LER-LHC Injector Workshop Summary and Super Ferric Fast Ramping Injector in SPS Tunnel

Vladimir Shiltsev, Fermilab
for collaboration team
H.Piekarz, G.deRijk, L.Rossi, T.Sen,
Y.Huang, S.Hays, J.Johnstone

http://ler06.web.cern.ch/LER06/

LER

Workshop on a Low Energy Ring in the LHC tunnel as main injector

CERN, Geneva, 11 - 12 October 2006

Hosted by the Accelerator Technology Department

- Home Page
- Announcement
- Link to Indico
- Program
- Registration
- Accommodation
- Org. Committee

Attendance by invitation only

34 participants, incl. 5 "devils advocates"

9 presentations, discussions

The basic idea

G.deRijk, H.Piekarz

- LER is a two beam machine
- Two-in-one superferric combined function magnets in LHC tunnel
- Inject beam from SPS into LER
- Accumulate and shape the two beams in LER
- Accelerate from 0.45 TeV up to 1.5 TeV
- Transfer the two beam simultaneously in a single turn transfer into the LHC

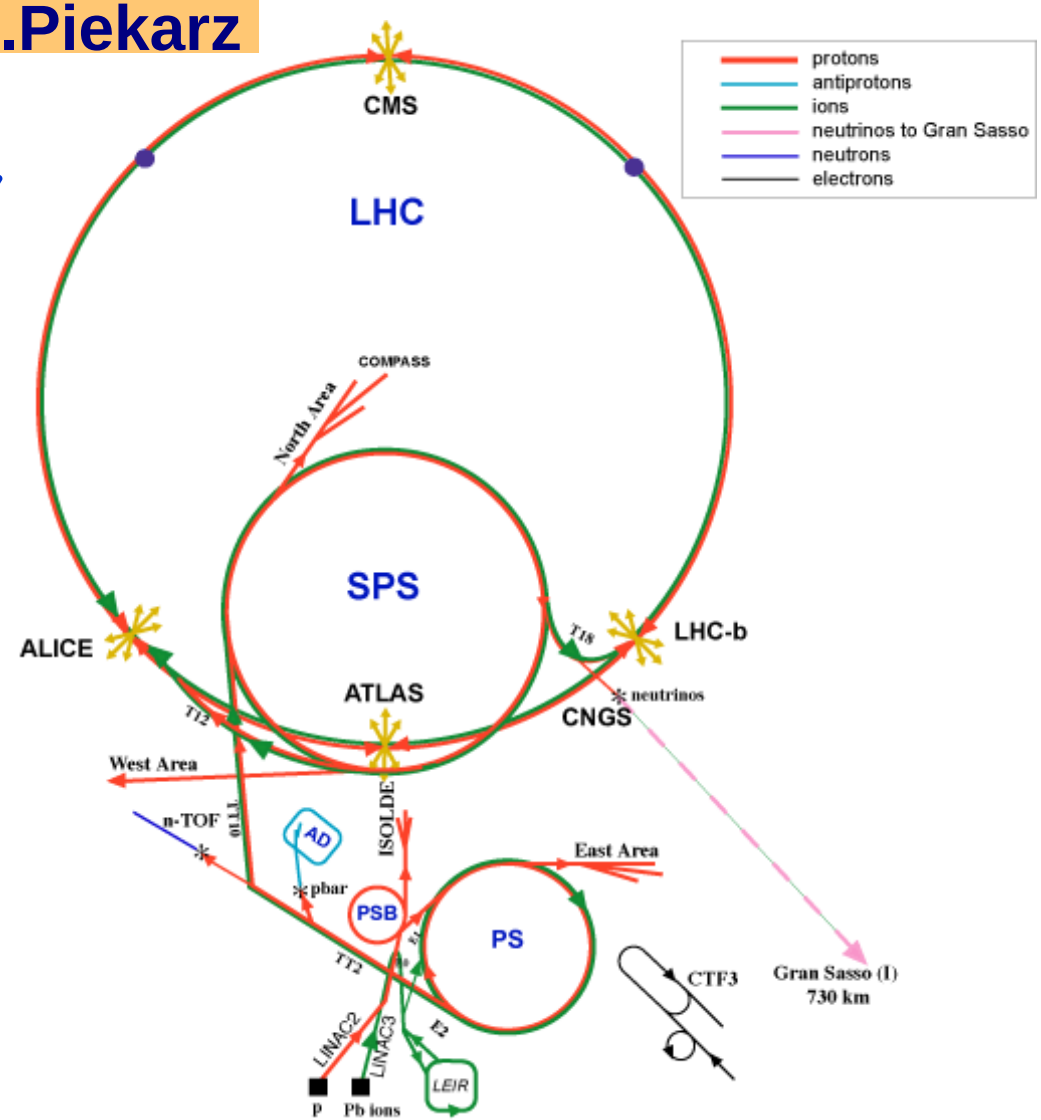
So:

- Beam coasting time in LHC at injection energy (0.45 TeV) is reduced to the minimum (~10 ms)
- Starting at 1.5 TeV the LHC can ramp faster
- Beam is coasting at 0.45 TeV in LER in a "clean" maching

Pre-accelerator LER

G.deRijk, L.Rossi,H.Piekarz

- Injection energy increased to 1.5TeV
- Better then SPS beam stability
- Cheap magnets
- Faster turnaround time
- Save ~1yr of no-L time, install during shutdowns
- Slip-staking - possible (?)

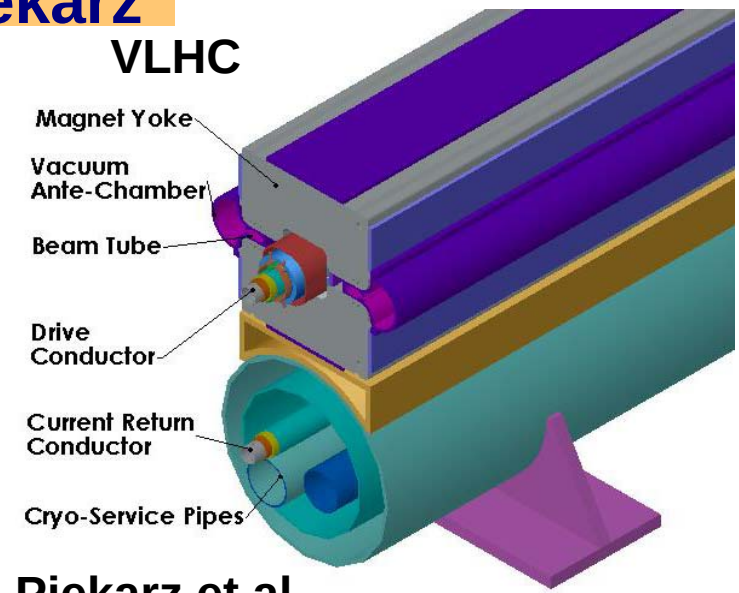


Pipetron - VLHC magnets FNAL

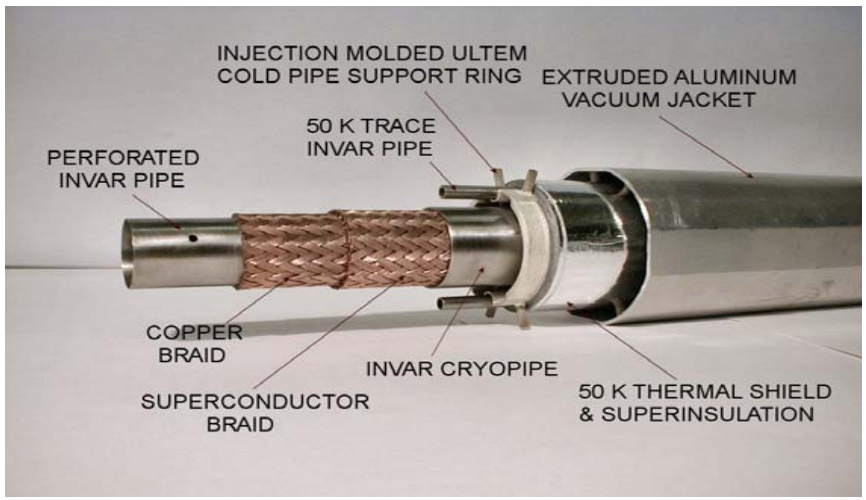
LARP

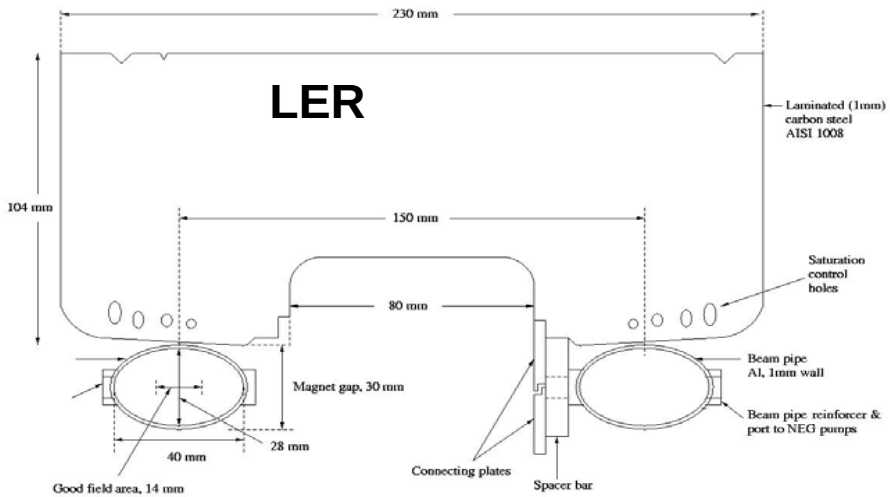
H.Piekarz

- 0.45 TeV injection at 0.48 T
- 1.5 TeV top at 1.595 T (72kA)
- Gradient ~ 3%
- Enlarged magnet aperture v 28 mm x h 40 mm



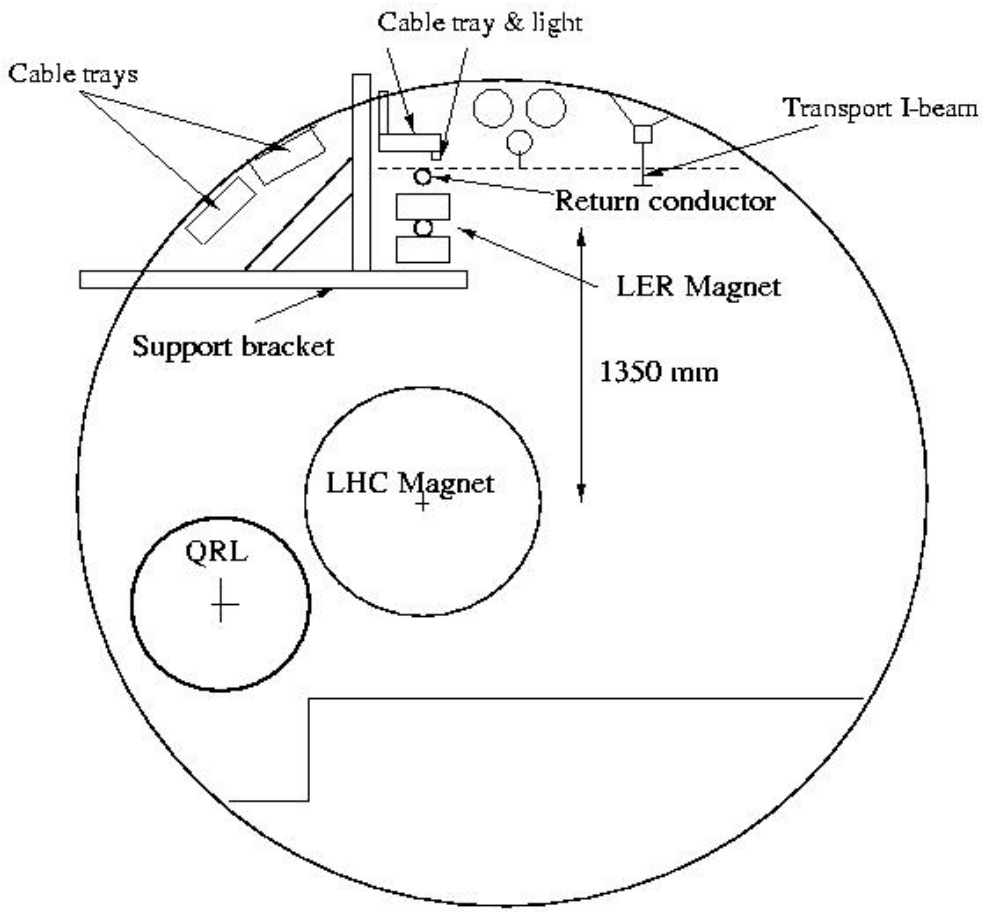
H. Piekarz et al.

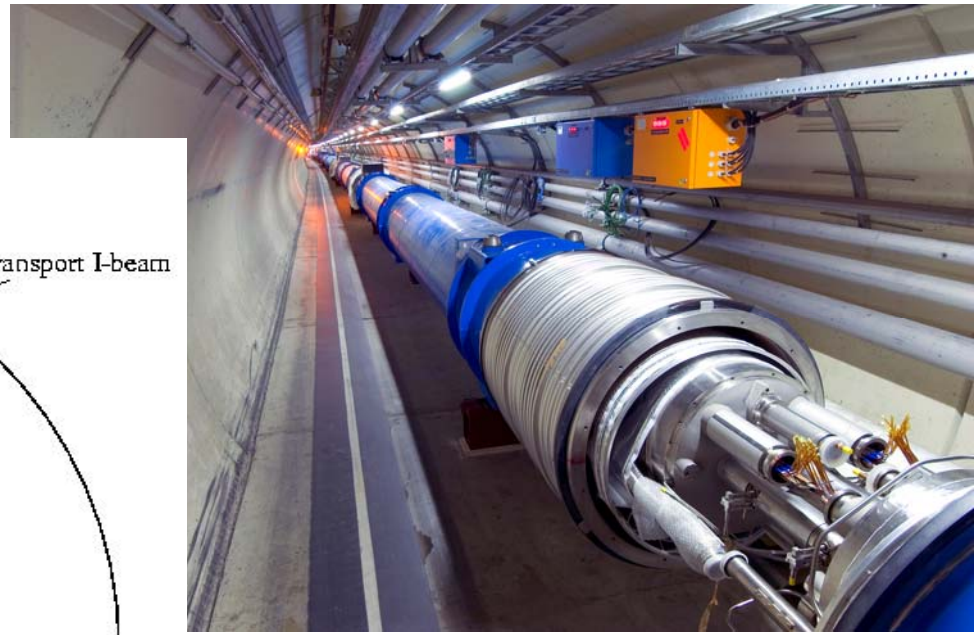




Feasibility study - tunnel space

G.deRijk





Fits above the LHC ring at a 1.35 m beam-to-beam vertical distance

(some cabling exceptions in straight sections)

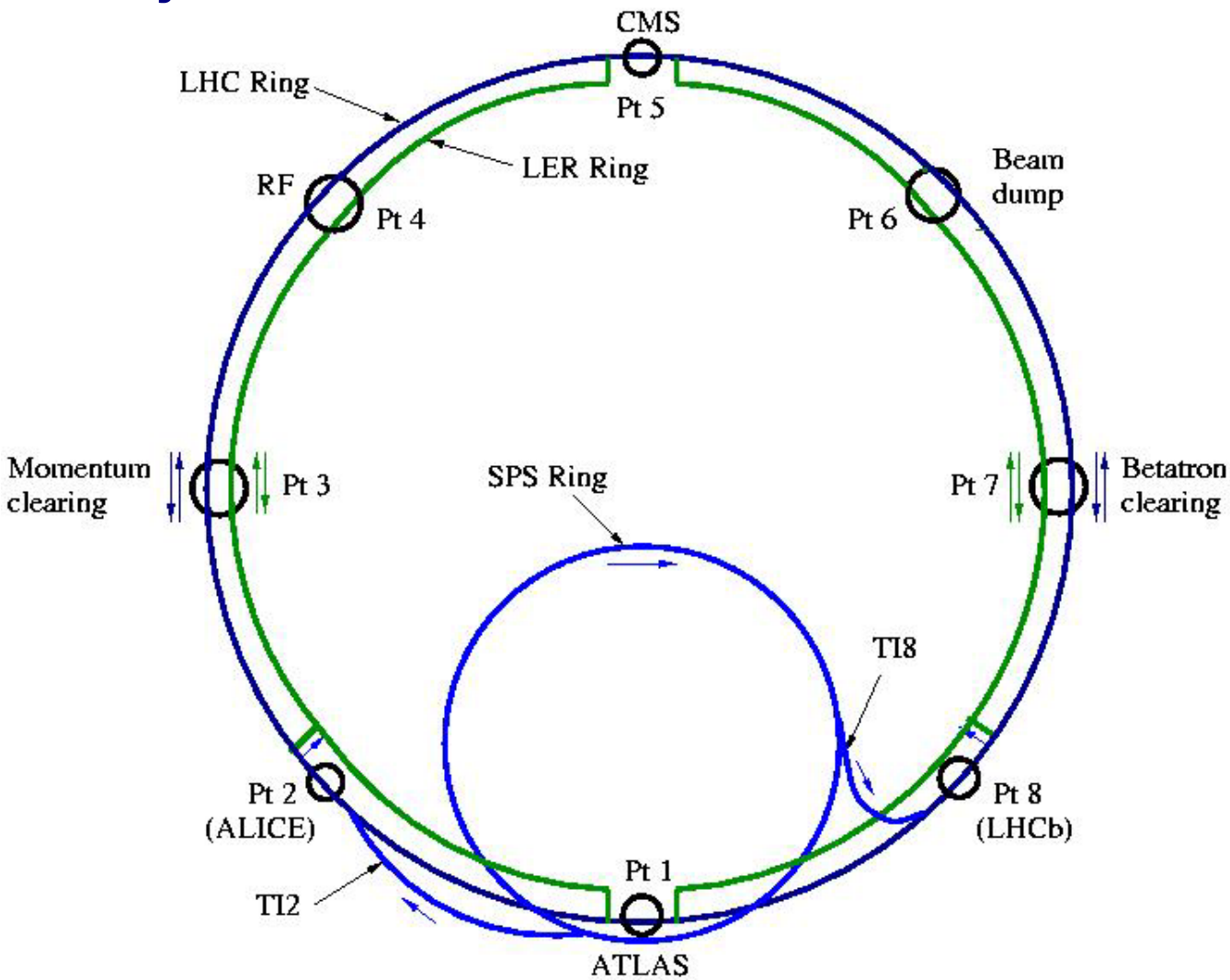
Injection / bypass scheme

G.deRijk

Use existing injection channel

Fast switched transfer lines in IP1 and IP5

RF, dump and cleaning separate from LHC

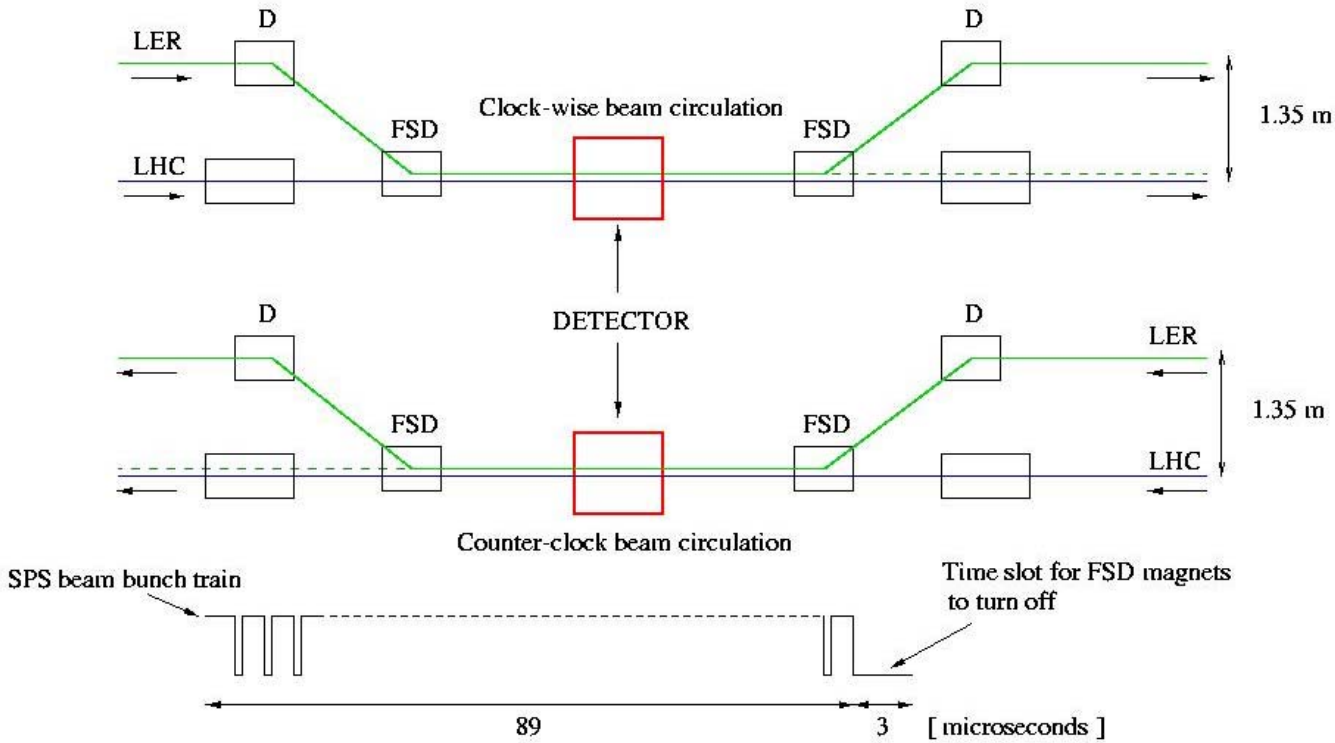


Injection / bypass scheme (2)

H.Piekarz

LER ops:
D and FSD on

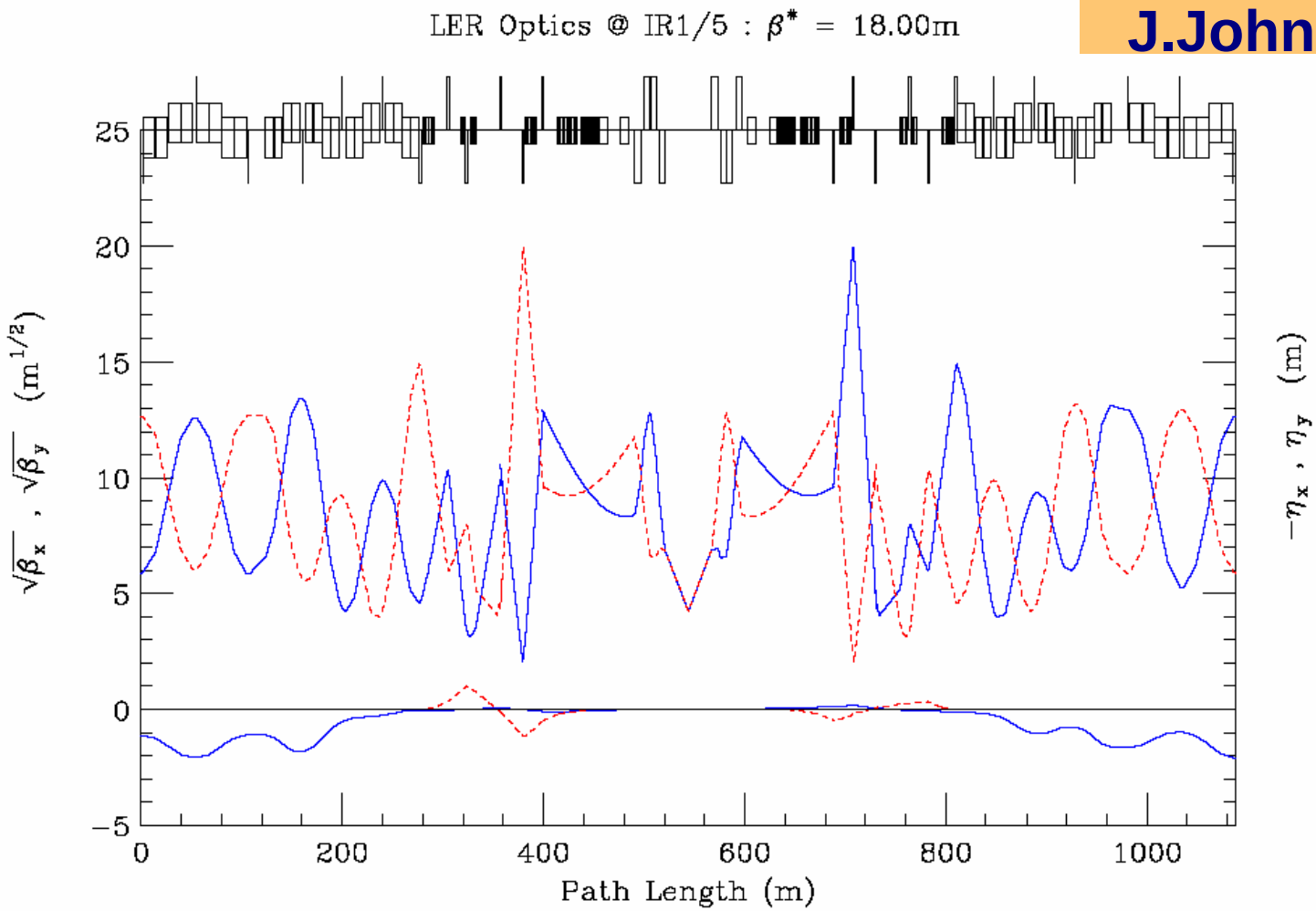
LHC ops:
D and FSD off



- Beam train of 89 μs + gap of 3 μs
- To inject in LHC switch Fast Switching Dipole off during 3 μs gap
- The following FSD go off in sequence when the gap passes

IR1 & IR5 Insertions

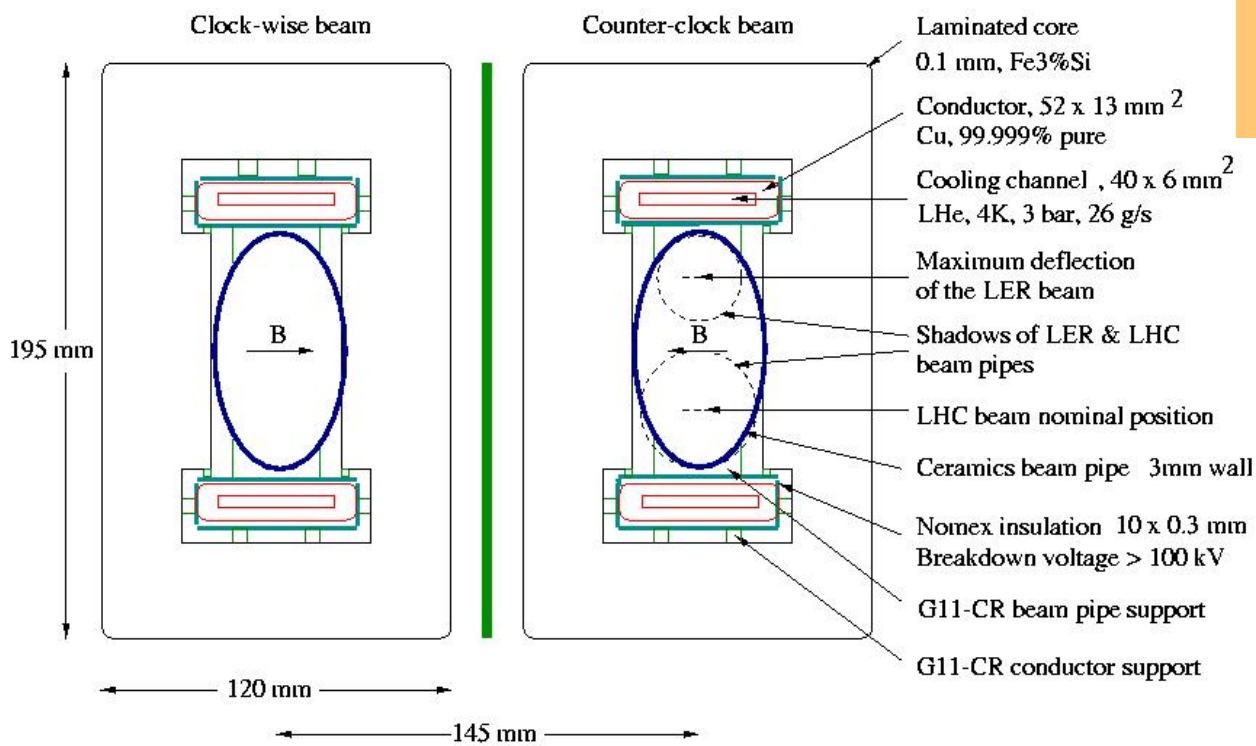
J.Johnstone



- Vertical bending is performed achromatically.
  - η* & η'* are ≡ 0 at the IP.

Fast switching dipoles- base option

H.Piekarz
S.Hays

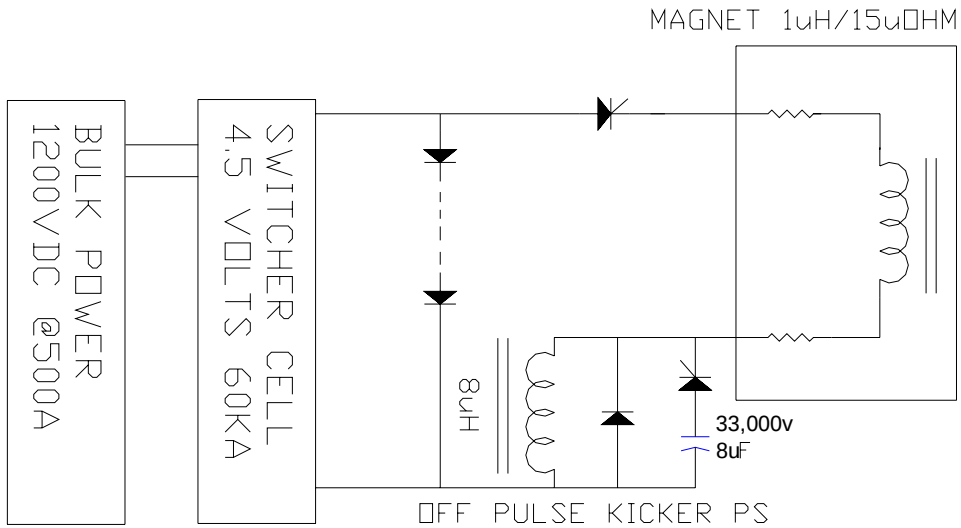


- A conceptual view of a possible fast switching dipole pair mechanical design. Conductor bars
- are wrapped in 10 layers of 0.3 mm Nomex insulation. The G11 pegs provide support for the
- conductors and also provide thermal insulation for the magnetic core. A common cryostat (not
- shown) houses assembly of two magnets, for clock-wise and counter-clock beams.

FAST PULSED OFF MAGNET SYSTEM CONCEPT

S.Hays

- The switcher power supply is a sub set of the 100k amp supply constructed at the FNAL MS-6 lab.
- This system uses a pulsed kicker style power supply and inductor to pulse the DC current off in the magnet and divert the stored energy into other elements.
- The elements that need to be as close to the magnet as possible to reduce the inductance, are the pulse supply, switch and bypass diode stacks.
- The switcher can be located a little farther away from the magnet because it's inductance adds to the pulsed inductor.
- All the fast pulse magnet power supplies can share one bulk power supply.

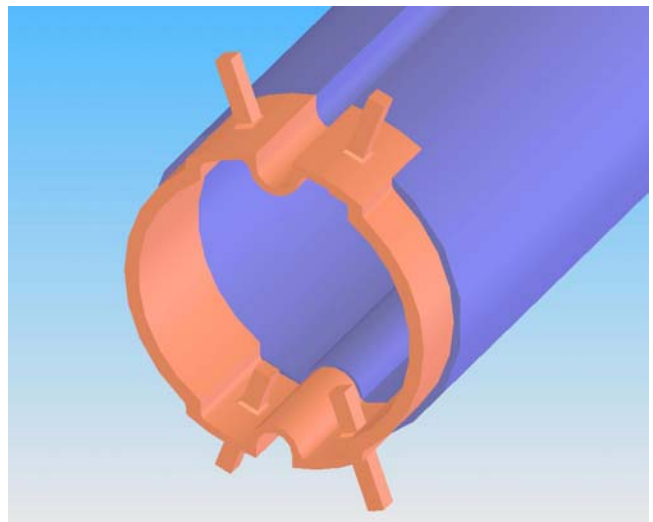


LER magnet calculated heat load small

Y.Huang

	4.5 K level	40 K level
Mechanical supports (mW/m)	53	670
Superinsulation (mW/m)	15	864
Beam loss (mW/m)	2	1
Splice (mW/m)	7	-
Total heat loads (mW/m)	77	1535

Mechanical support is provided by the pegs spaced at 0.5 m.
40 layers of MLI wrapped on the 50 K thermal shield and 20 layers on the conductor outer pipe to reduce the heat load at lower temperature level.



Beam Stability Comparison Table

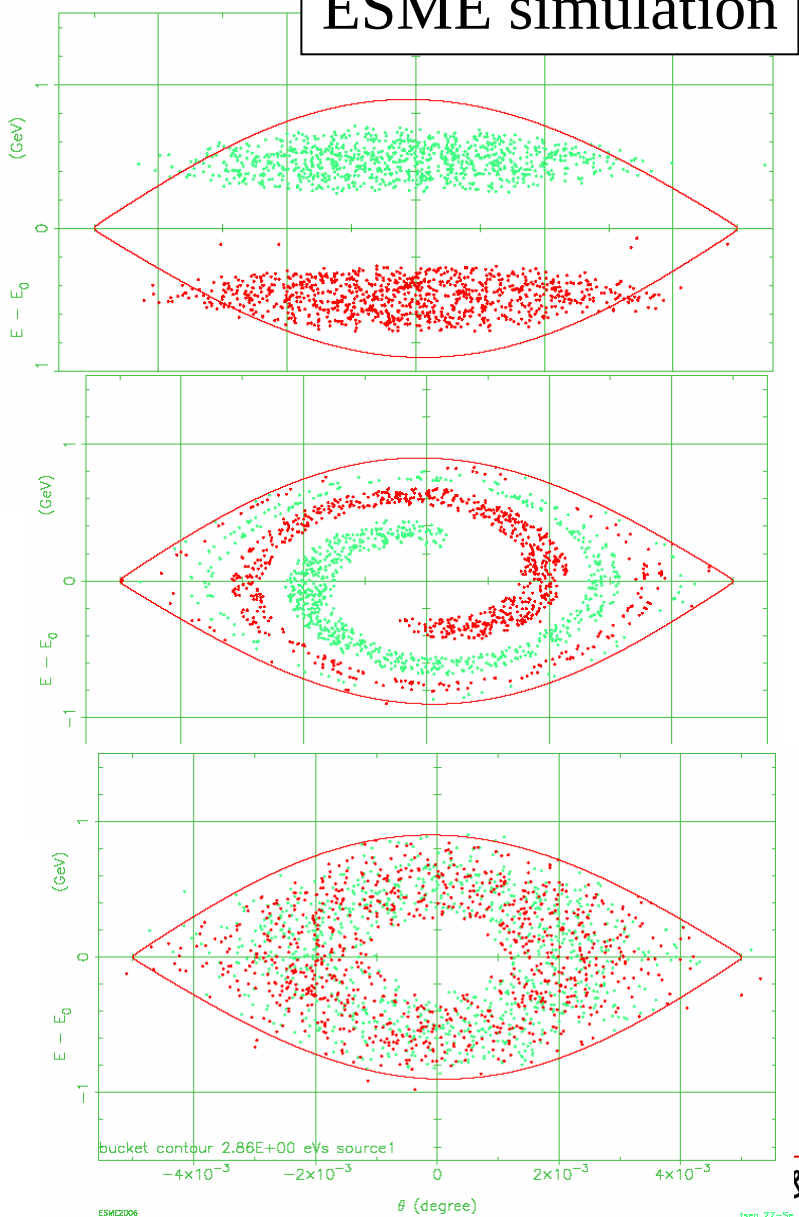
V.Shiltsev

	LER	SPS	TeV	VLHC
TMCI e9 N_{thr}/N_{nom}	770/115	260/115	1500/300	28/25
Space-charge dQ	0.0002	0.05	0.001	0
Res Wall N_{turns}	~50	~70	1800	1
AC tune e-3 max/comp	24/2	3	0.4	200/20
E-cloud wrt SPS	~1	1	0.12	0.3
Long.Cpld. bunch/SPS	~1	1		

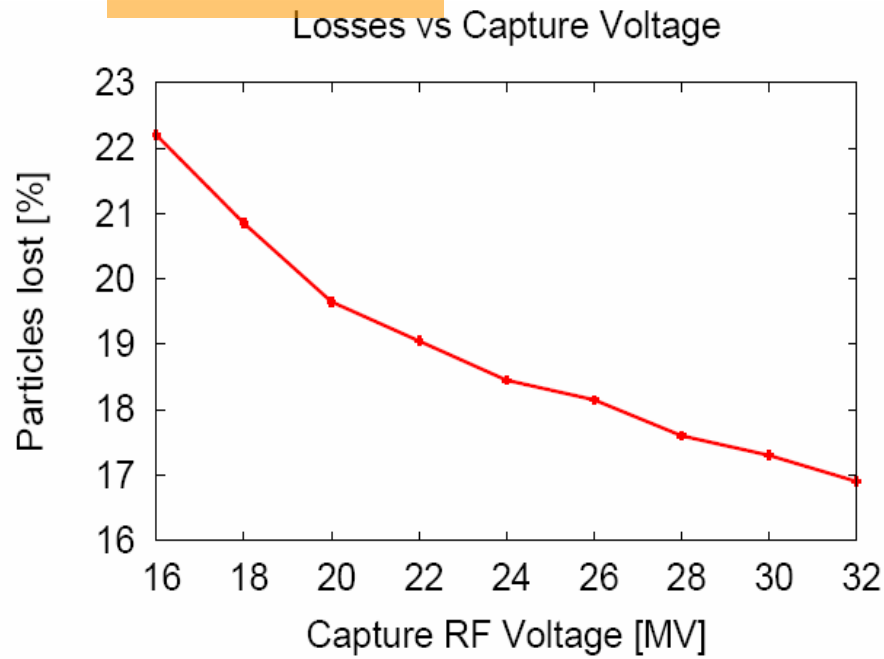
LER SlipStacking – not easy

LARP

ESME simulation



T.Sen



- Loss results are **very** preliminary – intended only to show variation with Vrf. This level of losses is **not** acceptable.
- Largest fraction of losses occur as beams are brought closer just before recapture
- Better control of the rf phases will reduce losses - losses in FMI < 7%

Summary of the LER Workshop

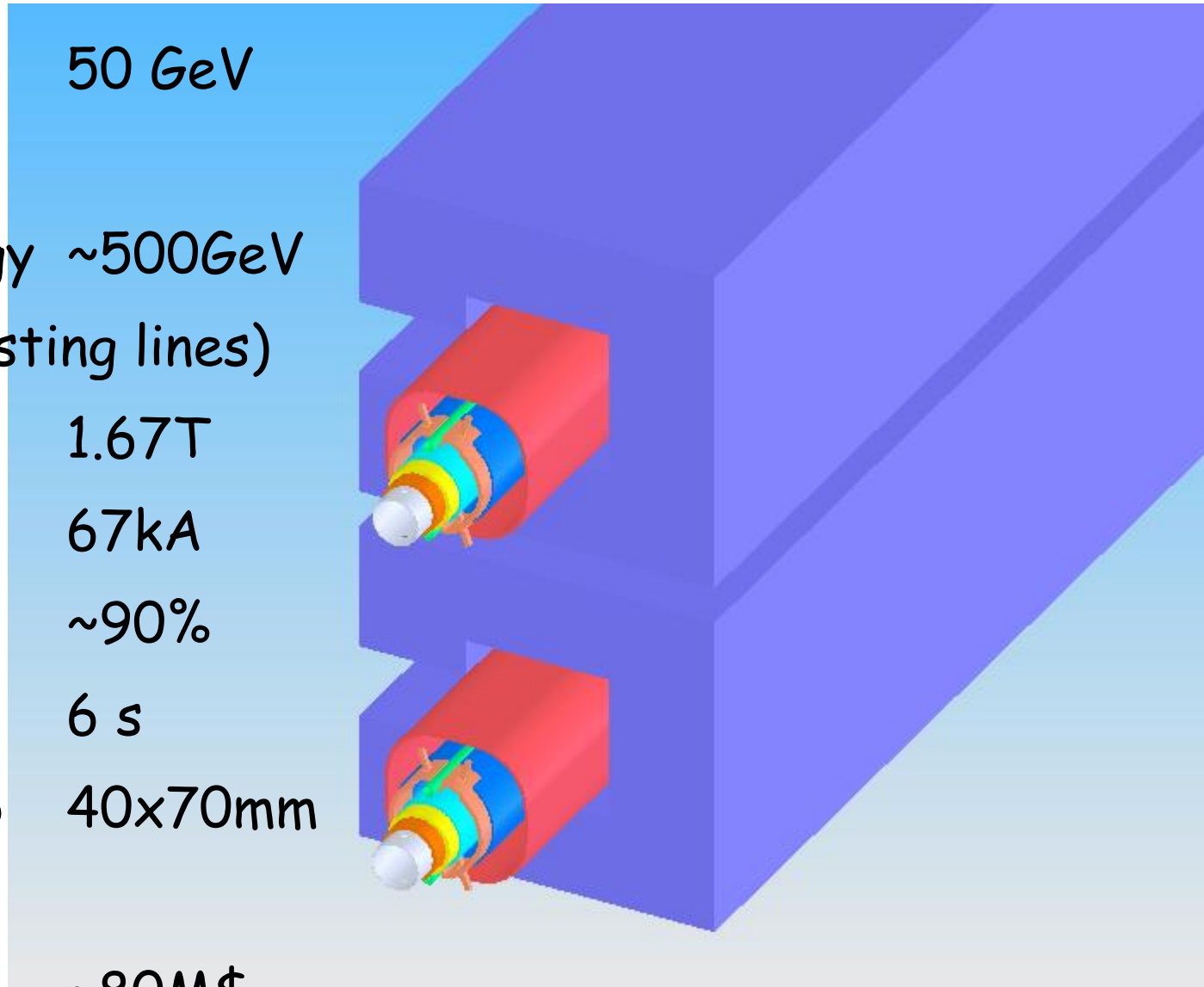
- LER in LHC tunnel
  - gains
    - Higher injection energy 1.5TeV
    - Faster turn around time
    - Better beam stability
    - Double Np/bunch by e.g. slip stacking
    - Save ~1yr or no-L time by installing during shutdowns
  - concerns
    - all the "gain" arguments are not strong
    - Problems: reliability, protection, n-flux, AC dQ, SlipSt.
    - 50GeV PS+ will address reasons #3-5
    - Pilot bunch…. many others concerning operation
- Team was very disingenouos in solving problems
  - E.g. pilot bunch problem – a neat soltion found, etc

Another Outcome of the Workshop

- Proposal of ~500 GeV superferric SPS+:
  - Addresses many (all) SPS problems
  - Promises same or faster filling time and x2 Np
  - Enables technology for 1.5TeV LER in future

SuperFerric Synchron in SPS Tunnel

Injection energy (from PS+)	50 GeV
Extraction energy (to LHC thru existing lines)	~500GeV
Max field	1.67T
Max current	67kA
Packing factor	~90%
Cycle Time	6 s
Beam pipe 2ax2b (coated Al)	40x70mm
Total cost	~80M$



SuperFerric Synchron in SPS Tunnel

H.Piekarz

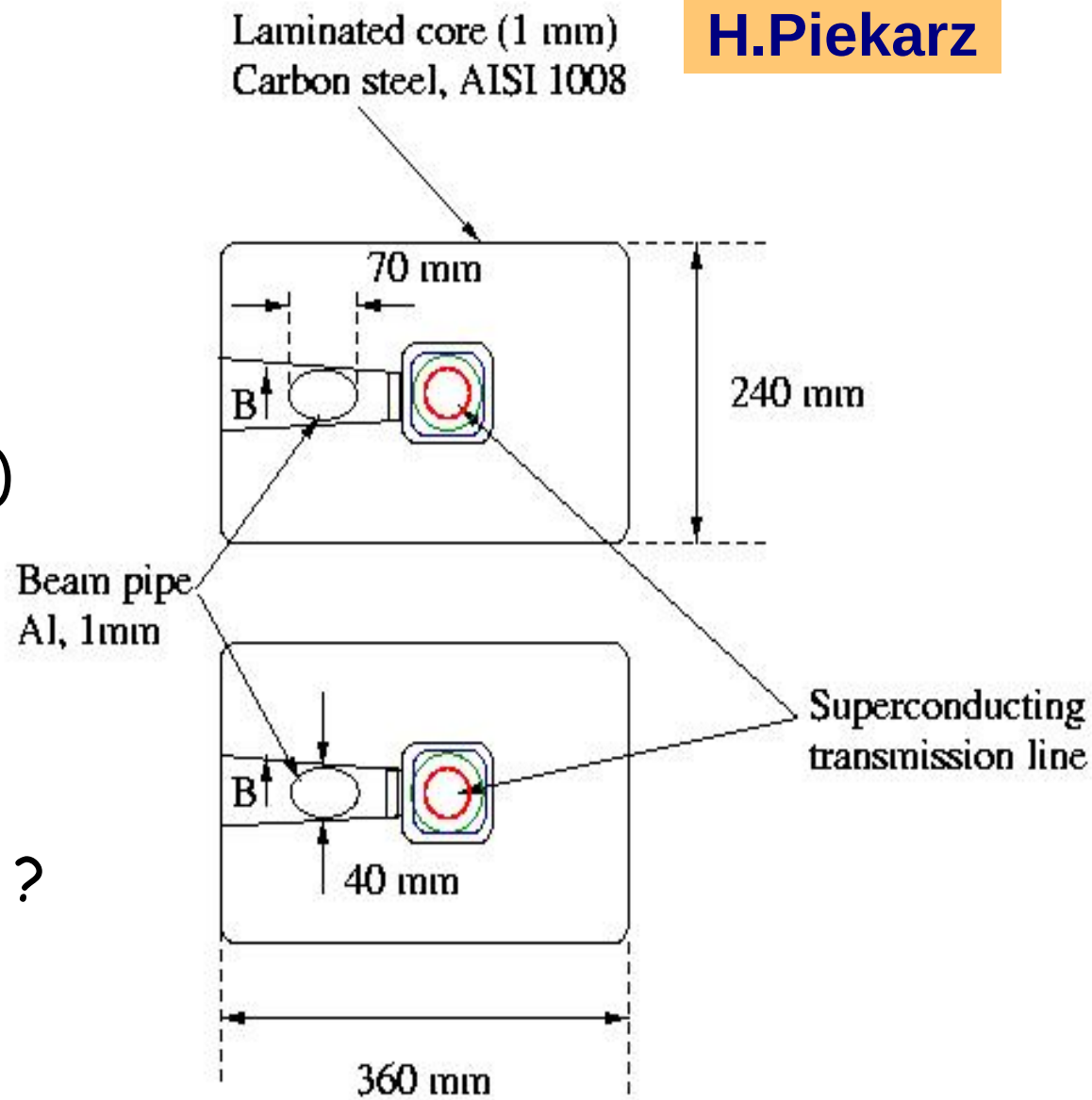
Inject, ramp and unload both rings

Advanced beam pipe (Al with anti-e cloud)

Sufficient aperture

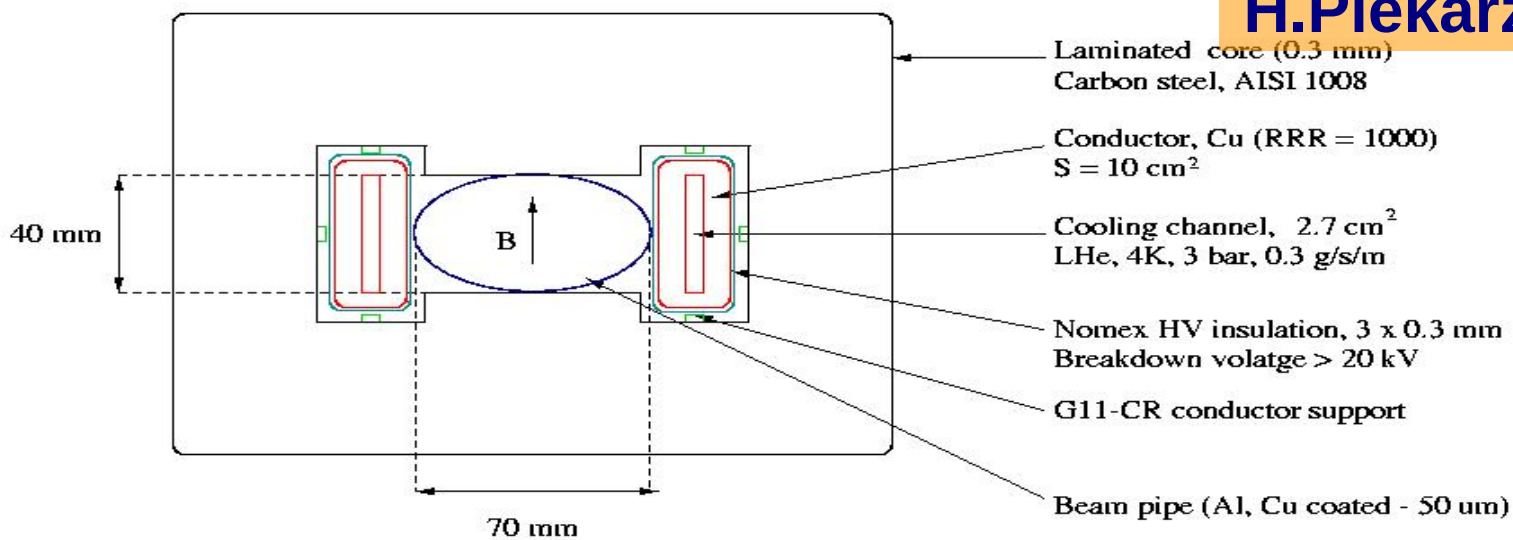
More p's for CNGS - ?

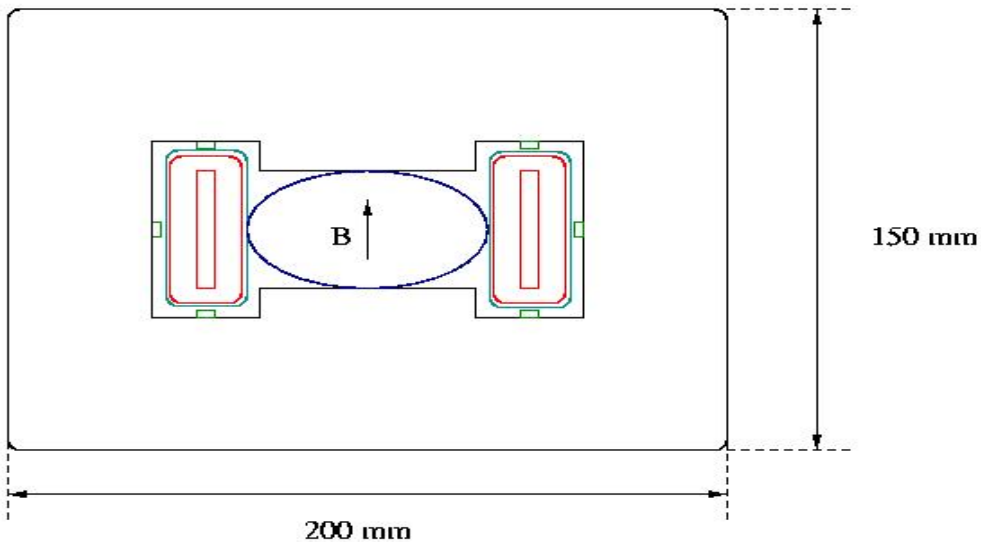
Slip Stacking - ?



Another Possible Magnet Design

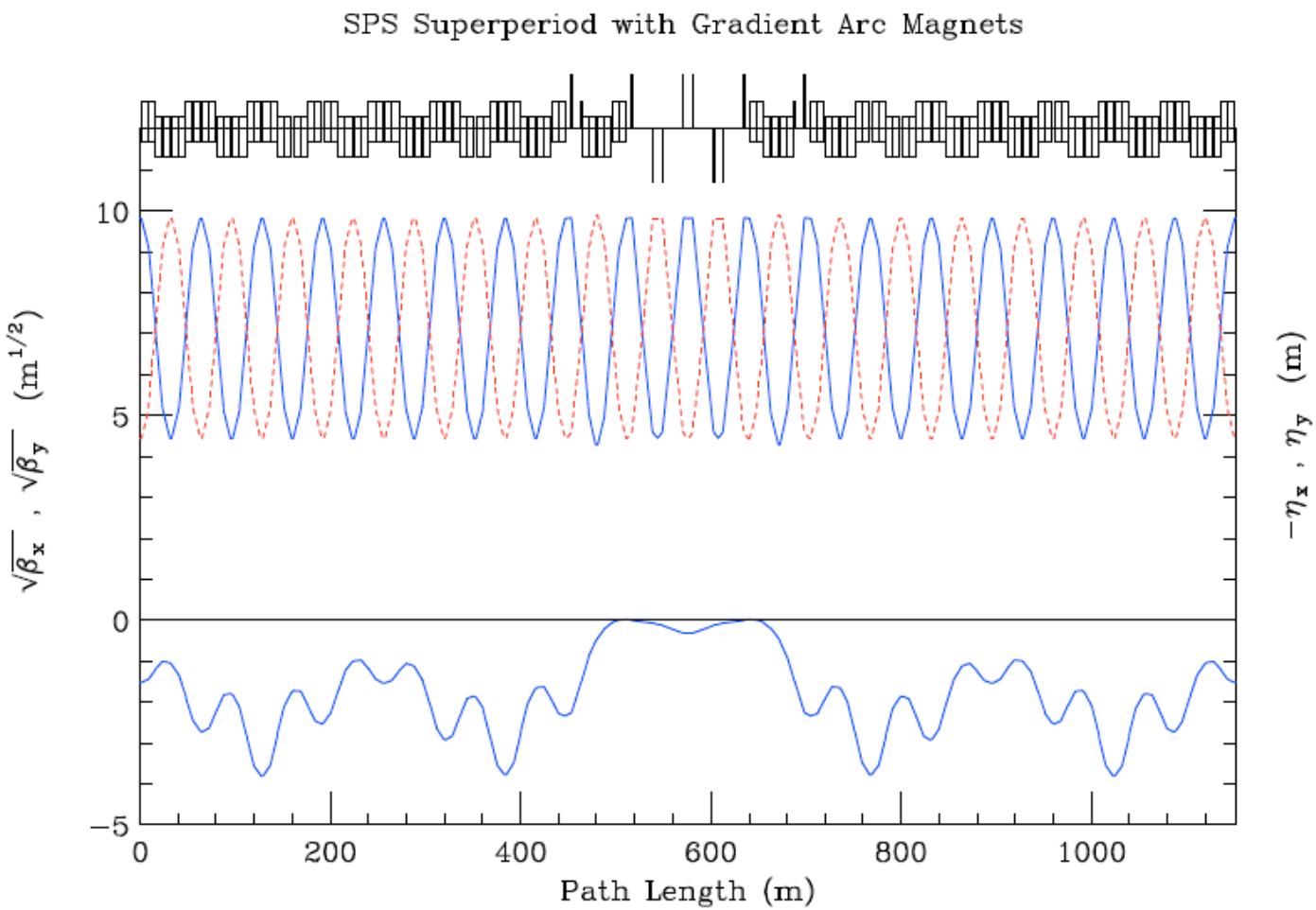
H.Piekarz





SF-SPS Superperiod Lattice

J.Johnstone



Cell & Superperiod Parameters

J.Johnstone

Cell Type	Magnet Type	L_{mag} (m)	#/ cell	cells / SP	B (T)	B' (T/m)
Arc	GF/GD	7.165	8	14	1.966	±4.704
Missing Magnet	GF/GD	7.165	6	2	1.966	±4.704
	QF	0.660	1		0.	70.00
	QTF	0.339	1		0.	70.00
Straight Section	QF/QD	0.660	4	2	0.	±70.00

- Magnet parameters evaluated at 500 GeV

	SPS	SF-SPS
Energy (GeV)	450	500
Cell Length (m)	63.99	63.99
Phase / cell	92.5°	92.5°
β_{max} (m)	108.9	96.4
η_{max} (m)	4.25	3.81

Gross comparison of current SPS and SF-SPS features

Parameter Set: SFSPS vs SPS

Parameter	Units	SFSPS	SPS
Inj./top energy	E inj/top, GeV	50/450	26/450
Circumference	C, km	6.916	6.916
Bunches/buckets	B, h_{RF}	288/4620?	288/4620
P/bunch	N_p, 10**9	115→230	115
Tune	ν	~26.6	~26.6
Slip factor	η	0.00186	0.00186
Beta av/max/min	β, m	~50	~41
Pipe ½ size	a/b, mm	18/32	22.5/70
Transv. Emitt	ε_T, π urad, rms	3.5	3.5
Ave/bunch current	I_B, mA,/I_b, mA	Upto 460/1.6	230/0.8
RF frequency	f_{RF}, MHz	400/200?/800?	200/800
RF Voltage (max)	U_{RF}, MV	~4-8	4/1
Synchr. tune (inj)	ν_s	0.007	0.0069
Bunch length (inj)	σ_s cm, rms	30	30
Dp/p, rms (inj)	dP/P	~0.01	0.007

SF-SPS advantages over SPS: stability

	SF-SPS	SPS	TeV	LER-LHC
TMCI e9 N_{thr}/N_{nom}	2000/115	260/115	1500/300	770/115
Space-charge dQ	0.012	0.05	0.001	0.0002
Res Wall incr. N_{turns}	~540	~70	1800	~50
Max AC tune var. dQ	0.001	0.003	0.0004	24
E-cloud Inc/SPS	~0.01	1	0.12	~1
Long. inst wrt SPS	same	same		

Cost Estimate (H.Piekarz)

Cost estimate (very rough) assuming 1400, 4 m long arc magnets for 3s cycle operation:

- 1. Arc magnets $M 24
- 2. Quads, Correctors, etc $M 4
- 3. Vacuum system $M 8
- 4. RF $M 10

Subtotal: $M50

- 5. Cryogenics (2 plants @ $20M + distr.) $M 50

Total: ~ $M100

Conclusions

- ~500 GeV superferric SPS+ could be a viable solution for luminosity upgrade:
  - addresses many(all?) SPS problems
  - promises faster filling time and x2 Np
  - enables technology for 1.5TeV LER in future
  - boosts CNGS NPOTs/yr (needed?)
- Near term SF-SPS R&D needed:
  - basic parameters set and magnet specs
  - magnet design, conductor choice
  - prototyping and tests
- Superferric LER in LHC tunnel can be postponed until LHC energy upgrade time frame will be specified