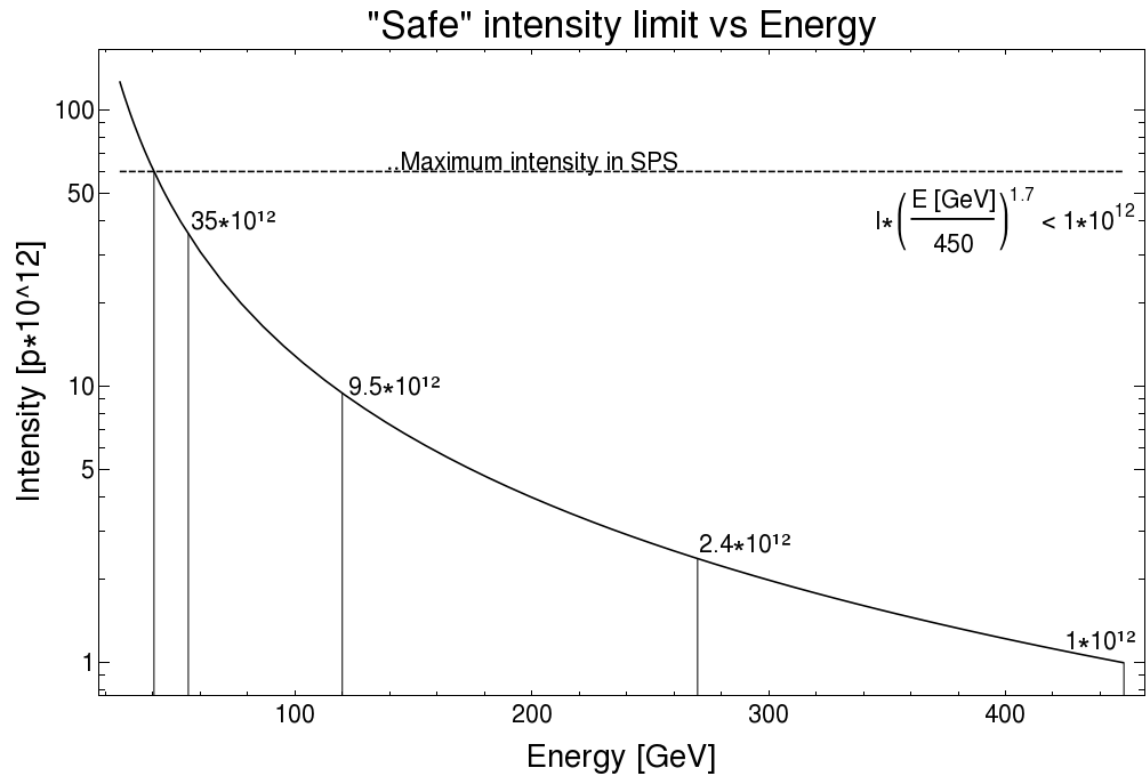


Machine protection requirements for crab cavity MDs with unsafe beam intensities

B. Lindstrom, M. Valette, J. Uythoven,
J. Wenninger, D. Wollmann, M. Zerlauth

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Re-cap Safe intensity limits for Crab Cavity MDs in SPS



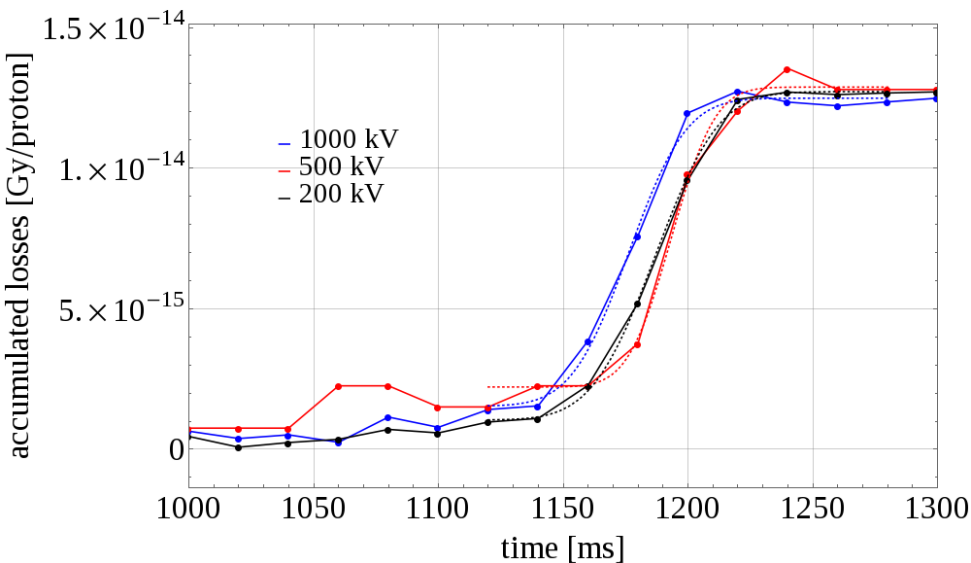
- Crab cavity MDs in early stage should be performed with total beam intensities **factor 10 below** the 'safe intensity' limit, i.e.:
 - @ **26 GeV**: $< 6 \times 10^{12}$; @ 55 GeV: $< 3.5 \times 10^{12}$; @ 120 GeV: $< 9.5 \times 10^{11}$
 - @ **270 GeV**: $< 2.4 \times 10^{11}$; @ 450 GeV: $< 1 \times 10^{11}$

Status of Crab Cavity Operation

- MDs with crab cavities have **progressed well** and the cavities are standardly operated at 2K. Nevertheless, operating both cavities at high voltage reliably is work in progress.
- MDs are performed with **teams in the CCC, BA6 and BA3**. During a cycle (26 GeV \rightarrow ramp \rightarrow 270 GeV \rightarrow dump) the **crab cavity parameters are following functions**. After validating their proper settings, the functions provide some protection against typing errors, when changing operational parameters
- **Beam instabilities** due to crossing the resonance frequency of the beam are the fastest and most violent failures predicted and observed for the crab cavities in the SPS and could cause critical losses within tens of ms (see more later)
- The **(slow) CC-RF interlock** will cause a beam dump within 6-8 ms, if a problem is detected, which causes the switch off of both cavities. The ring BLMs in the SPS have a minimum interlock time of 20 ms and minimum 2 BLMs have to reach the dump threshold to trigger a beam dump.
- It is foreseen to implement a **fast RF phase interlock** in BA3, which will interlock on the phase difference between the SPS-RF and the CC-RF. This interlock will only be active at flat top after the successful re-phasing. The phase interlock would **mitigate the danger** of triggering an instability at flat top

Resonant excitation of beam

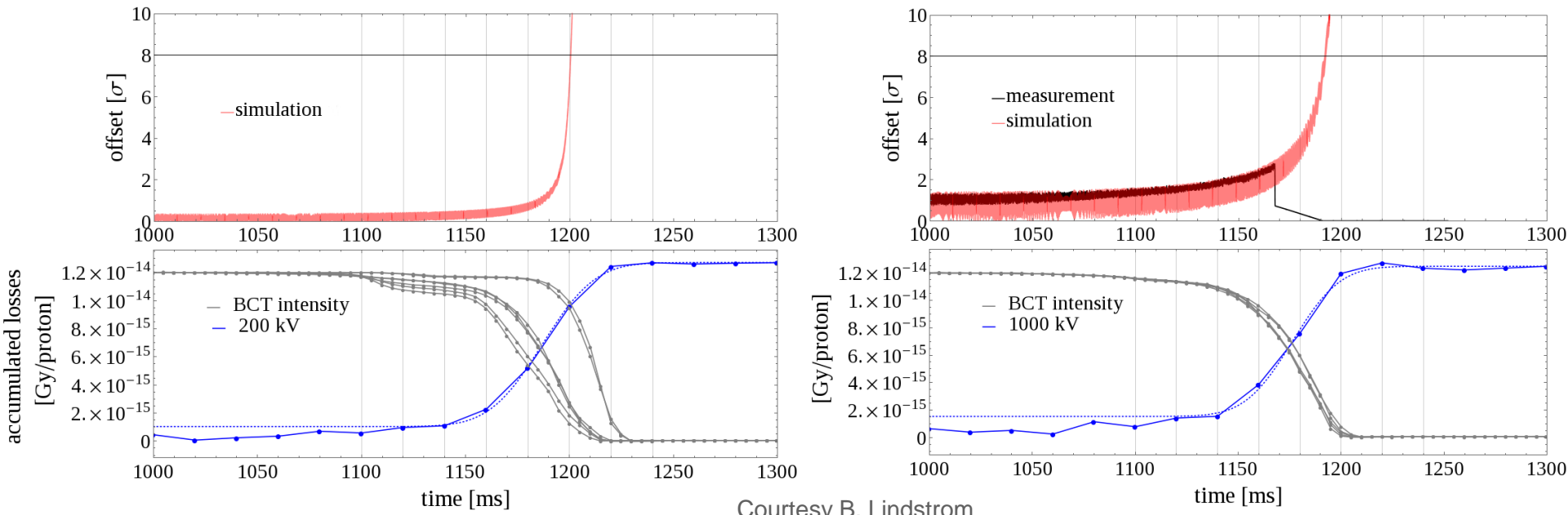
- Beam instabilities due to crossing the resonance frequency of the beam are the fastest and most violent failures predicted and observed for the crab cavities in the SPS and could cause critical losses within tens of ms.



Courtesy B. Lindstrom

- Observed rise times of losses (10%-90% - ~50 ms) are similar for 200 kV, 500 kV and 1 MV.
- With high intensity beams, critical loss levels would be reached ~20 ms after onset of losses

Resonant excitation measurements versus simulations



- Simulations show qualitatively good agreement with measurements, tune spread between particles seems to play important role for speed of onset of losses
- Excitation at 270 GeV is not expected to be significantly slower \rightarrow measurement required

MP requirements before high intensity operation (1/2)

- The rise time of losses due to resonant excitation by the CC should be measured at 270 GeV with low intensity beam → MD6?
- The **BLM thresholds** at the expected and observed loss locations **should be verified** to ensure protection in case of slow losses with high intensity beams
- The **RF Phase interlock** needs to be **ready** and its functionality and successful triggering (including triggering delay) **verified** with low intensity beam
- In case the use of two cavities is foreseen, the existing slow interlock needs to be modified in a way to trigger a beam dump if **one IOT switches off**. Its proper **functionality needs to be verified** with low intensity beam

MP requirements before high intensity operation (2/2)

- CCs need to be **off during the ramp**, as the phase interlock is only active at top energy (270 GeV) - the correct settings during the cycle using functions needs to be verified with low-intensity beam and the **intensity increased in steps**. If parameters are changed, these **changes have to be validated** with low intensity beam, before stepping up to unsafe beam intensities.
- Before using high intensity beams the **RBAC roles** of the RF experts should be **revoked**, the **tuners inhibited** and a **stable communication link** between the CCC and BA6/BA3 established. Ideally the high intensity part of the MD should be performed remotely from the CCC.
- A **detailed test procedure** needs to be prepared and checked by SPS-OP and MPP before high intensity operation



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