FRBC3: SPS Fast Spill Monitor developments

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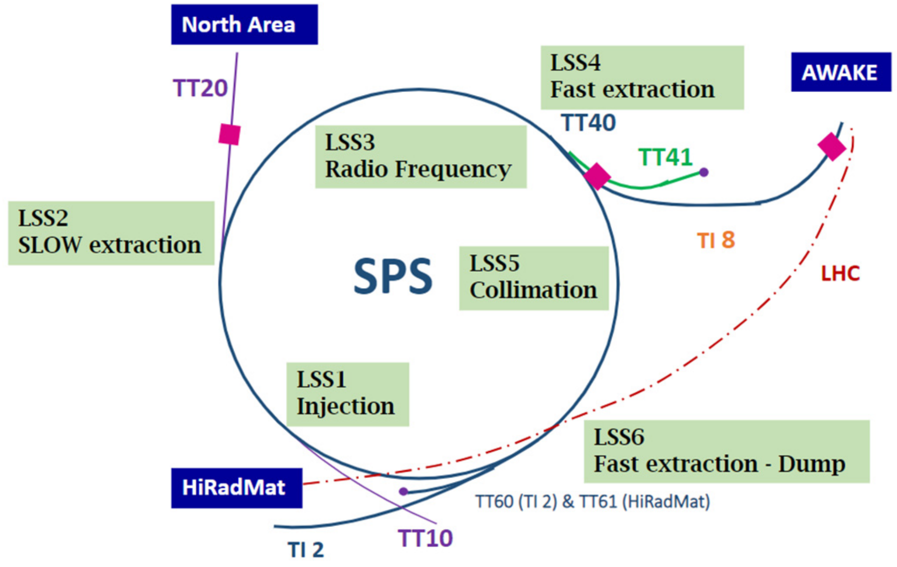
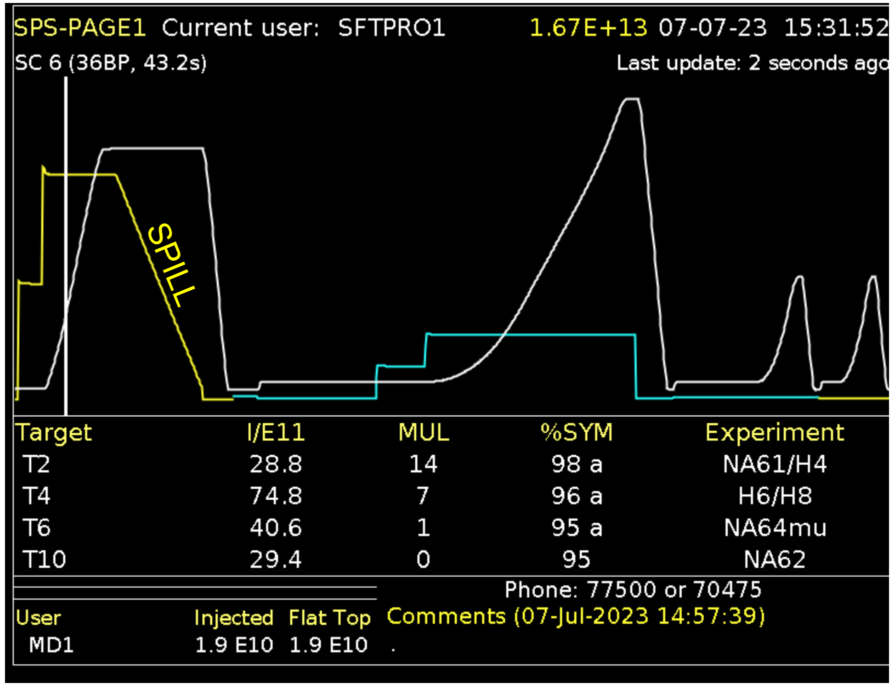
Outline

- SPS Spill Extraction to the North Area.
- Spill Monitoring General Requirements
- Fast Spill Monitor Prototypes
- Optical Transition Radiation- Photomultiplier Tube Monitor (OTR-PMT)
    - OTR-PMT First Prototype – Challenges, performances and issues.
- Cherenkov proton Flux Monitor (CpFM)
- Outlook and Future Work

SPS Spill Extraction





Slow resonant multi-turn extraction.

RF is disabled at the end of acceleration and the beam is de-bunched.

≈ 1 - 4x10^{13} protons at 400 GeV transferred **in spills** of 4.8 s, i.e., 2x10^{5} turns.

Spill Monitoring General Requirements

Parameter	Value or Range	Comment
Spill Duration	4.8 s 1 s	Present operation Future, e.g. PBC
Spill Intensity	1 e11p to 400 e11p	
Spectrum Harmonics of Interest	50 Hz,100 Hz 43.38 kHz 477 kHz 200 MHz 800 MHz 10 GHz	Noise, PC ripples SPS 1^{st} and 2^{nd} Harmonics[a] PS 1^{st} Harmonic[b] RF capture RF long, blow-up Future, e.g. PBC

[a] the SPS circulating beam structure includes 2×10.5 µs injections, spaced by a 1.05 µs *abort gap* for the dump kickers rise.

[b] The slow extracted beam can still contain a time structure from the Proton Synchrotron (the SPS injector).

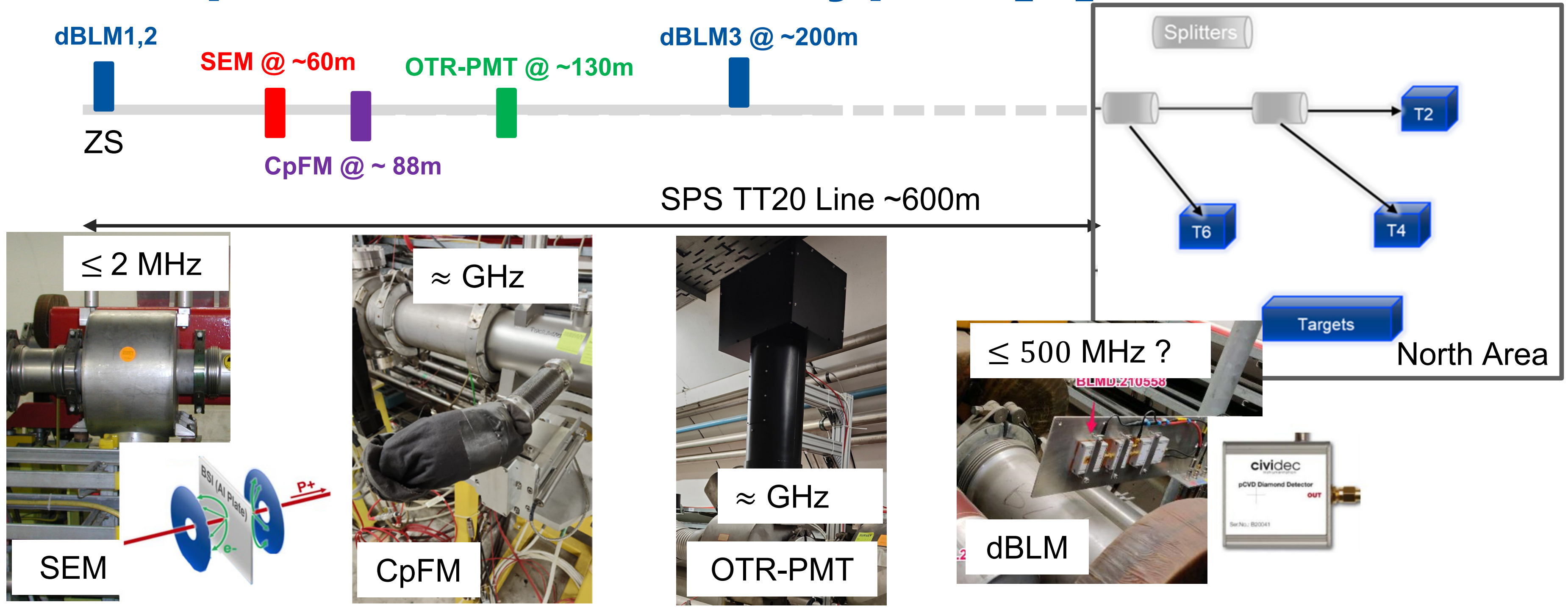
Monitoring beam currents:

From a **few nA** (1×10^{11} p in 4.8 s) to a **few uA** (4×10^{13} p in 1 s)

From a **few Hz** to

- **800 MHz** (SPS North Area CONSOLIDATION, short term)
- **several GHz** (Physics Beyond Colliders program and the search for Dark Matter particles, long term)

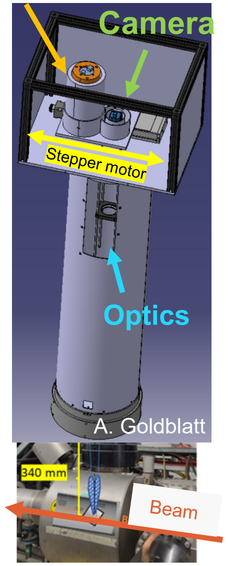
Fast Spill Monitor Prototypes [1]



Secondary Emission Intensity Mon.   Cherenkov proton Flux Mon.   Optical Transition Radiation – PMT Mon.   Diamond Beam Loss Mon.

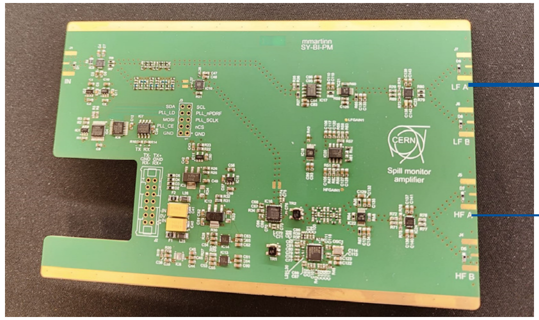
SEM and ORT-PMT measured full beam, CpFM measured beam halo particles, dBLM measured beam losses.

OTR-PMT System



	Acquisition Mode		
	Slow	Fast	Ultra-fast
Application	Autospill, power-converter ripple	RF debunching	Empty-bucket channelling
$f_{bw} = \frac{1}{2\Delta t}$ (MHz)	≥ 0.1	≥ 10	
f_{centre} (MHz)	$f_{bw}/2$	≈ 200	≈ 800
n triggers	1	≥ 10	
$T_{coverage}$ (ms)	Whole spill	≥ 10 (per trigger)	
$T_{offload}$ (ms)	200 (example, see text)		
Phase information	Yes	No	

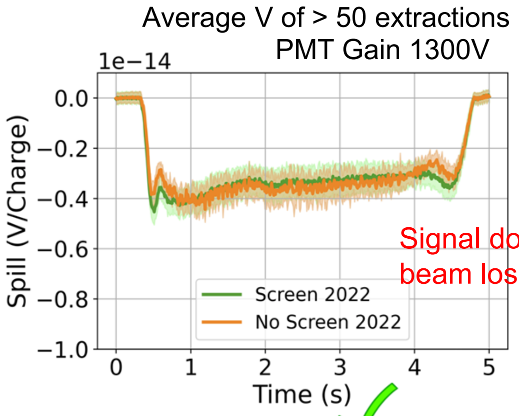
[3]



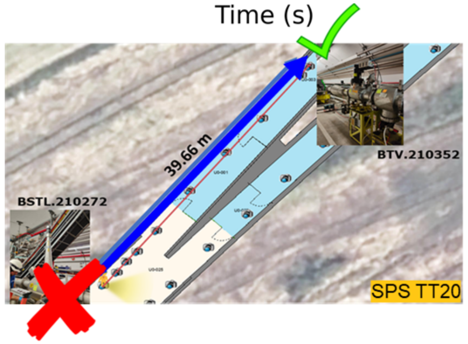
“Slow & Fast” channel
50 Hz – 250 MHz

“Ultra Fast” channel
800 MHz

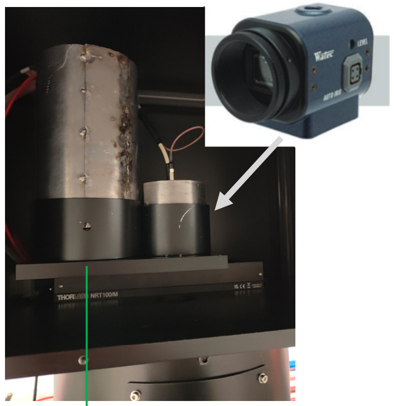
OTR-PMT First Prototype – Main Issues



Signal dominated by beam losses



BTV.210272 location is not favorable for OTR



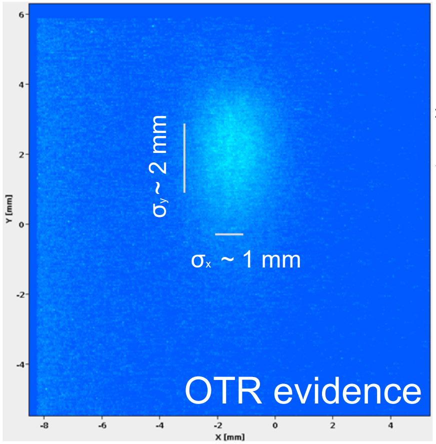
$I_{out} = 0.2\ mA$

$QE_{PMT} = 20\ \%$

$Gain_{PMT} = 4\ x\ 10^4$ @ $1300V$

$t_{Spill} = 4.8\ s$

Photons collected $\approx 7.5\ x\ 10^{10}$ ✓



$\approx 3.1\ x\ 10^8$

$t_{exp} = 20\ ms$

Photons generated [4, 5]

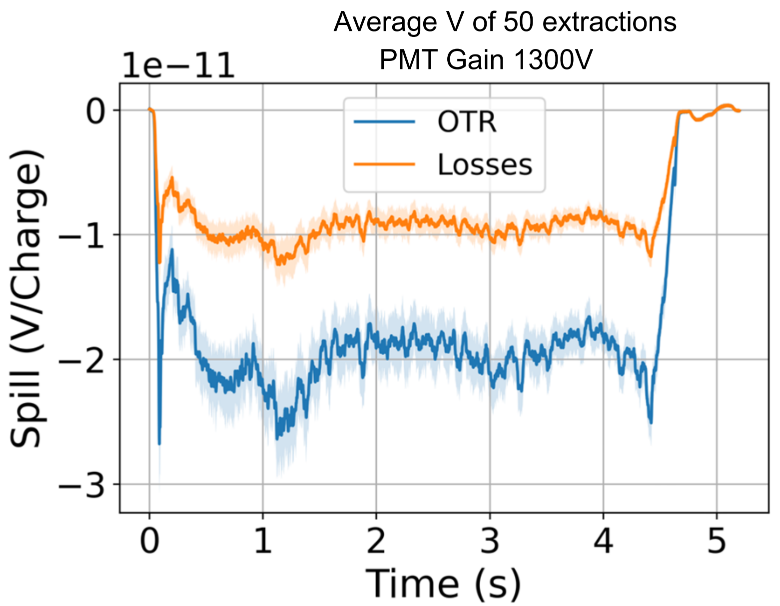
$[4.2\ x\ 10^{10} - 1.7\ x\ 10^{11}]$

[4] S. Burger *et al. IBIC16*
[5] E. Bravin *et al.* CERN-AB-2003-050-BDI

OTR-PMT Results 2024

New location, new layout, new electronics.

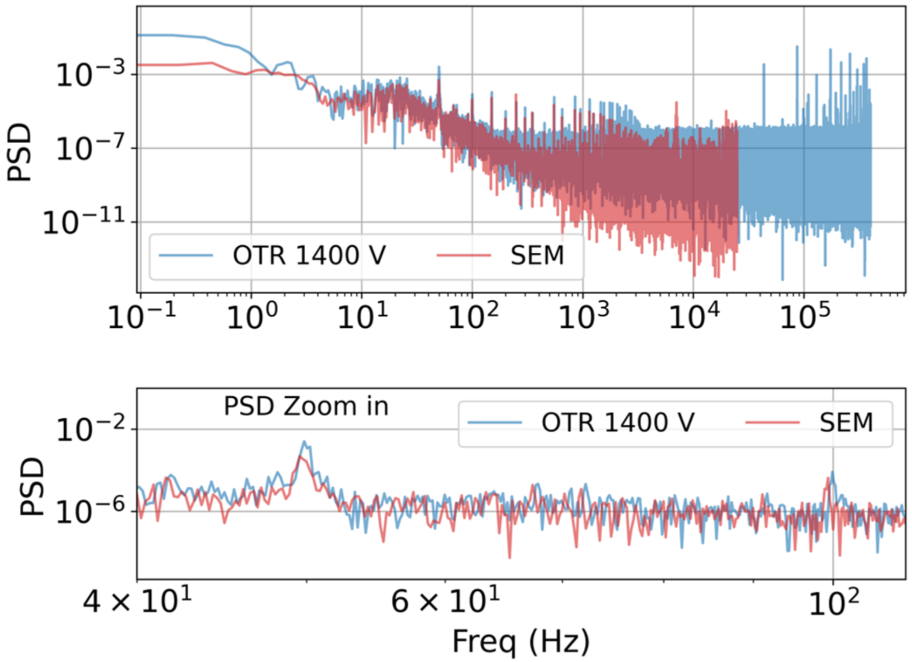
- OTR signal are now clearly measurable, but beam losses are still visible.
- It however shows that both losses and OTR are suitable for reconstructing the spill time structure and frequency content.



Screen IN & PMT powered continuously since beginning of July.

Frequency spectra

Comparison of OTR-PMT and SEM spectra.

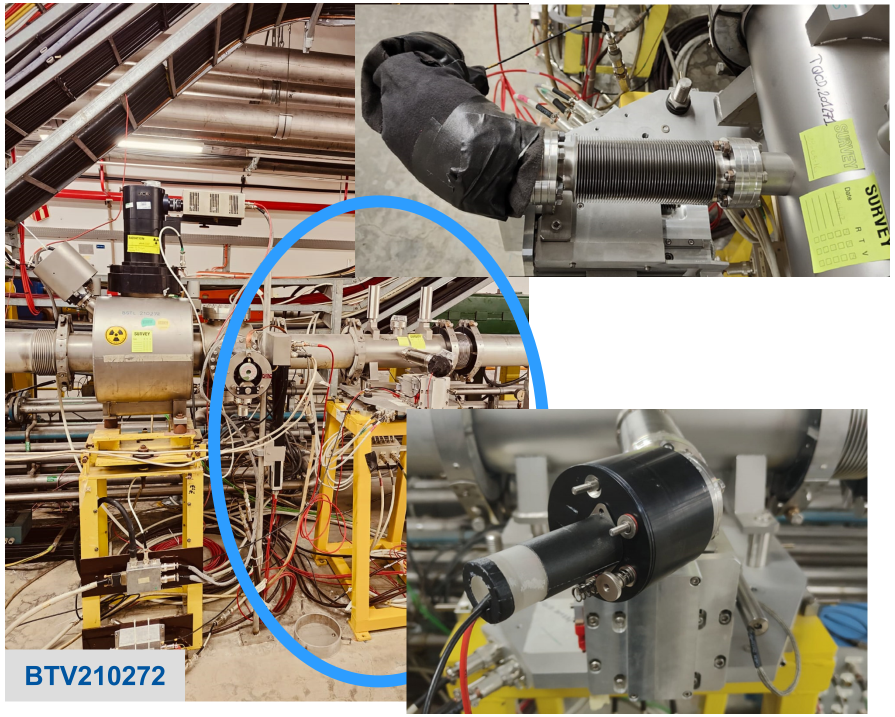


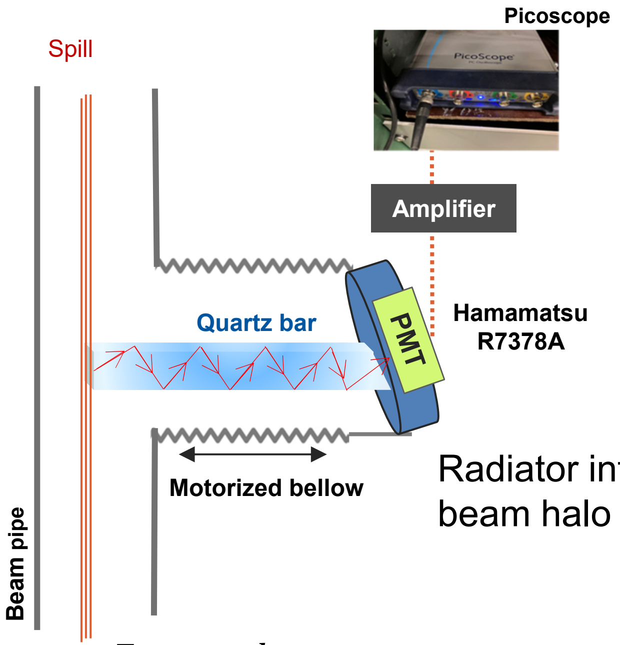
OTR-PMT monitor …

- can measure a broader range of frequencies.
- samp. freq. set to 800 kHz but it can go at much higher.
- performance can be improved by adjusting the gain of the PMT.

<u>Systematic tests still ongoing to understand the noise sources in the signal and optimise the SPS spill spectrum quality.</u>

Cherenkov proton Flux Monitor (CpFM) [6]



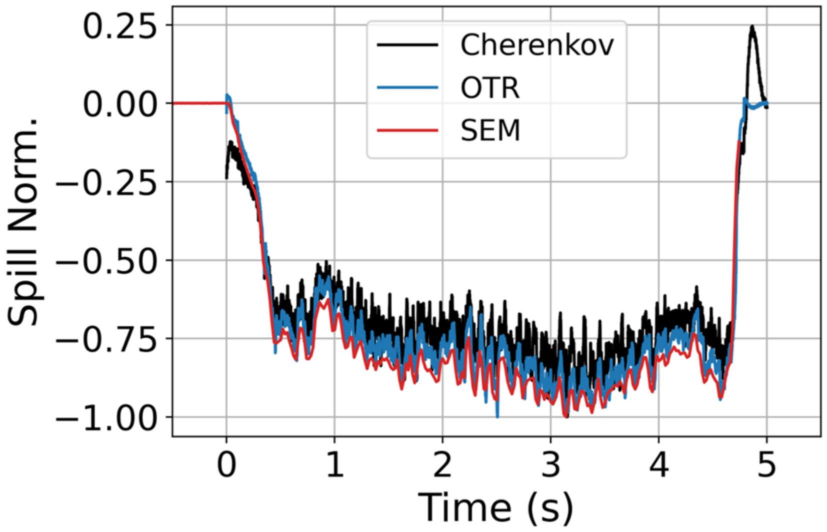


Radiator interacting with beam halo particles

$$\textit{Expected Cherekov Photons} \sim 10^{13} \gg \textit{OTR Photons}$$

CpFM Results 2024 (First tests)

Comparison of OTR-PMT, CpFM and SEM spill time structures.



- All systems are using different electronics.
- Very high agreement in tracking the spill structure.
- Waiting for the dBLM to complete the plot.

- Now:

Systematic measurements are being conducted to evaluate the performance of the CpFM.

Information Full beam = Information Beam Halo $\stackrel{?}{=}$ Information Beam Losses

Outlook & Future work

Significant efforts to improve the performance of the Fast Spill Monitors over the last 2 years.

- The OTR-PMT system was improved, and the new results demonstrated this enhancement.
- Measurements of the frequency spectrum with a better SN ratio than the SEM.
- The CpFM recently tested, and good agreement with SEM and OTR-PMT systems.

Next steps:

- Systematic tests to have more data and identify beam noise sources.
- Tests to measure the 200 MHz and 800 MHz components.
- Measurements with heavy-ion beams.

Long term:
Going to **> 1GHz** range, CpFM tests, also implies DAQ upgrades (“Ultra-ultra-fast” Mode).

Thank you very much for your attention!

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