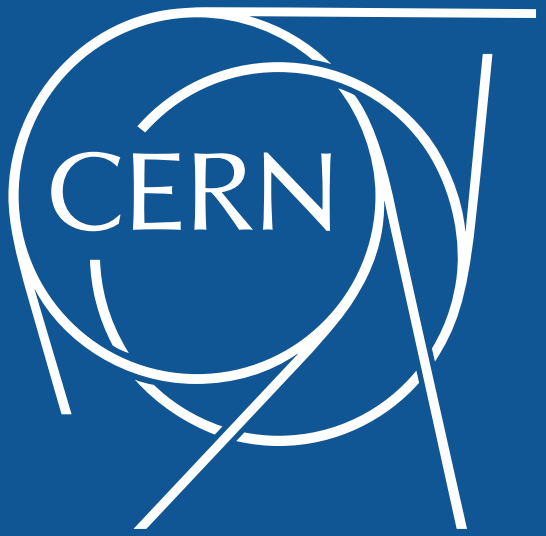

CERN

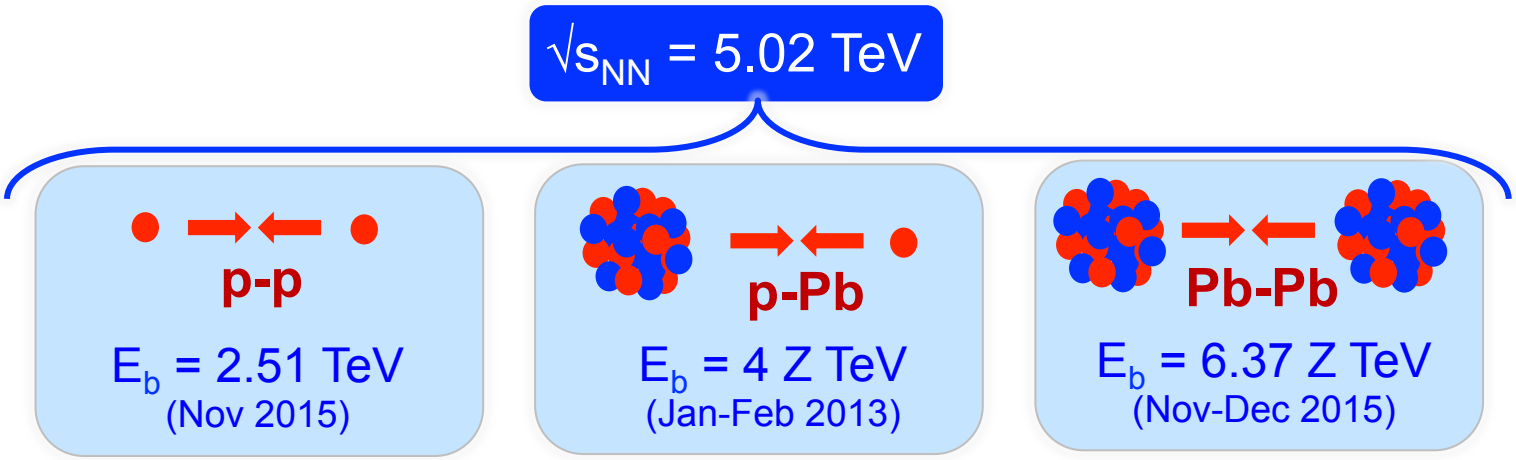
Lead-Lead LHC Operation Highlights in 2015

Michaela Schaumann
on behalf of the LHC Heavy-Ion Team

BE Department
OP Group

6.37 Z TeV Beam Energy

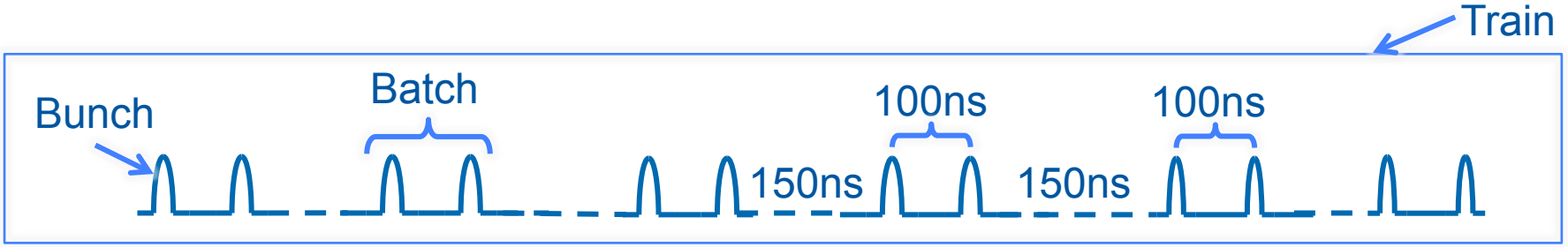
- **Energy exceeds 1 PeV per ion.**
- The LHC can provide **3 different collision modes**.
- Reducing of the beam energy from 6.5Z TeV to 6.37Z TeV provided the possibility to compare all collision modes at the **same center-of-mass energy per colliding nucleon pair**:



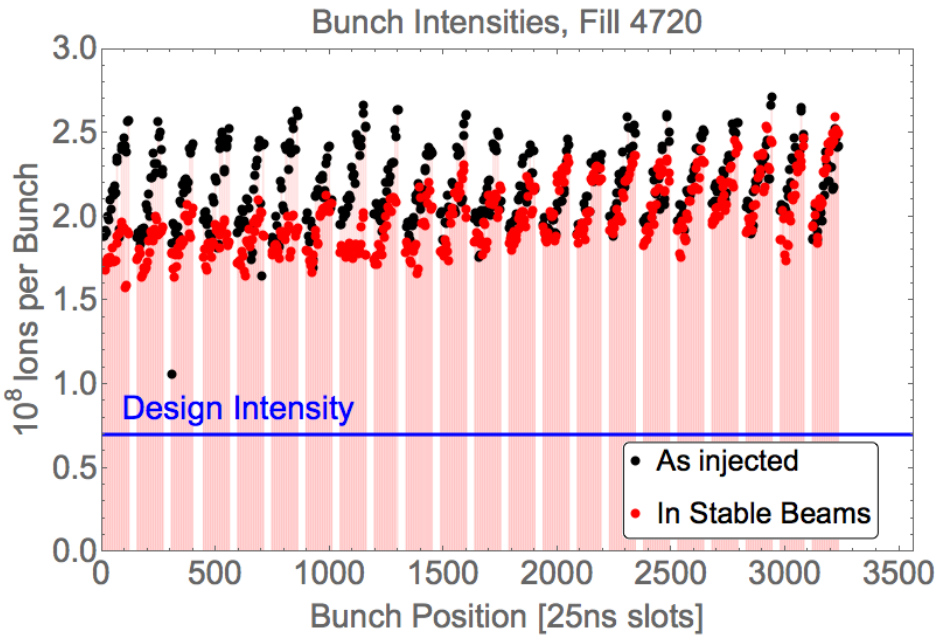
- The 2015 HI run covered Pb-Pb@6.37Z TeV and p-p@2.51TeV within one month of operation.

Injector Chain Improvements

- Unexpected optimization of the SPS injection kicker allowed **batch spacing of 150ns**.
  - ✧ Instead of the original 225ns.
  - ✧ Batch spacing <225ns was not expected before LS2 (if at all).
  - ✧ Increase from 426 to 513 bunches per beam.
  - ✧ Alternating 100/150ns bunch spacing.
- Many different filling schemes were used through the run, gradually improving the performance.



LHC Bunch Intensities

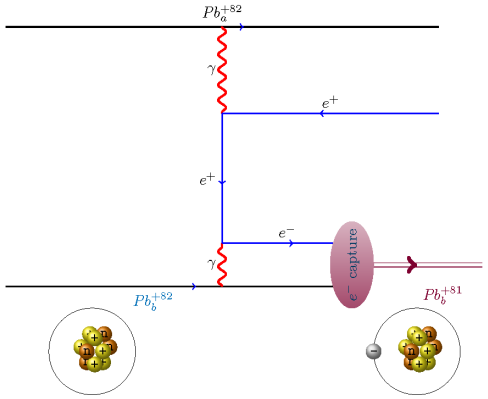


- Injectors provided **intensities far above the design**.
- Typical structure along the bunch train imprinted due to losses at the SPS injection plateau.
- Similar losses in the LHC imprint variations along the beam.

Secondary Beams created in the Collision

Bound-free pair production (BFPP)

$$^{208}\mathrm{Pb}^{82+} + ^{208}\mathrm{Pb}^{82+} \longrightarrow ^{208}\mathrm{Pb}^{82+} + ^{208}\mathrm{Pb}^{81+} + \mathrm{e}^{+}$$



Has large interaction cross-section (>200b) in Pb-Pb collisions and is the main contribution to fast luminosity burn-off.

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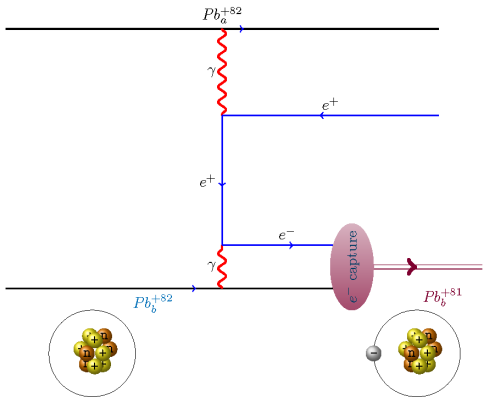
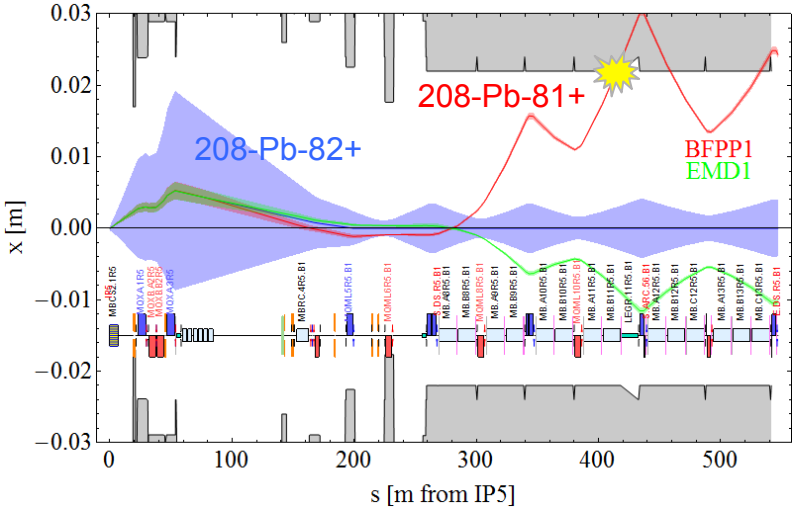


Has large interaction cross-section (>200b) in Pb-Pb collisions and is the main contribution to fast luminosity burn-off.

Secondary beams impact in superconducting magnets downstream the interaction points.

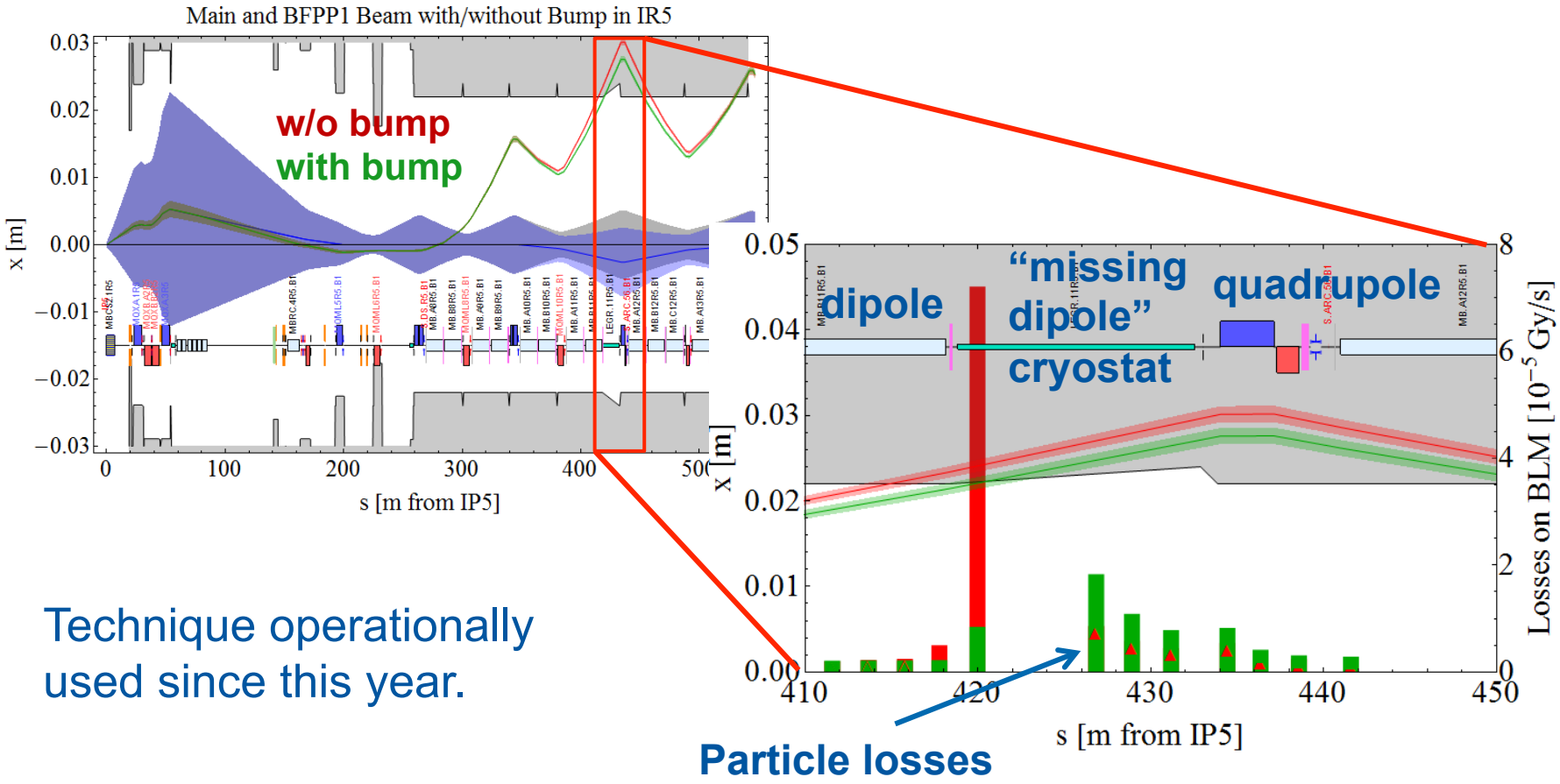


Deposited power exceeds quench limit.

Luminosity limit found at $L \approx 2.5e27 cm^{-2} s^{-1}$ (≅50W into magnet)

Quench Risk Mitigation with Orbit Bumps

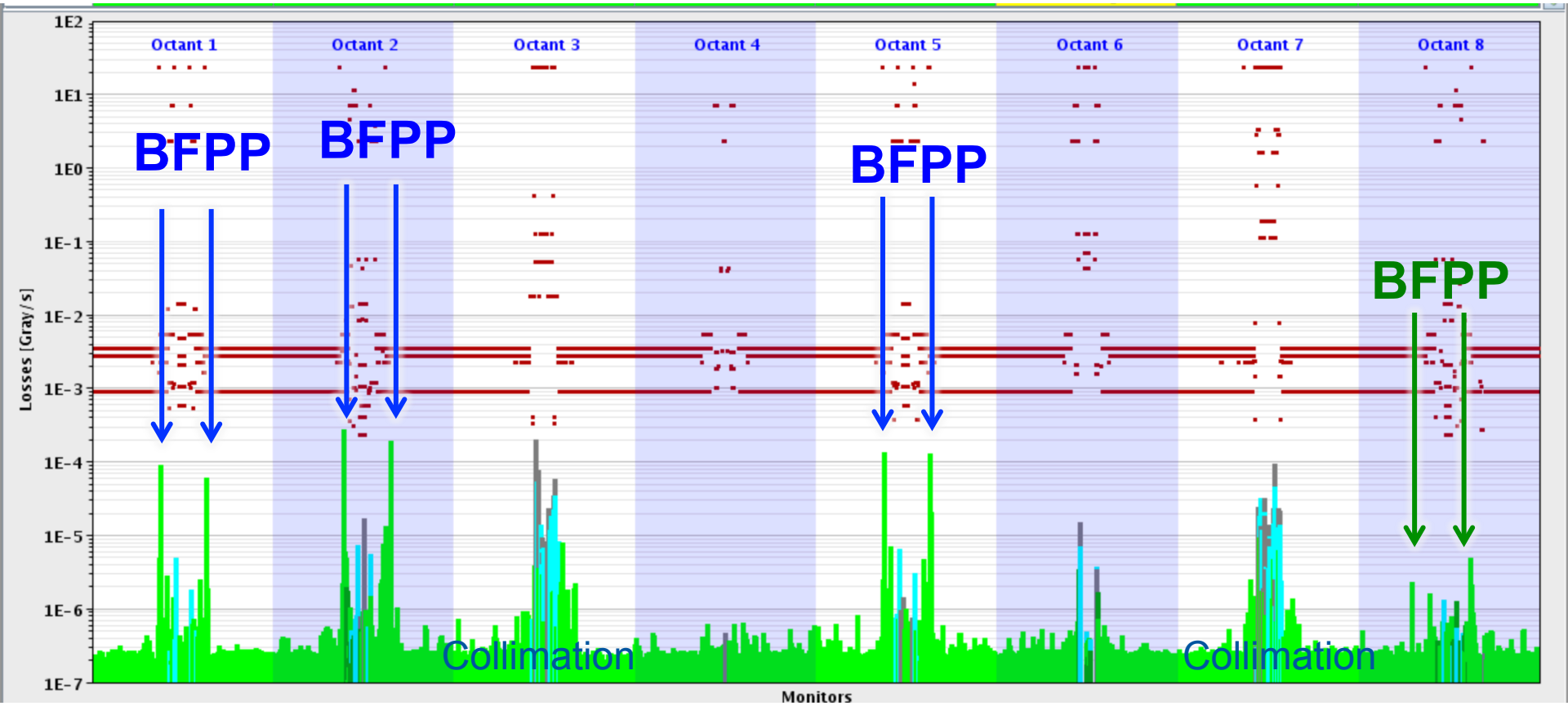
Orbit bumps are used to move the secondary beam losses to a less vulnerable location in order to reduce risk of quench.



Technique operationally used since this year.

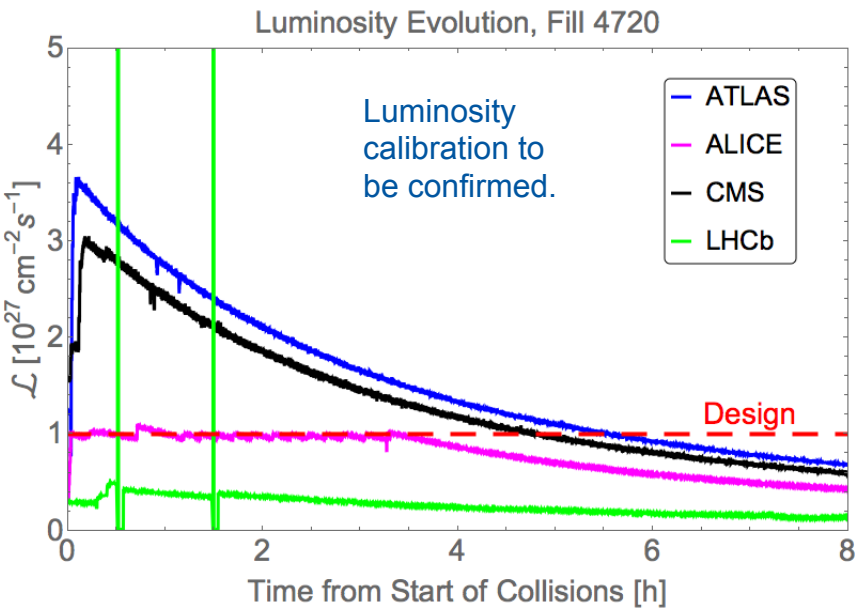
Loss Pattern around the Ring

Loss spikes around all IPs where ions collide …

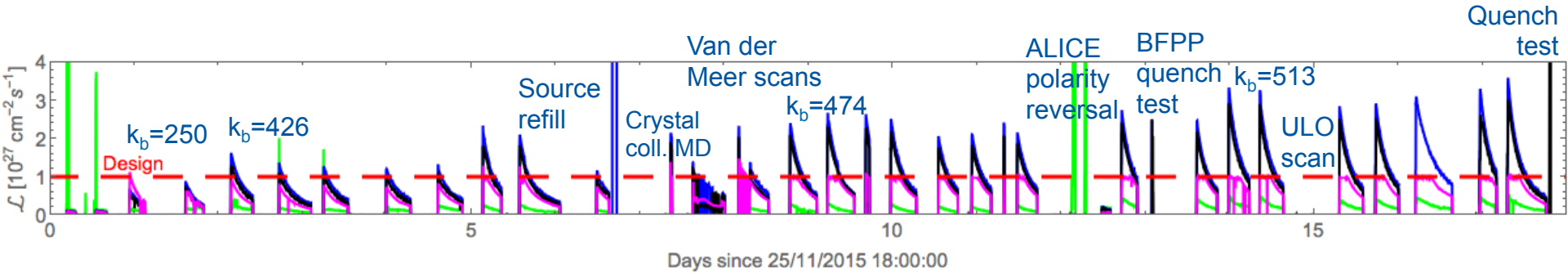


ATLAS ALICE CMS LHCb

Luminosity Evolution



- **Design peak luminosity was exceeded** by more than a factor 3 in ATLAS and CMS.
- ALICE was levelled to design saturation value.
- LHCb participated for the first time in Pb-Pb data taking.
- **Excellent availability.**
- Average turn around time 5-6h.



Summary

- 2in1 Month:
  - p-p reference data: $L_{int} \approx 28\ pb^{-1}$ (ATLAS, CMS)
  - Pb-Pb data: up to $L_{int} \approx 700\ \mu b^{-1}$ per Experiment
- Reached more than 3× design luminosity.
- Reached 1 PeV total beam energy.
- Upgrade of batch spacing to 150ns.
- Acquired important knowledge in view of performance limitations and future upgrades.

Acknowledgements

Many people in many groups and teams, working on injectors and LHC, have made exceptional efforts, often at short notice.

Without them the heavy-ion run would not have been so successful.

THANK YOU!

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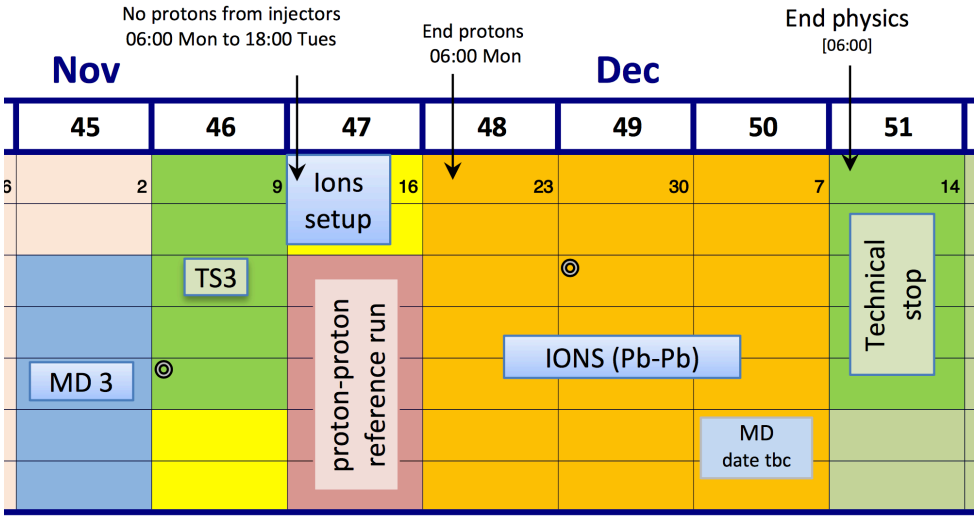
Schedule



14th Nov.:
Start of Pb-Pb commissioning

18th Nov.:
Start of p-p reference run

25th Nov.:
First Stable Beams at 6.37 Z TeV = **1.045 PeV** total beam energy

20 days for physics production with many interruptions for special machine development experiments, ion source refill, van der Meer scans (luminosity calibration), ALICE polarity reversal, …

13th Dec.:
End of Pb-Pb run

All 4 Experiments Taking Collisions