SPS Kicker Design Study

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Outline

The plan

- Establish a baseline for implementation of a vertical kicker system in the super proton synchrotron (SPS)
- Application: to control electron cloud (ecloud) and transverse mode coupling instability (TMCI)
- Review and determine the capabilities of several possible implementations with the criteria:
  - Shunt impedance
  - Beam broadband impedance
  - Bandwidth
  - Heating issues
  - Fabrication complexity & complications
  - Vacuum chamber compatibility
  - Ease of coupling to external amplifiers

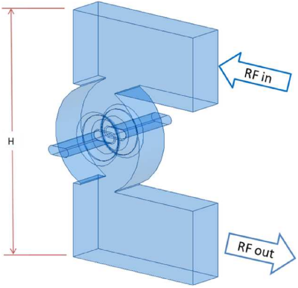
Known requirements

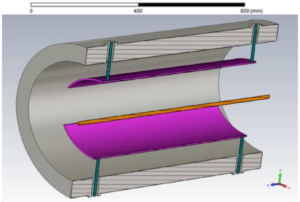
- Consistent with the SPS Beam Stay Clear, and installed length requirements
- Consistent with vacuum processing and surface requirements
- System bandwidth - 1 GHz desirable, specified by:
  - On-going beam excitation MDs
  - Simulations
- Operational implications - number of driven ports, estimates of needed power, bandwidth of power stages, sophistication of required time and delay adjustments.

Possible implementations

1. Overdamped cavity - see F. Marcellini's talk
   - Several bands
   - High shunt impedance
2. Striplines - see S. DeSantis' talk.
   - Wideband
   - Arrays, staggered in frequency
3. Slotline implementations
   - Used in stochastic cooling systems
   - Achievable shunt impedance, bandwidth?
   - Broadband impedance?

Courtesy of F. Marcellini





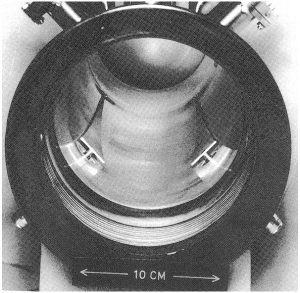
Courtesy of S. DeSantis

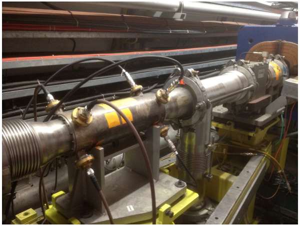
Evaluation and summary

- For several bandwidths
- Shunt impedance estimation, amplifier systems for some kick strength
- Fabrication considerations and constraints
- Operational consideration
- Provide CERN with summary of the best known systems for use in the SPS
- Conclude with a design approach for a detailed design

Directional coupler - Exponentially tapered pickup

- Four electrodes machined with exponential shape
- Distance of electrode to beam pipe wall varies since width changes, to maintain $f_c = 50\ \Omega$
- For current beam excitation studies, a pickup installed backwards at 319.01 is being used
- Response begins to roll-off at ∼200 MHz
- Need improved technology if we are to reach 1 GHz



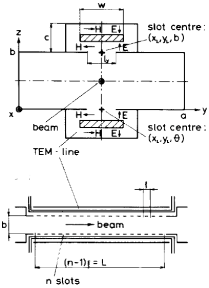


Linnecar, T. *CERN-SPS/ARF/78-17* (1977).

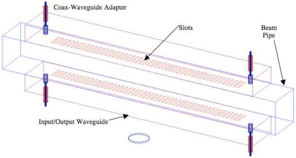
Slotline structures - Historical perspective

- As kickers for stochastic cooling
  - CERN ISR at 1 – 2 GHz (Faltin)
  - Fermilab Accumulator at 4 – 8 GHz
  - Debuncher
- As Schottky pickups
  - Fermilab Recycler at 1.7 GHz
  - Tevatron at 1.7 GHz
  - LHC at 4.8 GHz
- Bandwidth can vary, desirable for shunt impedance properties

Faltin, L. NIM 148 (449) 1978.



McGinnis, D. Proc. PAC 1999.



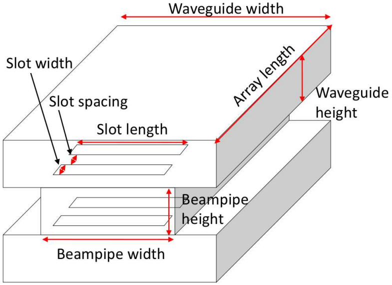
Mechanism, Methods, and Tools

- Slots will slow the phase velocity of the electromagnetic wave, dependent upon slot geometry and quantity
- Match wave velocity to beam velocity for optimal forward coupling via slots
- Study impedance and bandwidth properties of slotted waveguide structures with moment method calculations
  - Follows from Bethe's small hole coupling theory
  - Slots can be effectively represented by magnetic and electric dipole moments
- Using Fermilab's *Slotted Pickups* code developed by D. McGinnis
- Evaluate geometries with high shunt impedance and bandwidth coverage for 0.5 - 1 GHz

R. .F. Harrington, Proc. IEEE, Vol. 55, No. 2, pg. 136 1967.
D. McGinnis, Pbar Note 575.

Critical parameters

- Fixed parameters
  - Beam pipe height and width
    - Space available: Sextant 3, in place of MBB dipole
    - 132×52.3 mm
  - Waveguide width - For TE_{10}, 300 mm @ $f_{cutoff} = 0.5$ GHz



- Varied parameters
  - Waveguide height
  - Slot width, length, spacing
  - Overall length

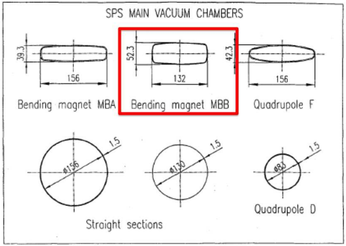


Fig 2: Vacuum chamber cross sections in the SPS

Courtesy of W. Hofle

A word about impedances

- Transverse shunt impedance as defined by Goldberg and Lambertson (1992):

$$R_\perp T^2 = \frac{\left(\frac{\Delta p_\perp \beta c}{q}\right)^2}{2P} \quad [\Omega] \tag{1}$$

- Simulation outputs impedance as:

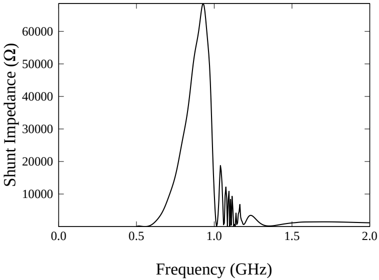
$$\sqrt{R_\perp T^2 \beta} = \sqrt{\frac{\left(\sqrt{\beta_k}\frac{\Delta p_\perp \beta c}{q}\right)^2}{2P}} \quad \left[\sqrt{\Omega - m}\right] \tag{2}$$

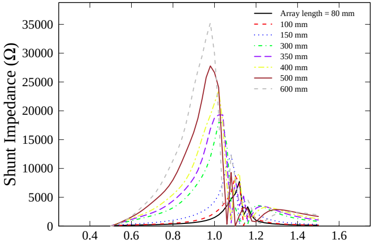
- We square this quantity an divide out β-function dependance so that units are $[\Omega]$

Goldberg, D. A. and Lambertson, G. R. Proc. Phys. Part. Accel. (1992).
McGinnis, D. Pbar Note 578.

Optimizing parameters - Initial simulations

- Vary parameters to optimize bandwidth coverage and impedance.
- An initial simulation (top right)
  - 1 m length
  - 250 slots
- Continue to probe parameter space (bottom right)
  - e.g., Variation of array length
  - Study ongoing!
- May be able to sacrifice impedance for more bandwidth



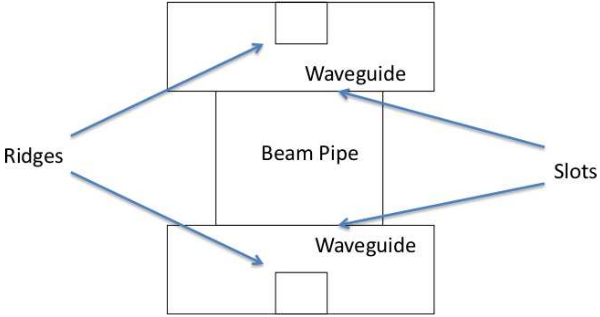


Other considerations

- Will this type of structure contribute too much to the broadband impedance?
- M. Zobov (Frascati) is working on calculations of the beam wake fields and coupling impedance
- With these initial calculations on the feasibility of a slotted structure, we will expand calculations into full electromagnetic FEM calculations as cross check
  - May be computationally intensive, start small, few slots
  - Use hfss, ACE3P, CST - MWS/PS

Alternative slotted geometries

- Size constraints, waveguide is 300 mm wide
- Investigate further the TEM slotline, no need for bulky WG
- Idea from F. Caspers: Include a ridge to the McGinnis style slotted waveguide
    - Reduce overall size by a factor of 2-3
    - Increase bandwidth
    - Has this been attempted/explored?



Future steps

- For slotted structures, further investigation necessary
- Time crunch! Need to provide a design report and suggested implementation to CERN soon
- Depending on complexity of structure, time needed for detail design and construction
- New kicker vacuum components must be ready for installation during LS-1, 2013 – 2014

Conclusion - closing remarks

- Frascati, LBNL, and SLAC investigating cavities, striplines, and slotlined structures for effective use as wideband kickers
- This working group is part of a larger effort of wideband control of intrabunch motion caused by ecloud instabilities and TMCI in the SPS
- A kicker design report for CERN is a high priority item for the wideband feedback project
- Thank you for your attention - insight, suggestions, and *feedback* are appreciated!

References

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- Goldberg, D. A. and Lambertson, G. R."Dynamic Devices: A Primer on Pickups and Kickers," Proc. Phys. Part. Accel. (1992).
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- McGinnis, D. "The 4 – 8 GHz Stochastic Cooling Upgrade for the Fermilab Debuncher," Proc. Part. Accel. Conf. (1999).
- McGinnis, D. Pbar Note, 575.
- McGinnis, D. Pbar Note, 578.