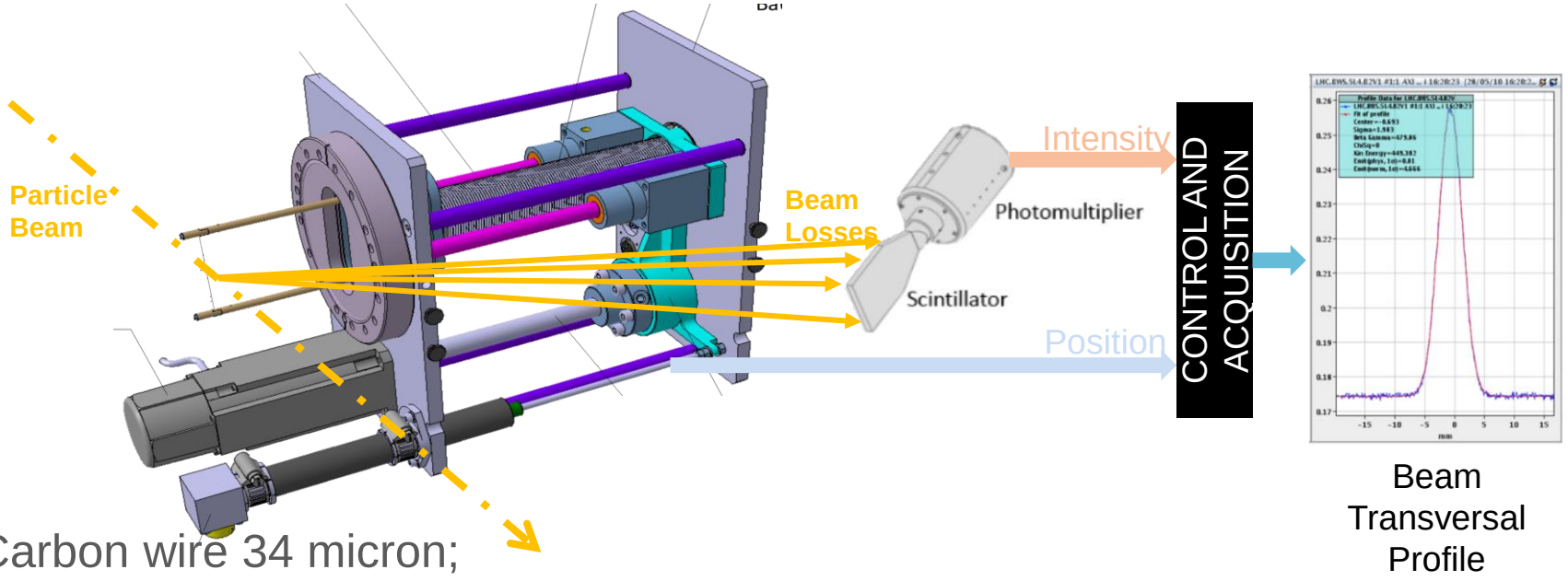
Low Density Wires: implementation during LS3 (and beyond)

C. Pasquino, R. Veness, W. Andreazza, H. Sullivan, G. Aliana, J. Emery, F. Roncarolo

HL-LHC Beam Halo Review

Beam Wire Scanners in the LHC



Beam Transversal Profile

- Carbon wire 34 micron;
- Scanning speed 1 m/s;
- 10 micron of the beam size accuracy;
- Use case: LHC injection energy, few bunches only; used to calibrate the BSRT.

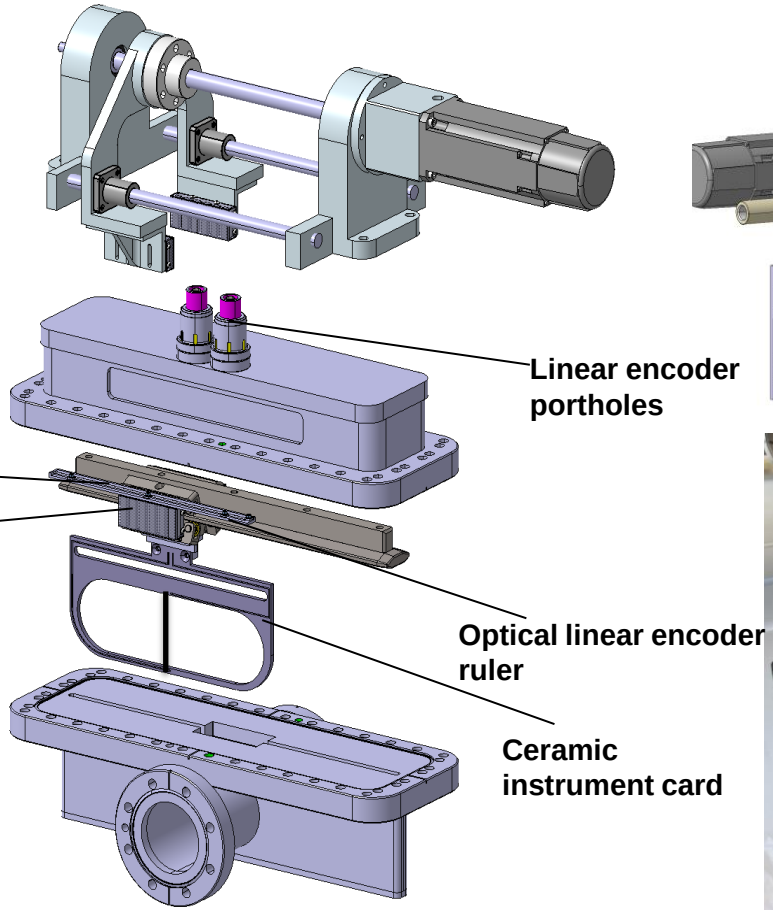
Beam Wire Scanners in the LHC

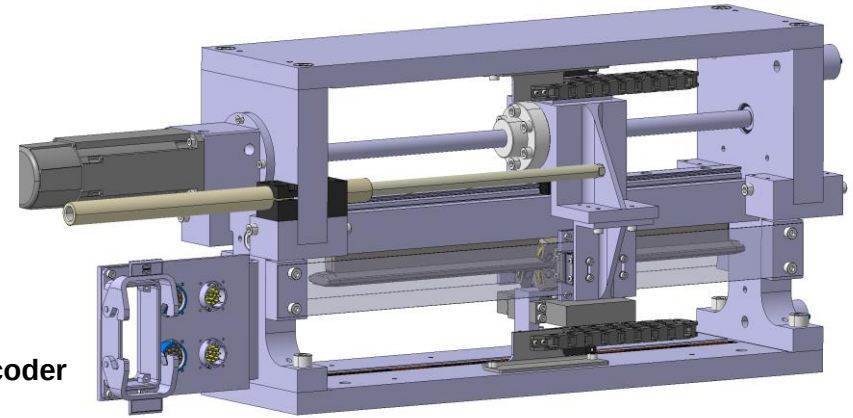
- 8 BWS: 2 per plane per beam;
- 4 Legacy systems inherited from LEP;
- 4 Hybrid+, featuring new electronics and new feedthrough: intermediate implementation to bridge to the new generation of WS.

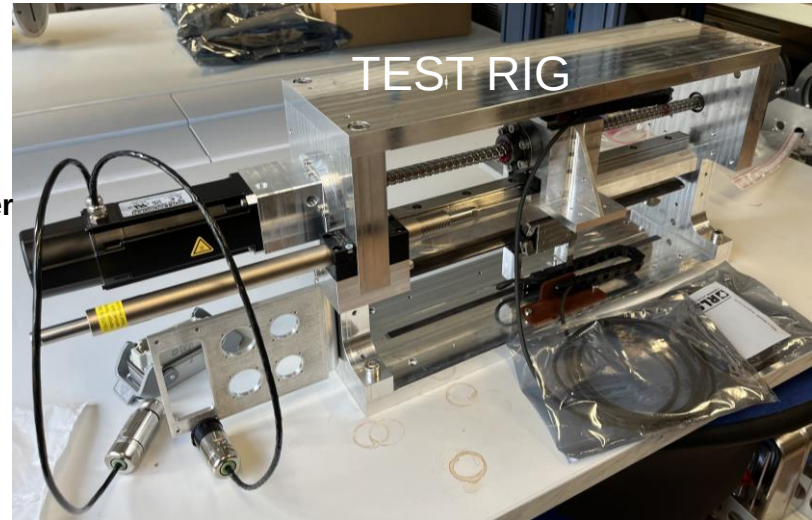
Beam Wire Scanners in the LHC - CONS

- Approved CONS program: EDMS 2282009 - Consolidation of LHC Beam Wire Scanner Electro – Mechanics;
- Improve performance
  - Reduce vibrations;
  - Reduce position uncertainty;
  - Improve positional resolution;
- Improve reliability
  - Reduce intervention frequency;
- Broaden the use case
  - Potential for use as halo monitor;
  - Higher intensity measurement – can be designed to support CNT implementation;

Beam Wire Scanners LHC CONS - STATUS



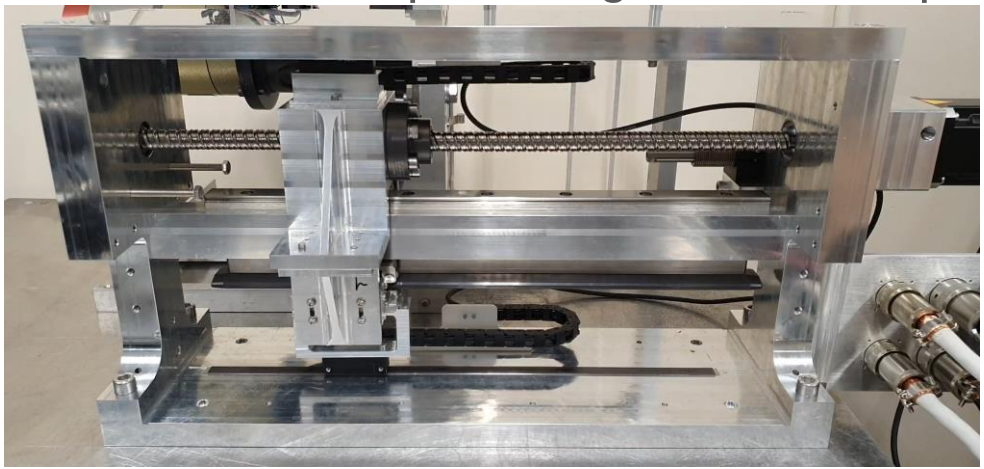




Pre-LS3 Development Phase

What is already designed (completed), installed, validated

- Magnetic coupling validated with the test rig;
- Adaptation of the control system to the new mechanism;
- Mechanical design well advanced – detailed design with MME to start in January;
- Impedance design well advanced – longitudinal impedance studies completed, transverse to be computed together with a power loss map;



Pre-LS3 Development Phase

What is planned and expected to be implemented before LS3

Roadmap up to LS3:

- Instrument design and development:
  - Impedance prototype to be installed in YETS 2025-2026 for beam validation;
  - Detailed mechanical design, with feedback from beam validation;
  - Test rig testing campaign for carriage lifetime and controls validation;
- CNT R&D:
  - HRMT tests foreseen in 2025 in the shadow of the 4 experimental weeks;
  - Dedicated HRMT week in 2026;
  - Installation of a CNT in the SPS linear wire scanner during YETS24-25;
  - Feasibility study for CNT gold ball bonding technique;
  - Assessment of the carbon (or CNT) wire position determination of the future scanner using laser system in the lab

LS3 Implementation Phase

- Confirmed installation plans:
  - 4 BWS to be installed (2H+2V);
  - Vacuum layout discussed with VSC;
  - Cabling request filed, PLAN 12763 .
- Non confirmed plan and open items requiring resolution/decision: → see next slides
  - Technical challenges
  - Resource gaps
  - Approval/coordination needs, including support from integration, cabling, vacuum and other groups/teams/units

Technical challenges

Use Case 1 : Scanning the full beam

- Measurement that comes for ‘’free’’ by replacing the standard C wire with a CNT.
- R&D activities:
  - CNT tension tests;
  - CNT assembly on the card by gold ball bonding;
  - Vibrations studies;
  - Braided wires – possible solution?

Suitable for SPS full scans at flat top

Use Case 2 : Scanning the Halo only

- Scan from 8.5 to 3.5 σ only, assuming beam fully symmetric.
- R&D activities & open points:
  - How to know where the 3.5sigma is systematically? Coupling with another technique needed.
  - Only half halo distribution;
  - Improved moving mechanism? Or preloaded?
  - Speed?
  - Wire exposure to beam?
  - Possible test on Hybrid+ calibration tests bench
  - Challenges in the controls – absolute position measurement needed.
  - Signal to background/noise ratio & related quenches?

Suitable for LHC partial scans at flat top

Resource gaps

- R&D on CNTs:
  - PhD position for CNT simulations;
  - PhD/GRAD for mechanical design implementation;
  - GRAD for CNT position measurement, motion control and electronics design;
- Material budget:
  - Prototype WS for CNT;
  - Equipment for nanomaterial handling;

Approval/coordination needs, including support from integration, cabling, vacuum and other groups/teams/units

- Depending on the strategy:
  - SPS installation, full beam scans at extraction:
    - All supports needed from SPS teams (integration, cabling, vacuum, survey) → feasible within LS3
  - LHC installation, halo beam scans at flat top:
    - All supports needed from LHC teams (integration, cabling, vacuum, survey) → longer timescale

Post-LS3 Phase

- Features/capabilities that
  - will be available after LS3 → none in the LHC
  - will need to be developed after LS3 → a proto WS for LHC
- Expected timeline for transition from expert to operational mode→ NaN ☺
- Known risks related to schedule and (also picking from 'technical' presentation before) performance → it is an R&D program, fully based on the material quality and characteristics!

Budget (and Other General) Considerations

- Budget status:
  - Cost estimates for development and implementation phase vs available budget → see slides above
  - Funding gaps to be addressed ? → yep!
- Long-term budget considerations:
  - Maintenance and operational costs, including manpower → depends on the scenario, could be in the shadow or not
  - Possible need for upgrade, anything can be already anticipated → see slides before.

Key Milestones

Phase	Timeline	Deliverables	Dependencies	Budget Status
Pre-LS3	By 2026	❑ HRMT test ❑ Material sim ❑ Material chemistry optimization ❑ Ball bonding	No dependencies	Covered
During LS3	By 2028?	❑ Proto for SPS	R&D dependecies	Not Covered
Post-LS3	?	❑ Proto for LHC	R&D dependencies	Not Covered

Conclusions

- Implementing a CNT wire within the new design of the linear wire scanner is feasible but entails R&D;
- In the SPS: the scanner could work in the full scan modes, LIU intensity and flat top energy;
- In the LHC: the scanner could work potentially from 8.5 to 3.5 σ, but with much more R&D required (timeline beyond LS3).

		2025												2026												2027											
		Q1			Q2			Q3			Q4			Q1			Q2			Q3			Q4			Q1			Q2			Q3			Q4		
		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	D
PROTO	Design Office - Proto																																				
	Impedance Design																																				
	Proto Fab																																				
	Impedance Meas																																				
	VSC Acc. Tests																																				
	YETS INSTALLATION																																				
	Impedance feedback with beam?																																				
SERIES	Raw material Proto + series																																				
	Design Office - Final Instrument																																				
	LHC Series Fabrication																																				
	LHC Series Motor test and Calib																																				
	Installation																																				
Dummy	Dummy vacuum chamber design																																				
	Dummy vacuum chamber production																																				
Lab tests	Test rig tests - lifetime carriage																																				
	Test rig tests - controls with mockup card																																				
	Test rig test with dummy vacuum tank																																				

		2027									2028											
		Q2			Q3			Q4			Q1			Q2			Q3			Q4		
		April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
PROTO	Design Office - Proto																					
	Impedance Design																					
	Proto Fab																					
	Impedance Meas																					
	VSC Acc. Tests																					
	YETS INSTALLATION																					
	Impedance feedback with beam?																					
SERIES	Raw material Proto + series																					
	Design Office - Final Instrument																					
	LHC Series Fabrication																					
	LHC Series Motor test and Calib																					
	Installation																					
Dummy	Dummy vacuum chamber design																					
	Dummy vacuum chamber production																					
Lab tests	Test rig tests - lifetime carriage																					
	Test rig tests - controls with mockup card																					
	Test rig test with dummy vacuum tank																					