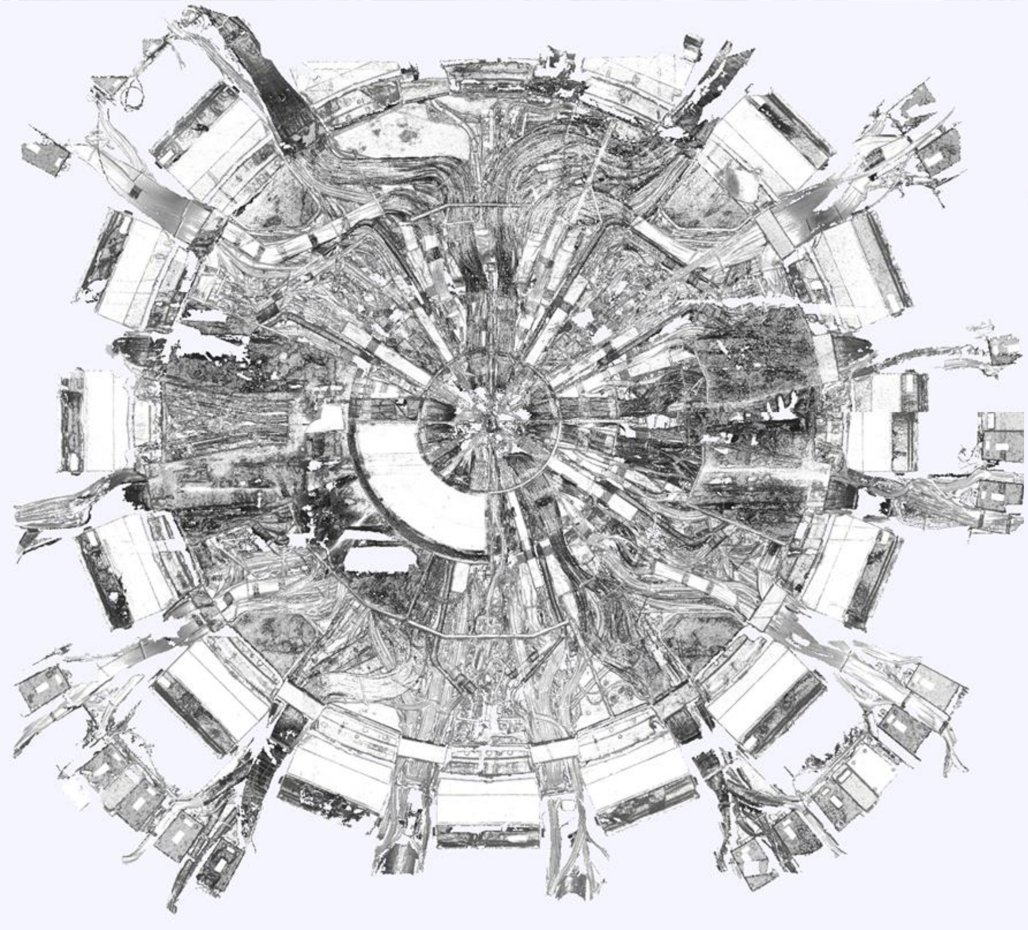


1 – MEASUREMENT (February 2009)
Scan : 1 day/side – 12 stations Side A
16 stations Side C
Standard survey : 2 days (Geo-referencing)

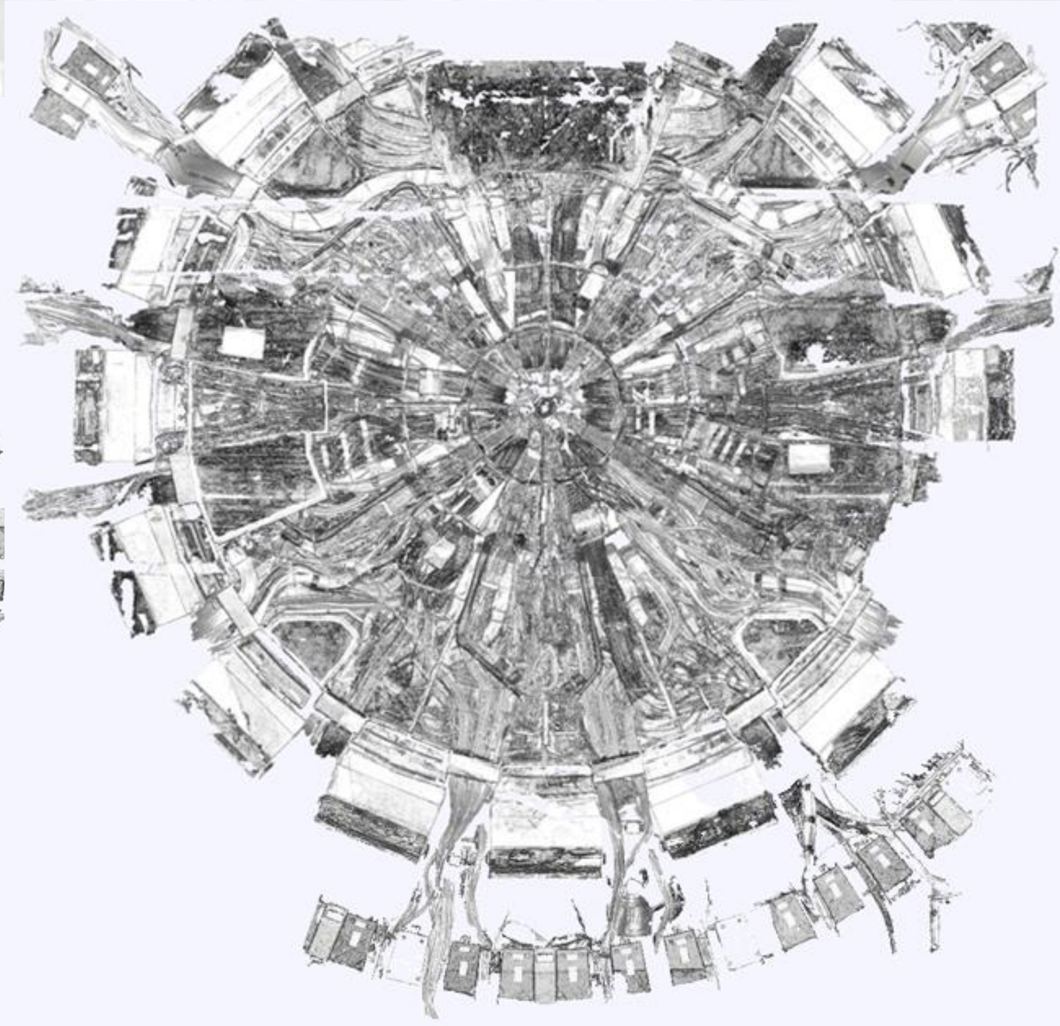
2 – POINT CLOUD PRE-TREATMENT & TREATMENT
Station assembly, geo-referencing, reducing and cleaning of point cloud – 1 week/side

EXAMPLES OF RECONSTRUCTIONS
ATLAS – ID Services on LAr Barrel Face

3 – MESH
Cleaning, division – 1 week/side



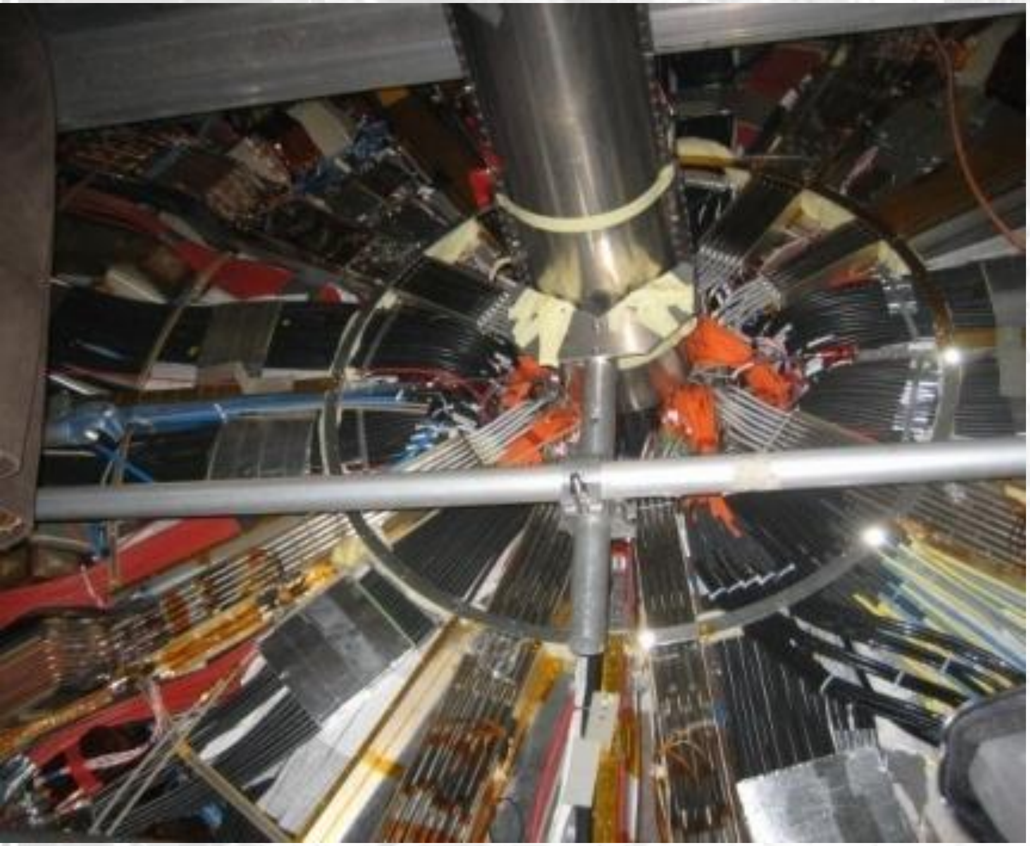
Mesh Side A
5 parts



Mesh Side C
6 parts

EXAMPLES OF RECONSTRUCTIONS
ATLAS – ID Services on LAr Barrel Face

AS-BUILT documentation for IBL, beampipe as well as tooling design

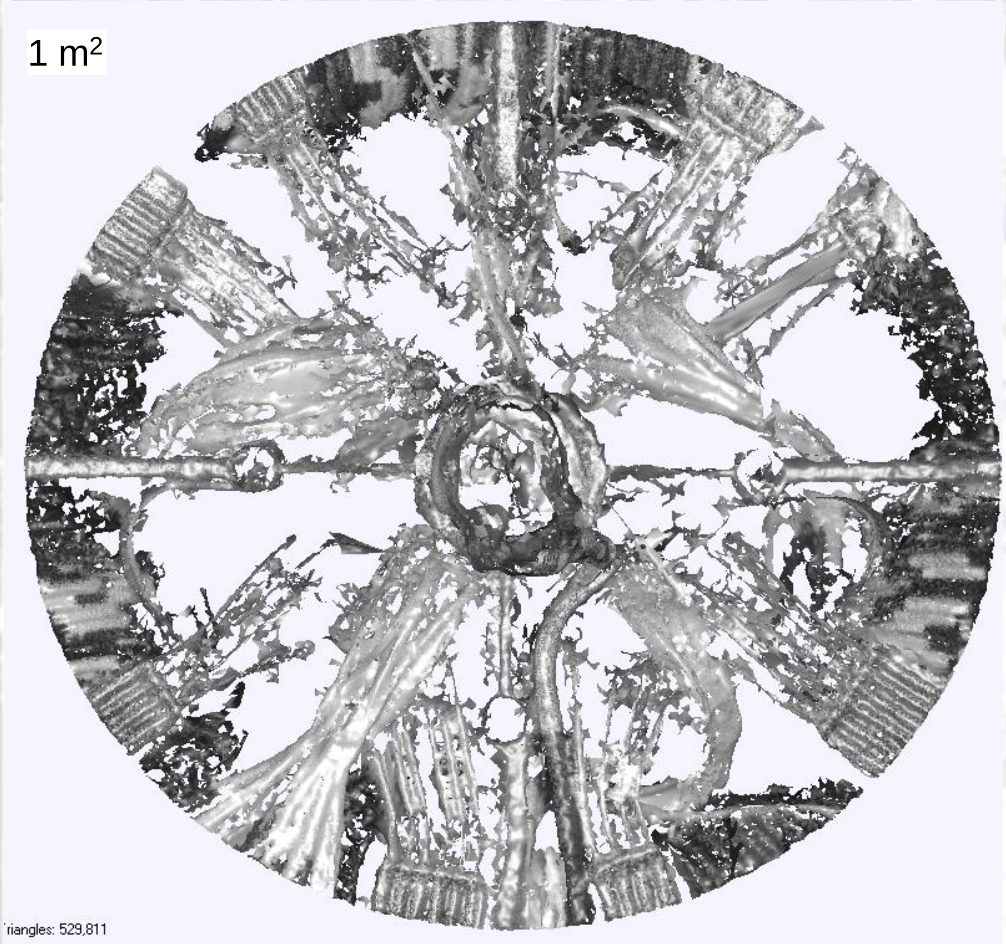


Zone of interest
1 m^2 around beampipe

Corresponding point cloud

EXAMPLES OF RECONSTRUCTIONS
ATLAS – ID Services on LAr Barrel Face

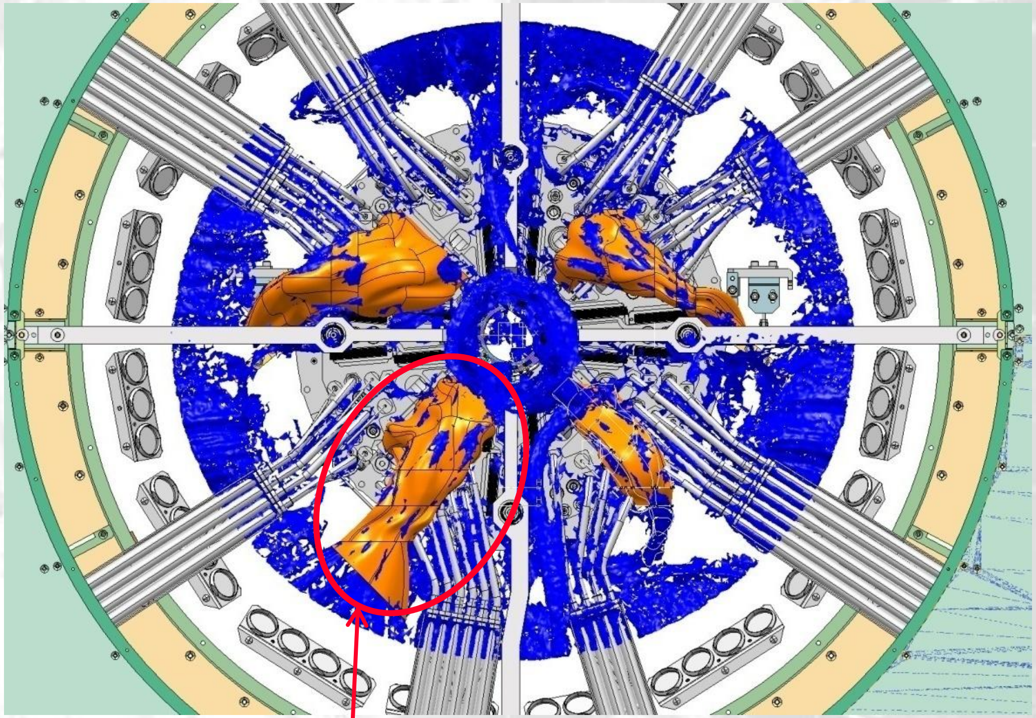
Triangulated mesh obtained



Insertion of the mesh in CATIA

Superposition with existing CAD model

Construction of lighter CATIA surface to
COMPLETE / UPDATE existing CAD data

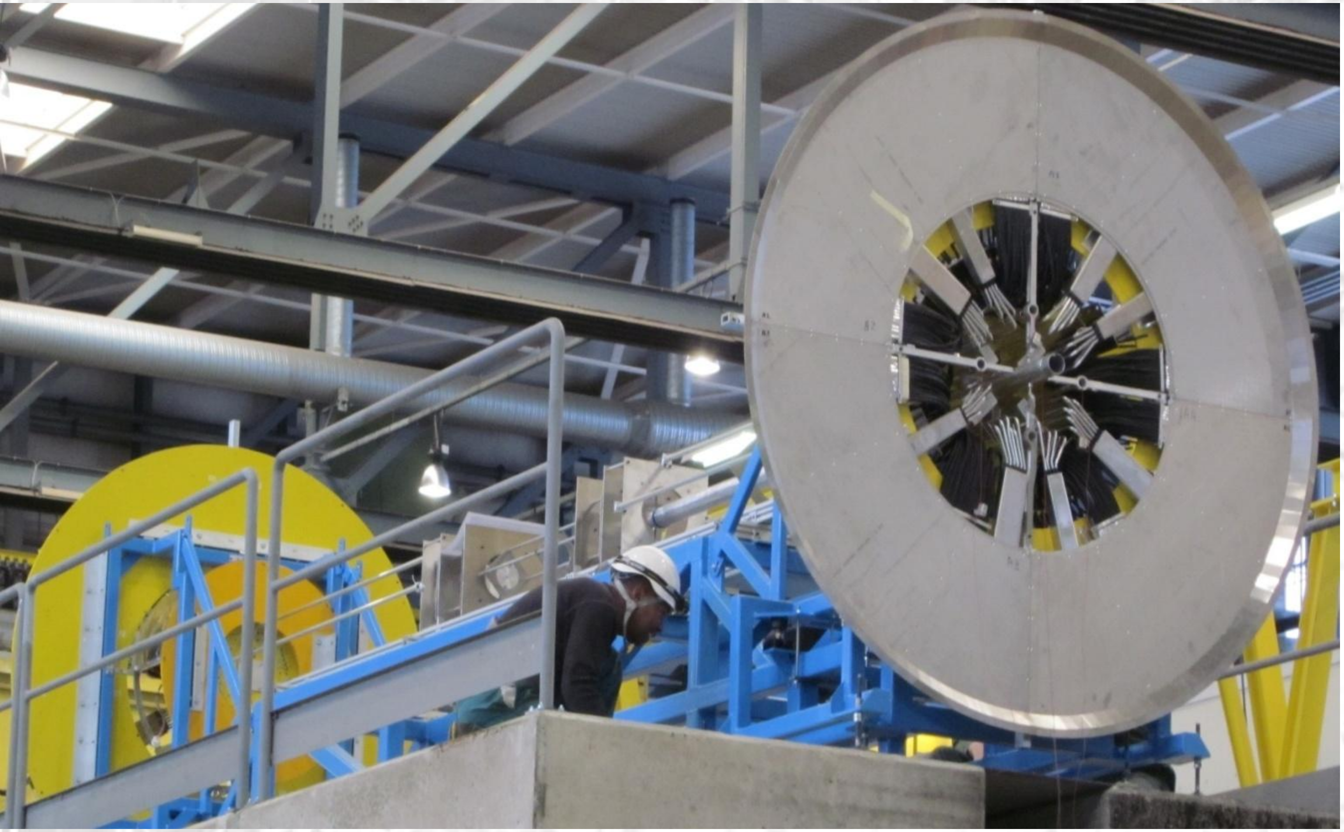


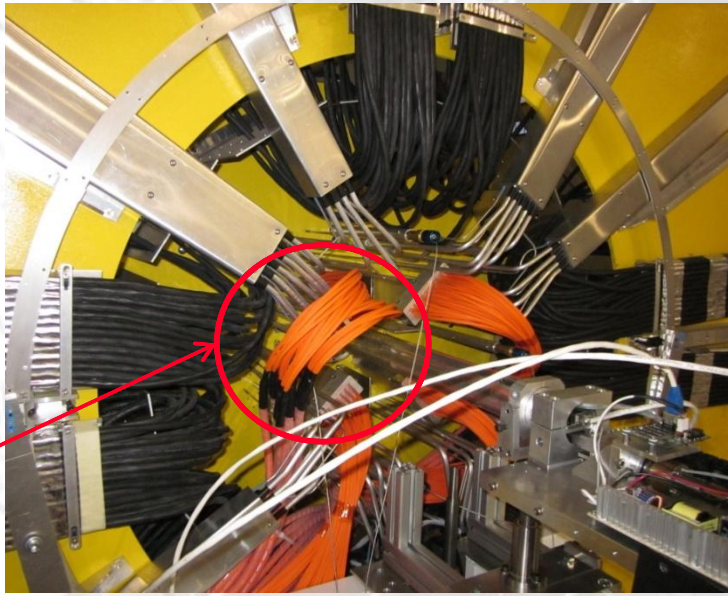
Cables not existing in CATIA CAD model

EXAMPLES OF RECONSTRUCTIONS
ATLAS – ID Services on LAr Barrel Face

Scale 1/1 mock-up of ATLAS ID Services on LAr Barrel Face

A mock-up for TRAINING OF TEAMS, to LIMIT INTERVENTION TIME in these POTENTIALLY RADIOACTIVE AREAS





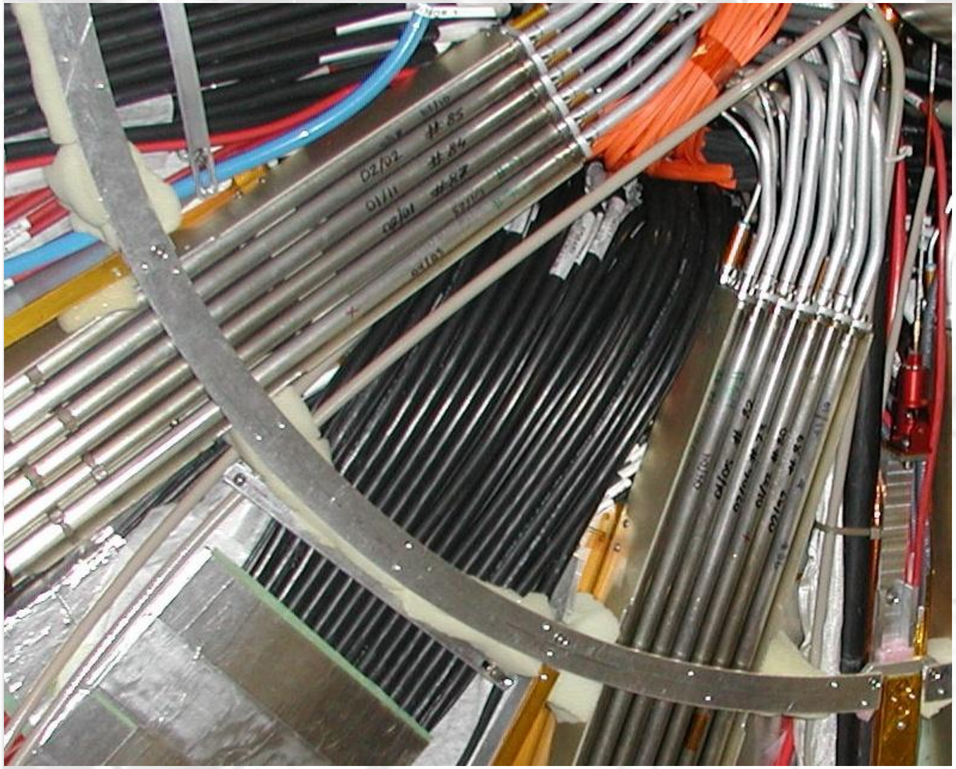
Cables not existing in CATIA CAD model

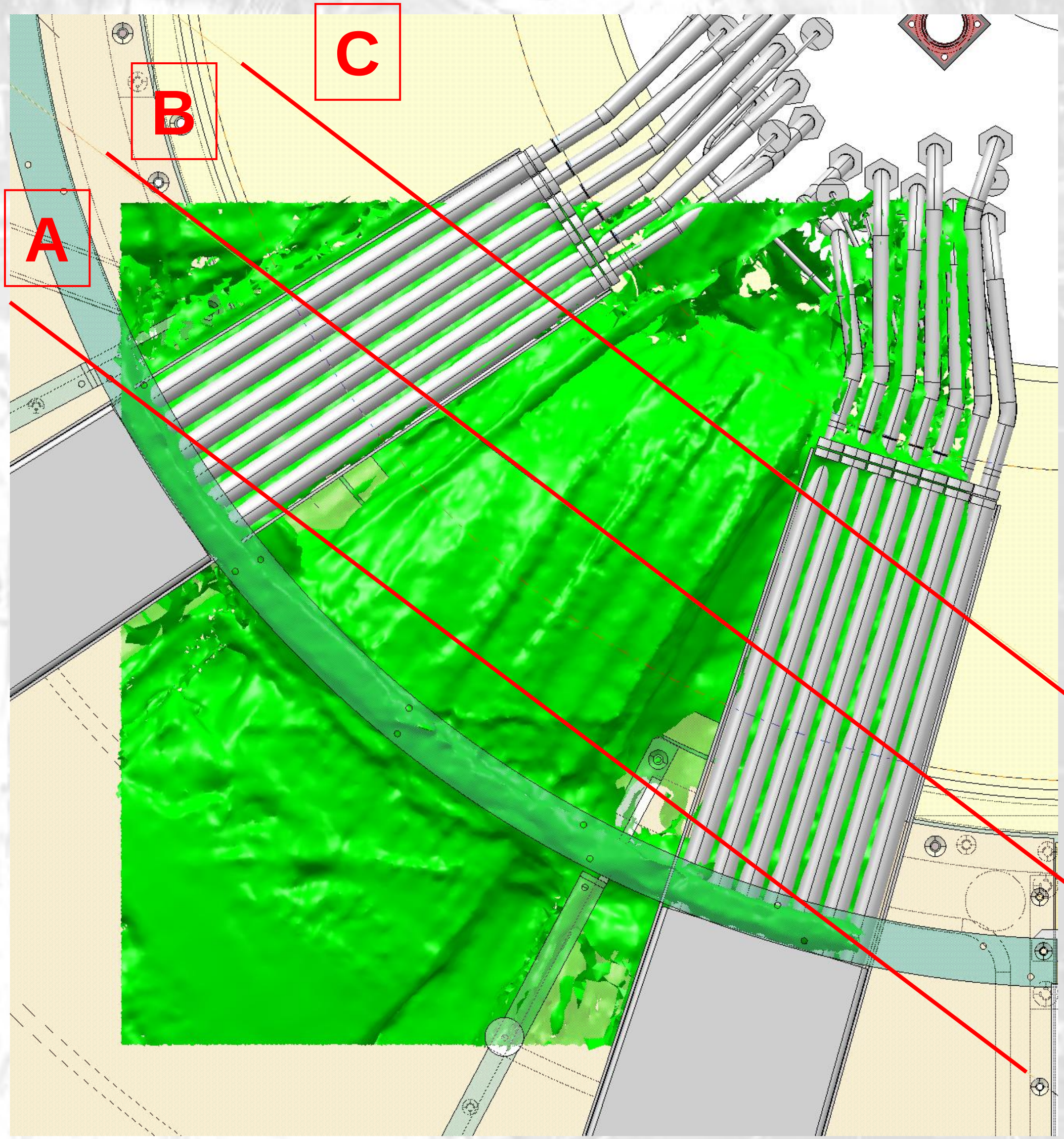
CATIA work: Sébastien MICHAL (PH/ADO)

EXAMPLES OF RECONSTRUCTIONS
ATLAS – ID Services on LAr Barrel Face

CHECKING OF NEW CABLE PASSAGES IN 3 LOCATIONS

Use of the scan to plan and check IBL project

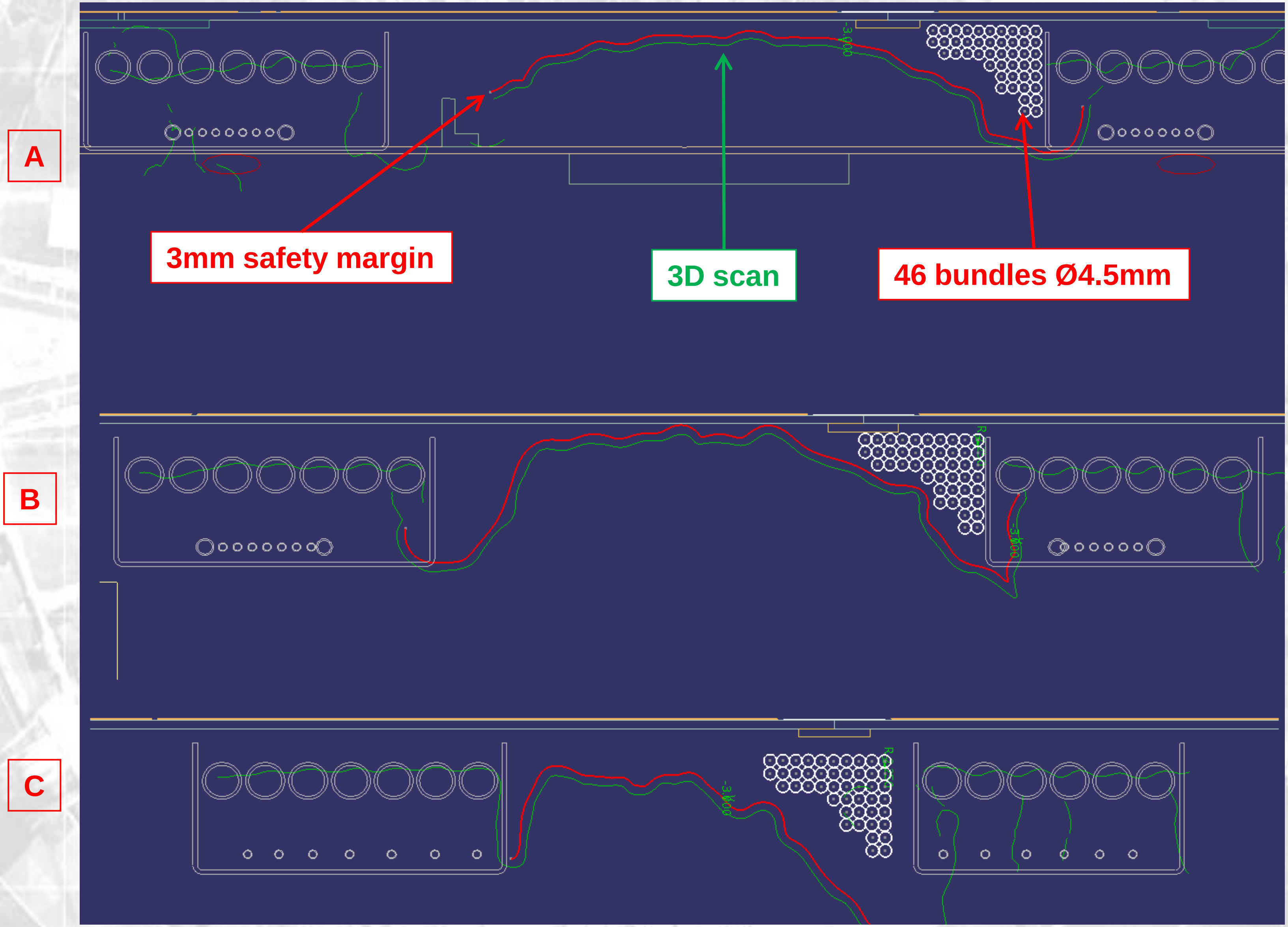




CATIA work: Erik RICHARDS (PH/ADO)

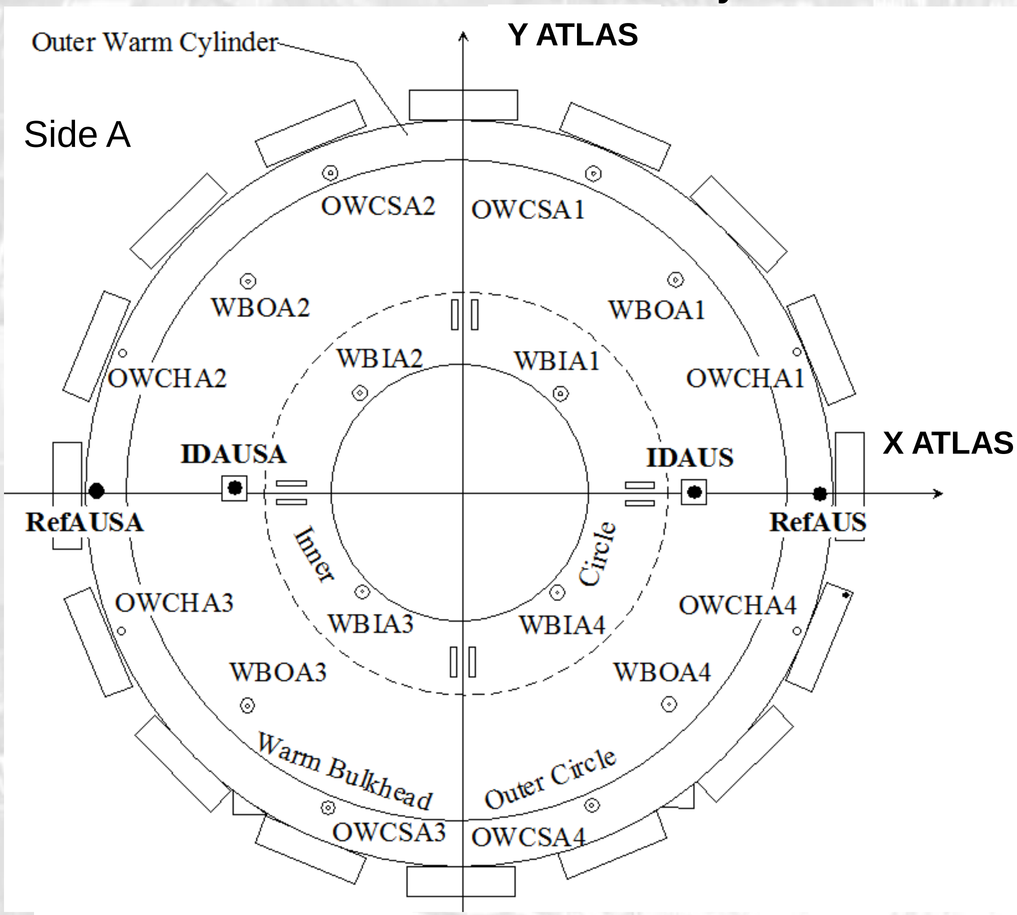
EXAMPLES OF RECONSTRUCTIONS
ATLAS – ID Services on LAr Barrel Face

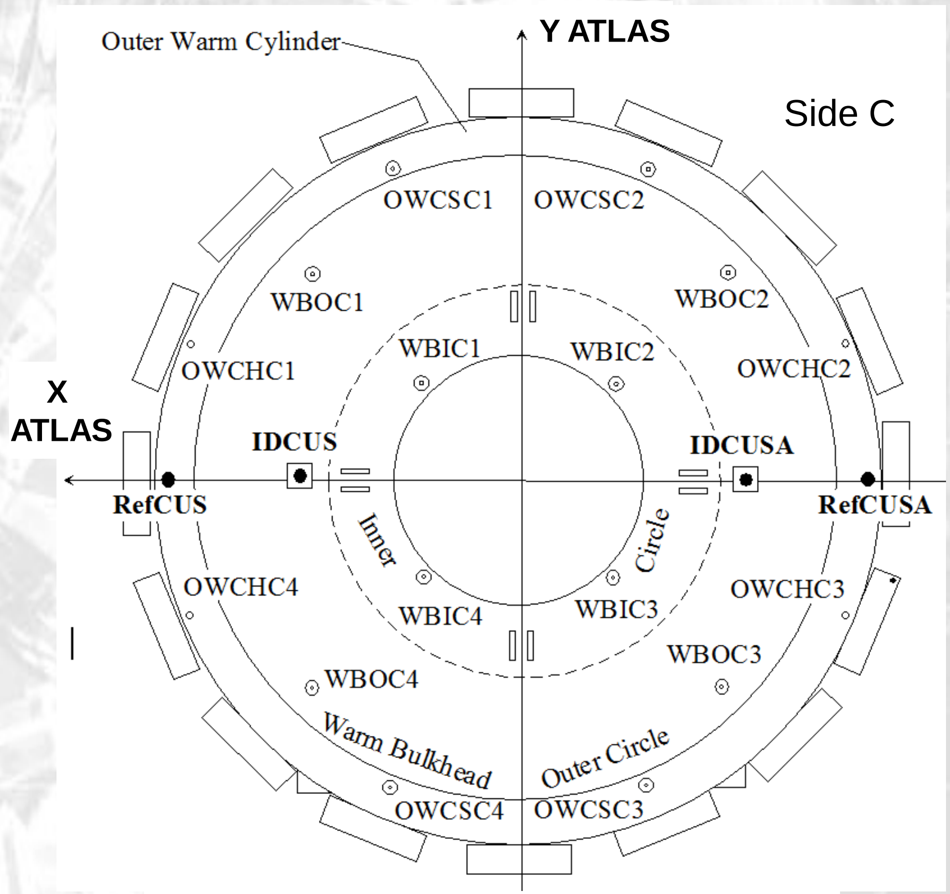
CHECKING OF NEW CABLE PASSAGES IN 3 LOCATIONS

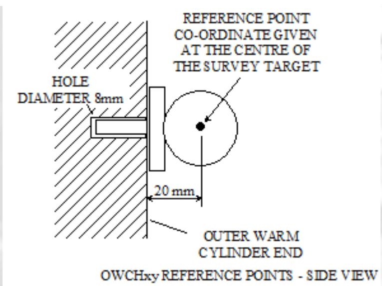


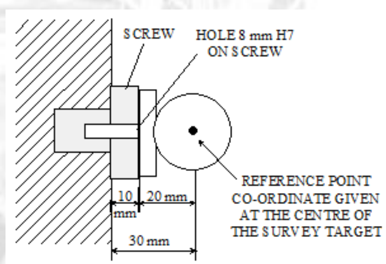
EXAMPLES OF RECONSTRUCTIONS
ATLAS – ID Services on LAr Barrel Face

Survey references on ATLAS LAr Barrel Face









⊙ Ref. points, hole diameter 8 mm H7 on screws

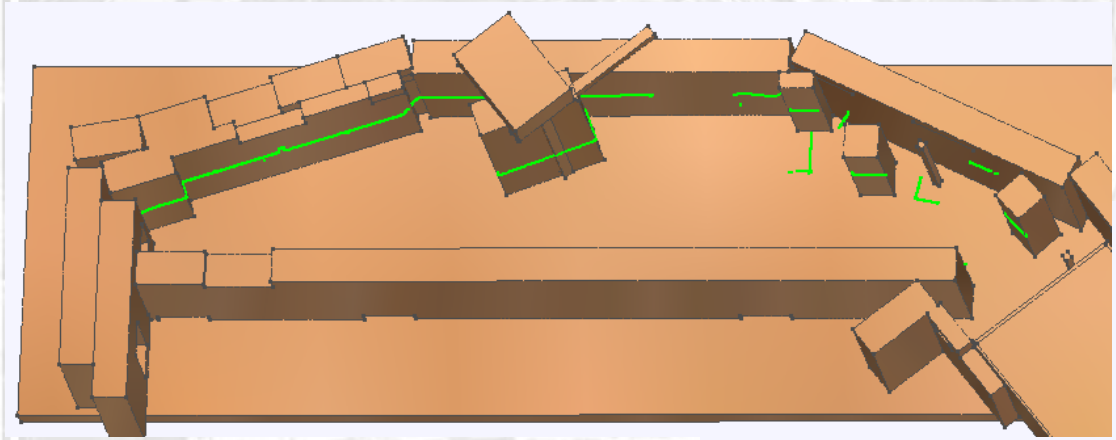
◦ Cylinder Ref. holes diameter 8 mm H7 on cylinder end

Scan coordinates compared with standard survey data :

- **along XY ATLAS : +/- 2 mm**
- **along Z ATLAS : +/- 3 mm**
- **distances between reference points : + 3 mm**

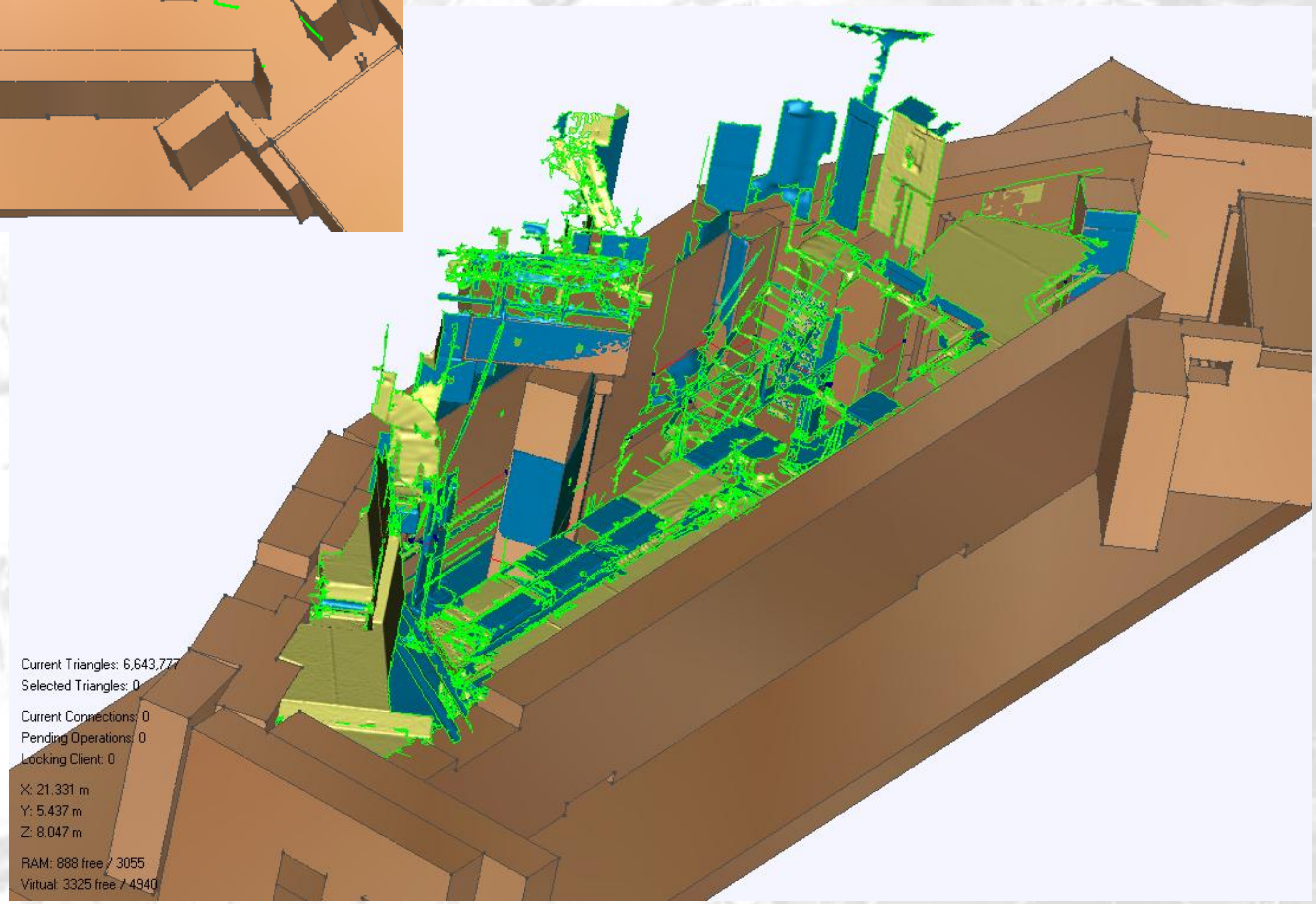
EXAMPLES OF RECONSTRUCTIONS
ZONE AEGIS

A scan to UPDATE CAD model



Measurements : Scan : 2 days, 3 stations
Standard survey : 1 day
Data processing : 2 weeks

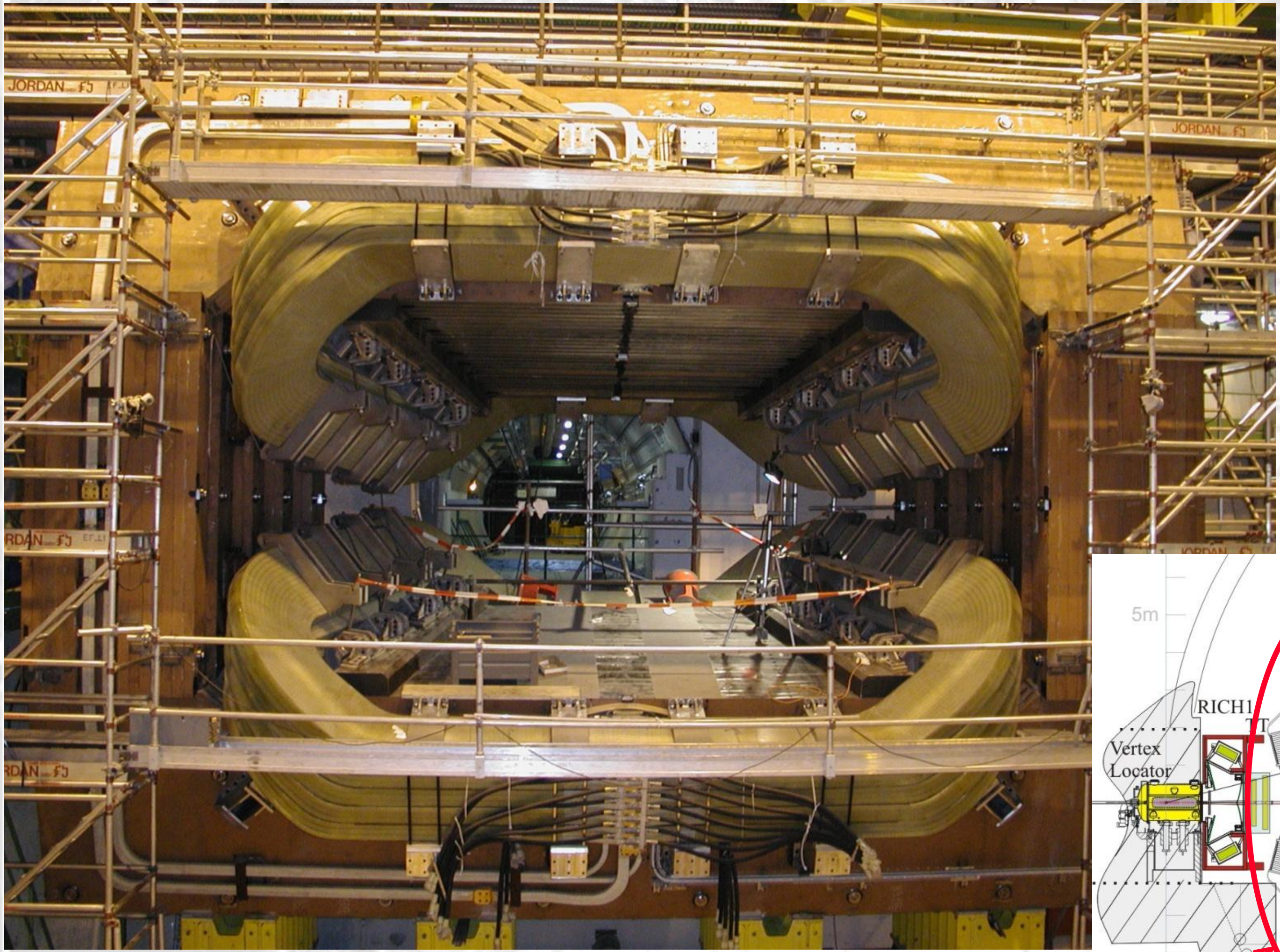
LEICA HDS 3000
BE/ABP-SU
October 2009



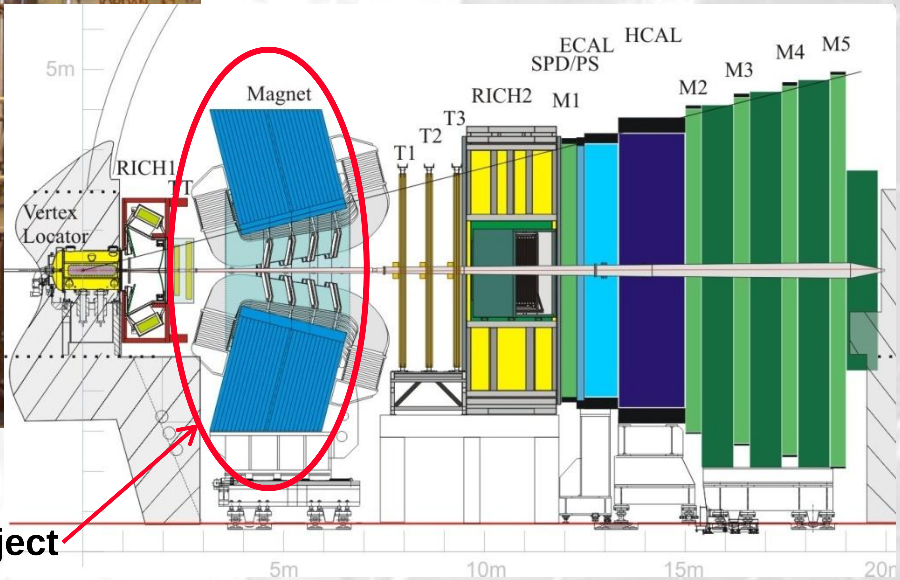
CATIA work : Didier GABRIELE (PH/DT-PO)

EXAMPLES OF RECONSTRUCTIONS
LHCb – MAGNET COIL

A scan to POSITION THE AS-BUILT LHCb MAGNET COIL in CATIA CAD model



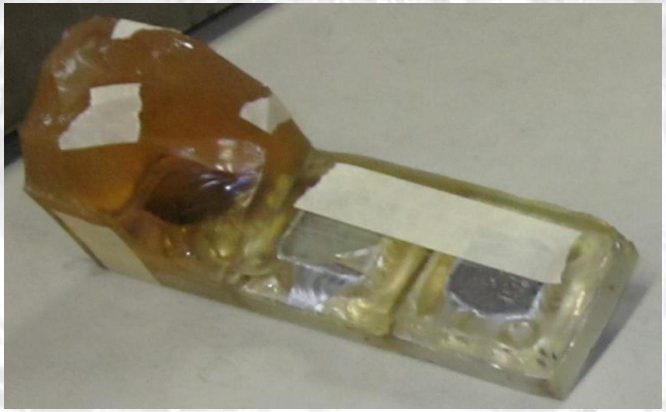
Old picture before installation of detectors

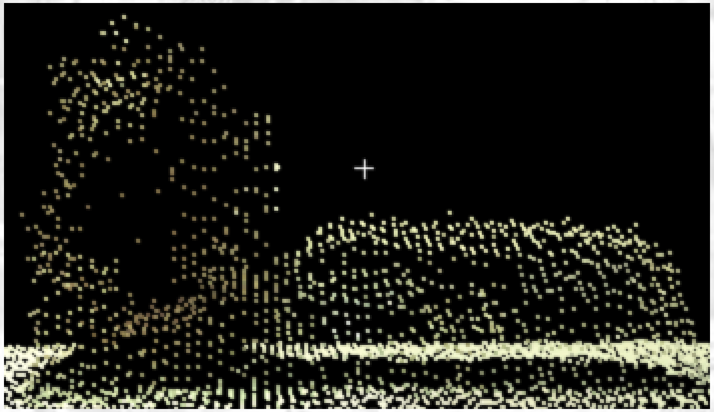


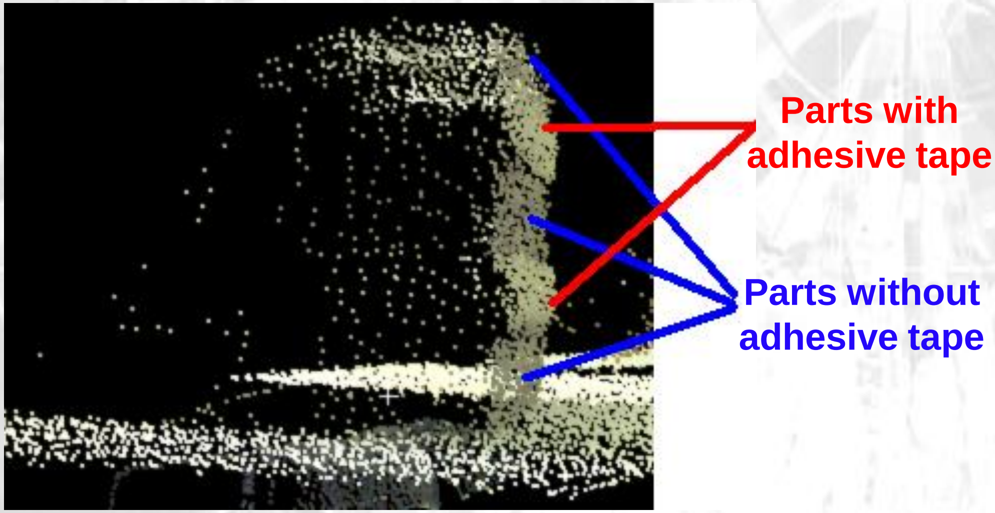
Measured object

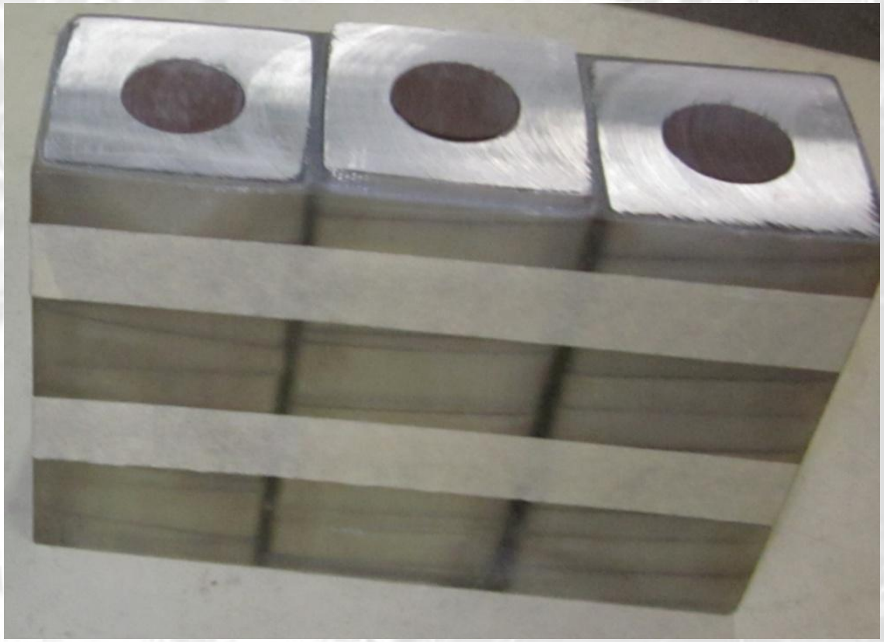
EXAMPLES OF RECONSTRUCTIONS
LHCb – MAGNET COIL

Tests on resin (semi-transparent) similar to LHCb magnet coil prior to in-situ measurement







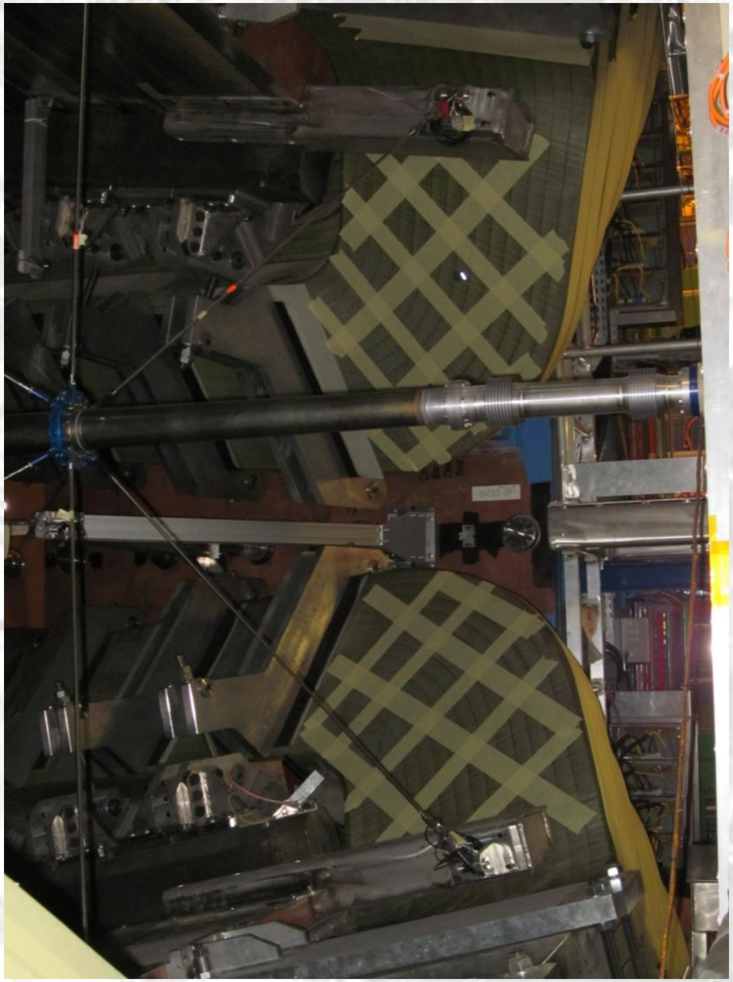


Distance between points on parts with adhesive tape and points on parts without adhesive tapes is 7-8 mm

EXAMPLES OF RECONSTRUCTIONS
LHCb – MAGNET COIL

LEICA HDS 3000, BE/ABP-SU – August 2011

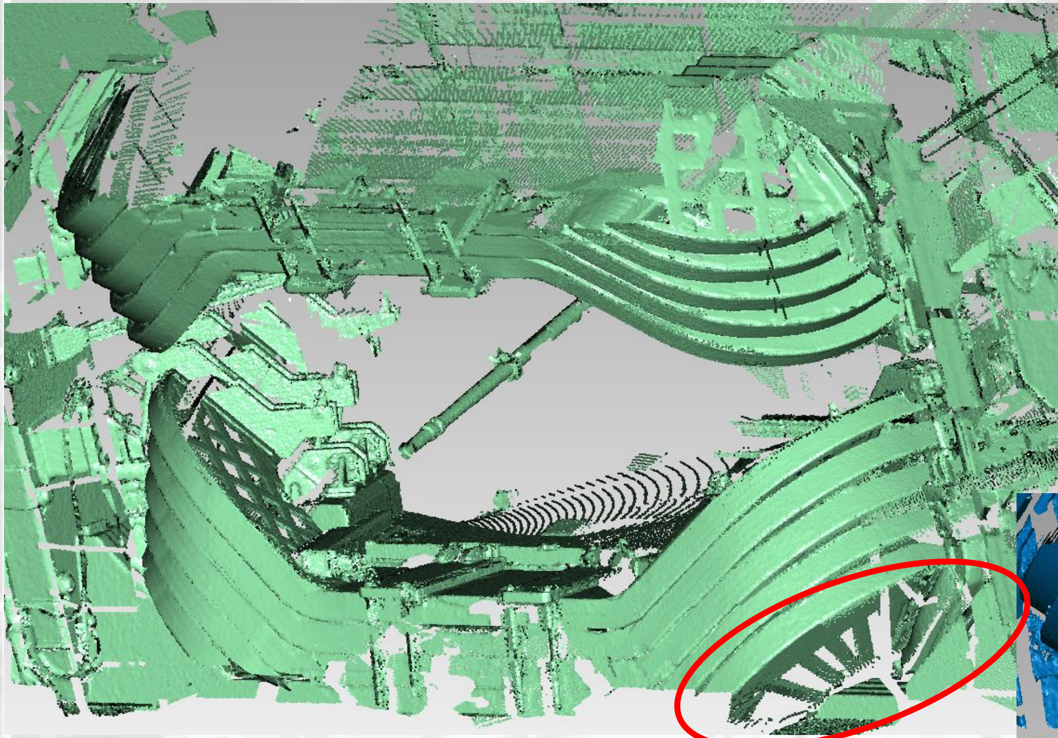
Measurements : **Scan : 1 day, 5 stations**
Standard survey : 1 day
Data processing : Pre-processing and scan reconstruction done.
To be implemented in CAD 3D model by project office.



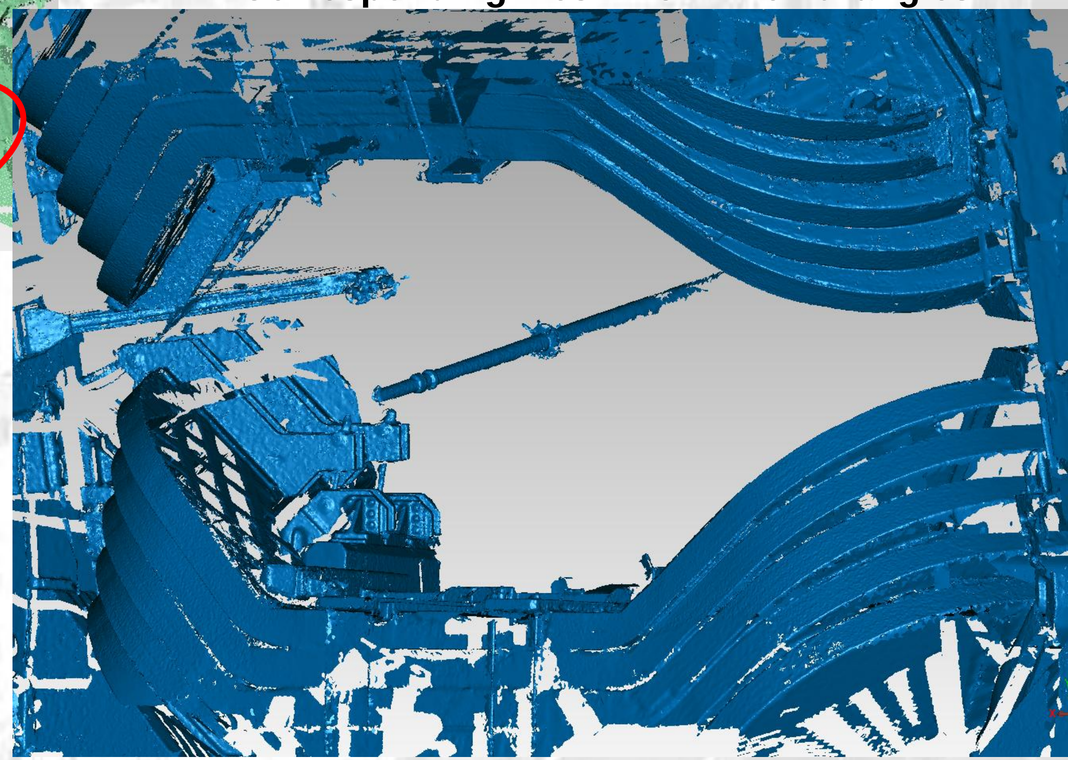
Collaboration : Olivier JAMET (PH/DT-PO)

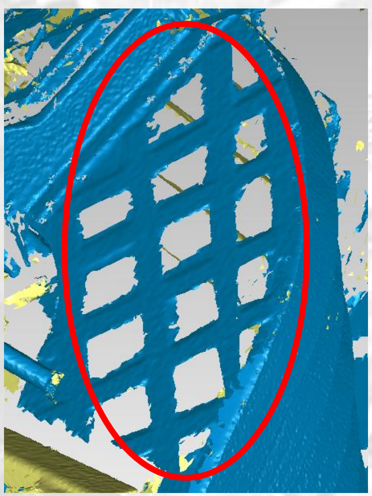
EXAMPLES OF RECONSTRUCTIONS
LHCb – MAGNET COIL

Point cloud – 5 million points
Assembly and referencing accuracy : +/- 2mm



Corresponding mesh – 8 million triangles

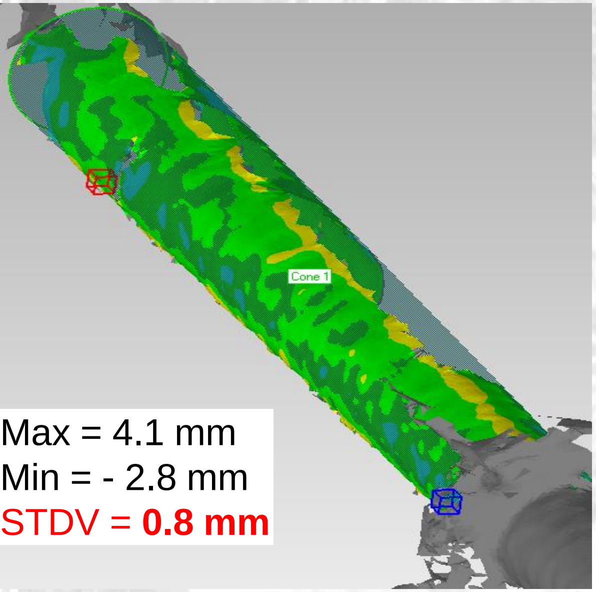




Traces from adhesive tape

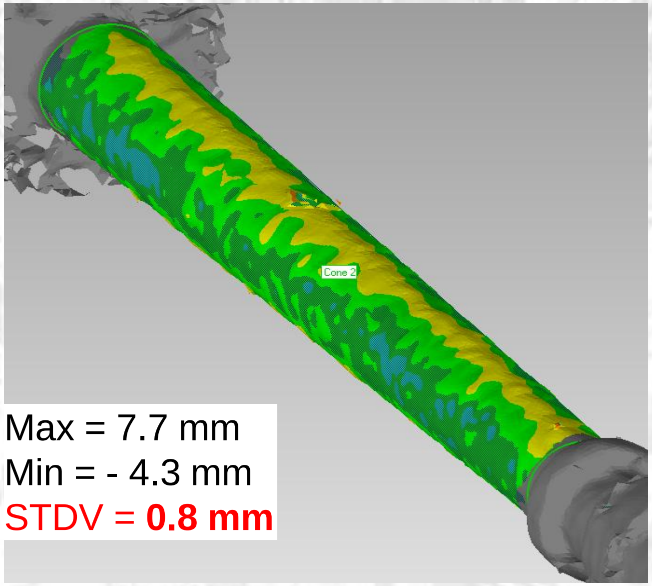
EXAMPLES OF RECONSTRUCTIONS
LHCb – MAGNET COIL

Beampipe position – cone reconstruction



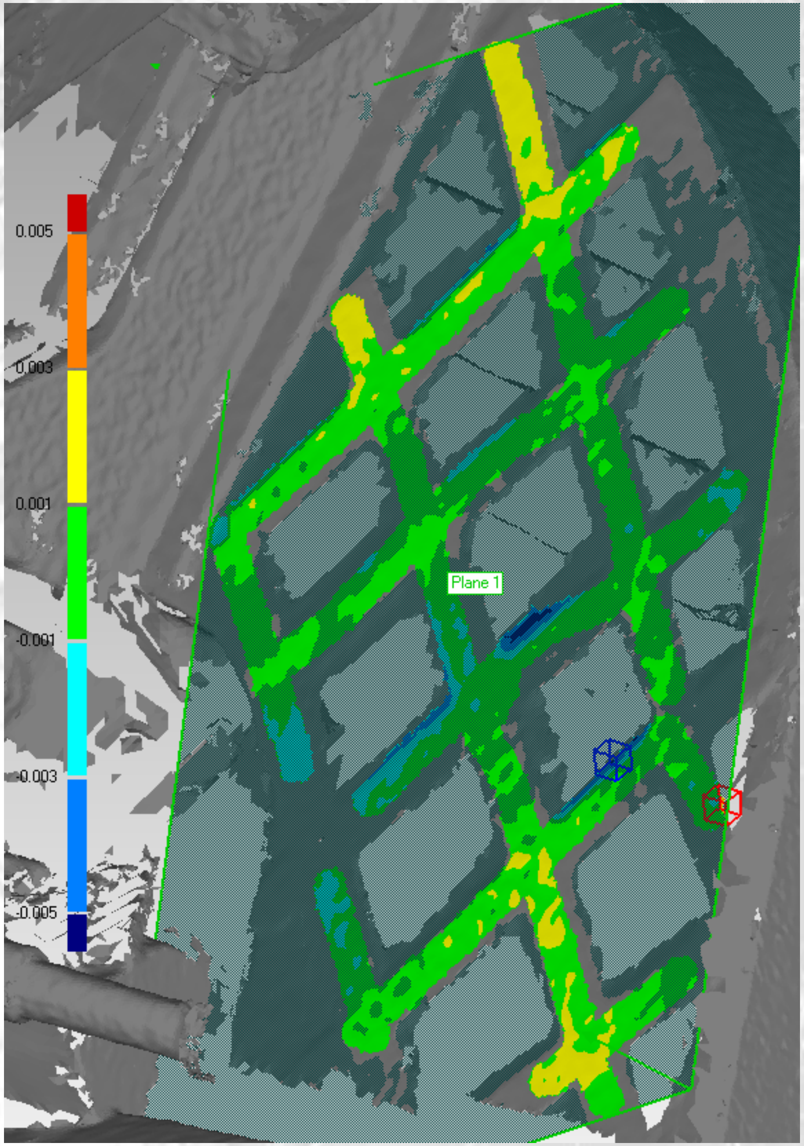
Max = 4.1 mm
Min = - 2.8 mm
STDV = **0.8 mm**

Base Point:	0.0012, 0.0001, 4.0587 m
Direction:	0.002, -0.002, 1.000



Max = 7.7 mm
Min = - 4.3 mm
STDV = **0.8 mm**

Base Point:	-0.0002, 0.0001, 3.2623 m
Direction:	0.001, -0.001, 1.000

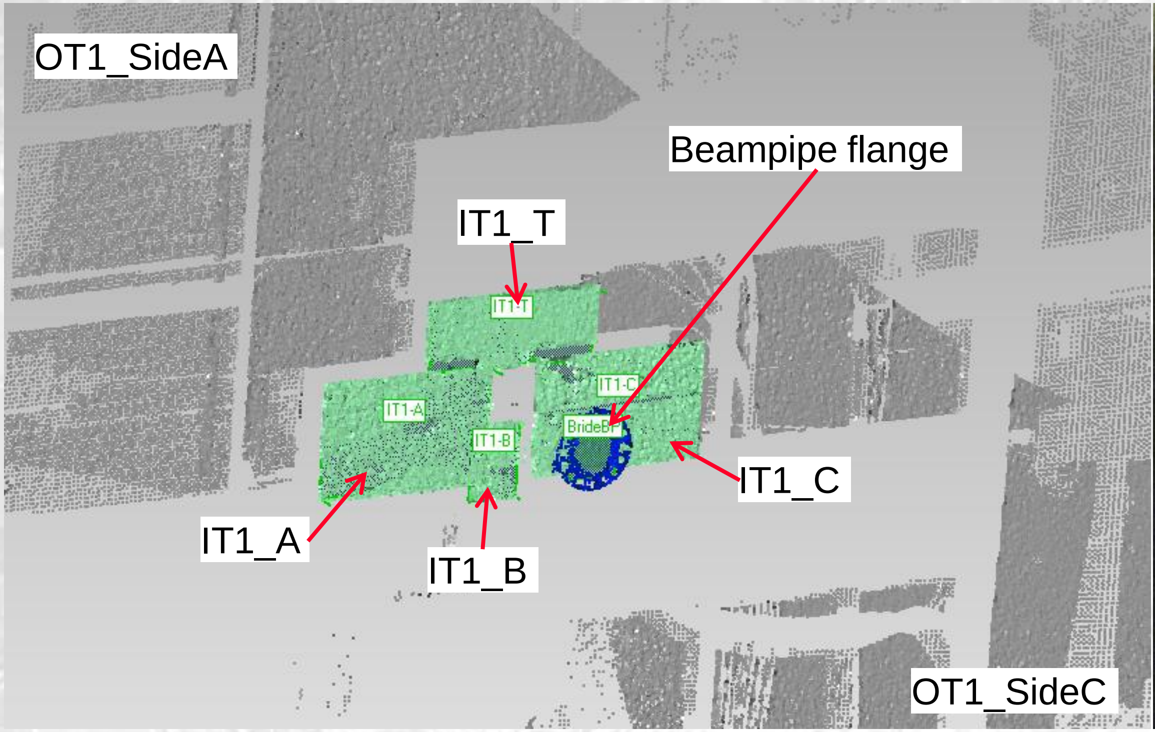


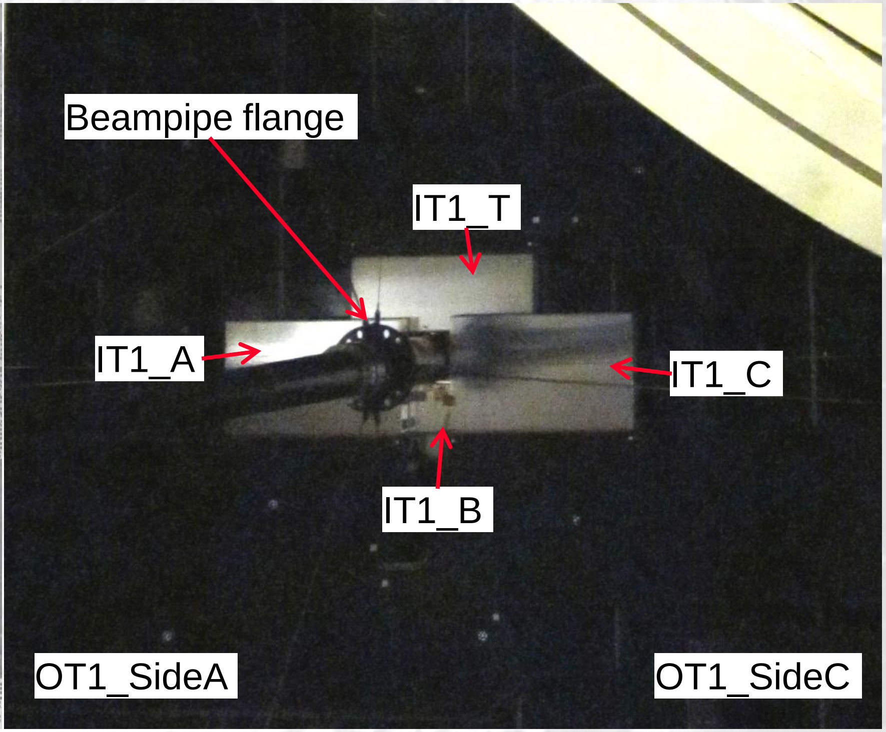
Flatness of magnet part – plane calculation

Center:	-1.8463, -0.6176, 3.8522 m
Normal:	0.673, 0.642, 0.368
Principal:	0.740, -0.584, -0.335

Max = 5.3 mm
Min = - 6.7 mm
STDV = 1.0 mm

EXAMPLES OF RECONSTRUCTIONS
LHCb – MAGNET COIL

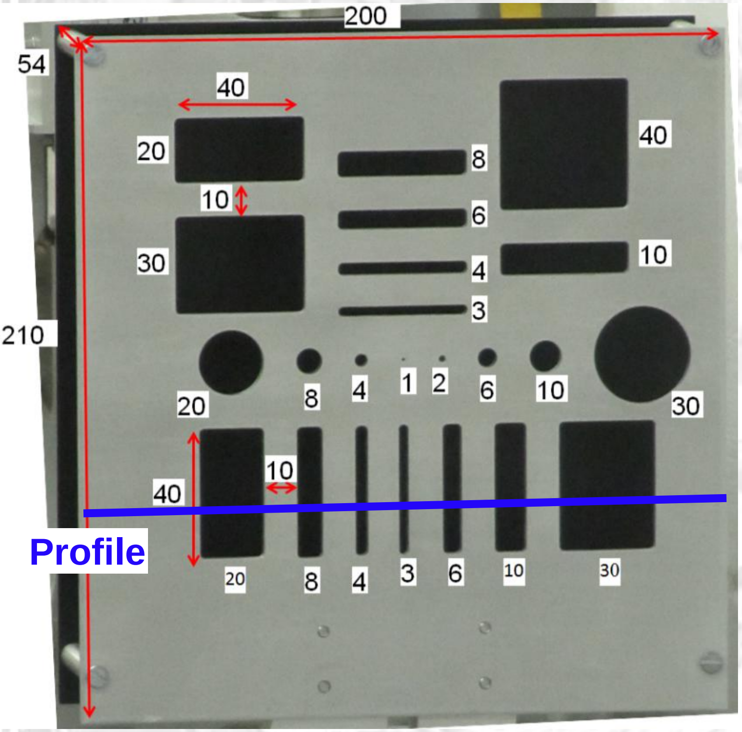




Scan coordinates compared with standard survey data :
- in XY phys : +/- 2 mm
- in Z phys : +/- 3 mm

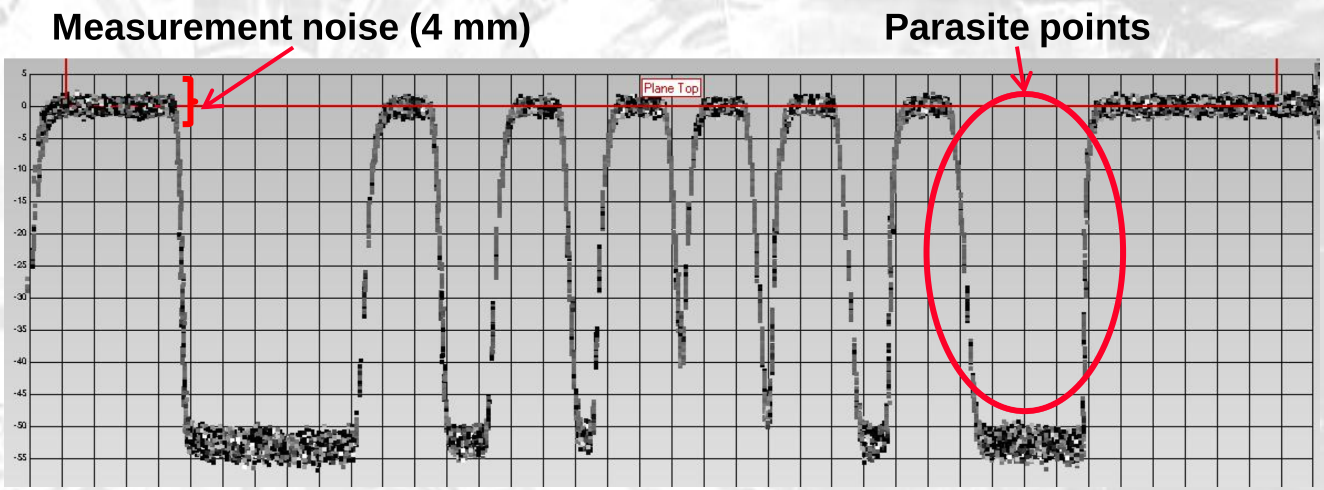
DIFFICULTIES MEASUREMENTS

Problems of laser scanning systems measurements : noise, create parasite points



Box composed of 2 parallel plates, distant of 54 mm, with cut-outs on the top

Leica HDS 6200 measurement at 2.5 m from the box with maximal resolution



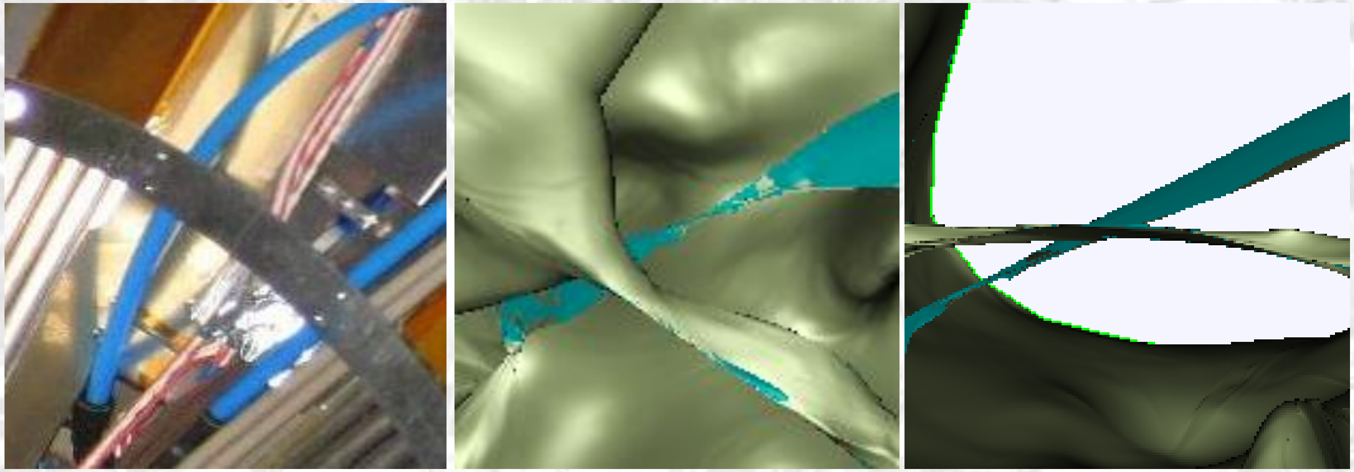
Grid scale: 5 mm * 5 mm

	Exit size [mm]	Divergence [mrad]
Leica HDS6200	3	0.22

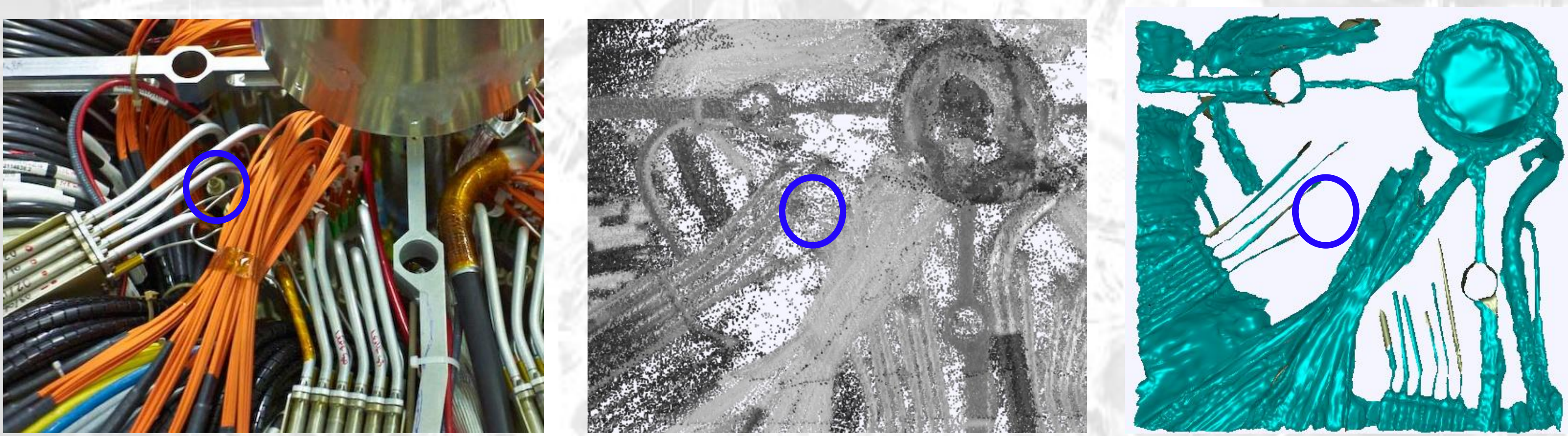
What can be measured depends of the size of the laser beam and of the distance between instrument and object

Difficult surfaces to measure for laser scanning systems : reflective, transparent, black

DIFFICULTIES
RECONSTRUCTION



Difficulties with superposed objects



Difficult mesh construction on surfaces with a too low point density

CONCLUSION

Characteristics :

- Flexible method can be used for all machines and experiments
- Optimize efficiency and reduce exposure to radiations
- Non-contact measurement
- Instrument needs to be adapted to object (size, precision, resolution)
- Short acquisition time
- Needs geo-referencing
- Accuracy +/- 3 mm for equipment used up to now at CERN
- Softwares for treatment (CATIA and Geomagic)

Provides as-built data for :

- Integration
- Update 3D model
- Documentation
- Reverse engineering
- Base for automated intervention
- Quality control

Collaboration

BE/ABP-SU : Measurement, pre-processing

Project Office : Modelling...

CONCLUSION

Scan contacts:

For experiments

- **Aurelie.Maurisset@cern.ch**
- **Dirk.Mergelkuhl@cern.ch**

For accelerators

- **Tobias.Dobers@cern.ch**

Equipment:

- **HDS3000**
- **HDS6200 (soon)**
- **Geomagic licenses contact:**
  - **C. BAULT, A. MAURISSET**
  - **D. MERGELKUHL**

Thanks for your attention!

Thanks to all the participants to the 3D scan cooperation!