Electrostatic separator limits and R&D

With input from:

B. Balhan

N. Garrel

B. Goddard

Design and Technical Challenges of the ILC Small Angle Interaction Regions

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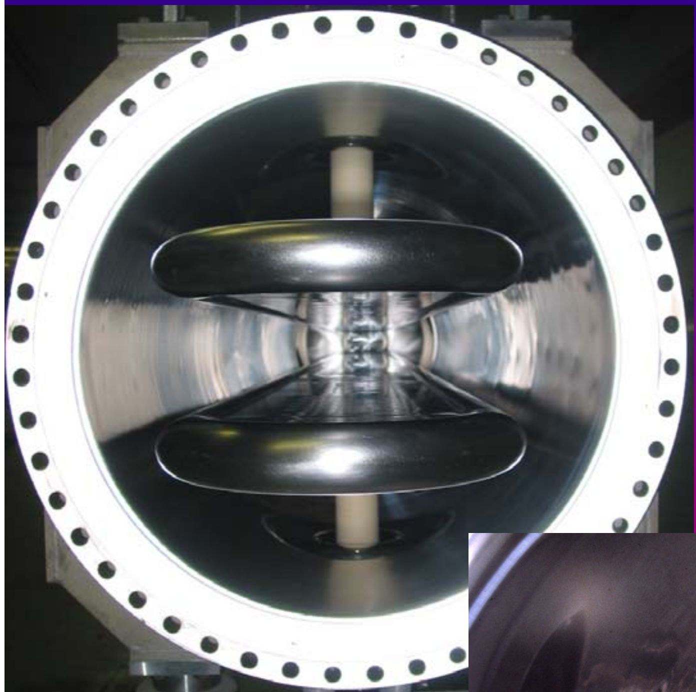
Some reported separator experience throughout the world

	LESB II (1979) [1]	Tristan (1989) [2]	Tevatron (1992) [3]	SPS ZX (1982) [4]	LEP ZL (1996)	CESR (1999) [5]	BEPC II (2001) [6]
Nominal gap (mm)	150	80	50	40 (20 – 160)	100 (60 – 160)	85	100
Operational field strength (MV/m)	< 5.2	3.0	5.0 max.	5.0	2.5 (tested to 5.0)	2.0	2.2
HV supply (kV)	+/-390	+/- 120	+/- 125	0/-200	+/- 150	+/- 85	+/- 110
Electrode dimension (mm x mm)	n.a.	4600 x 150		3000 x 160	4000 x 260	2700	
Electrode material	Glass	Titanium		Titanium	Stainless steel		
Device length (mm)	n.a.	5105	3000	3380	4500		
Working pressure (mbar)	10^{-6}			10^{-10}	10^{-10}		
Operational spark rate (#/h)	<1	<0.02		< 0.03	0.2	0.04	
Particle beam	p-	e- e+ 9mA 15GeV	p p-	p p- (270 GeV)	e- e+ (100 GeV)	e- e+ 150 mA	e- 576 mA

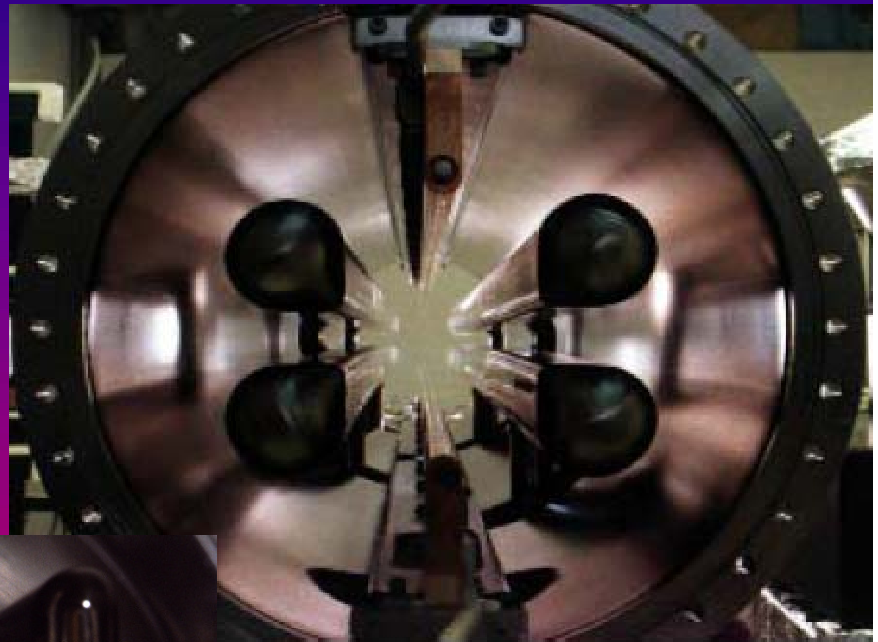
Design issues

- Layout issues
  - Electrode configuration (continuous or split electrodes)
  - Vertical / horizontal
  - Polarity choice for top/bottom electrode
  - Physical length vs active length
  - Coupling (beam coupling, spark coupling)
  - Number of units / redundancy in case of failure
- Field homogeneity
  - Electrode shape, shims
- Field strength
  - Electrode material
  - Surface preparation

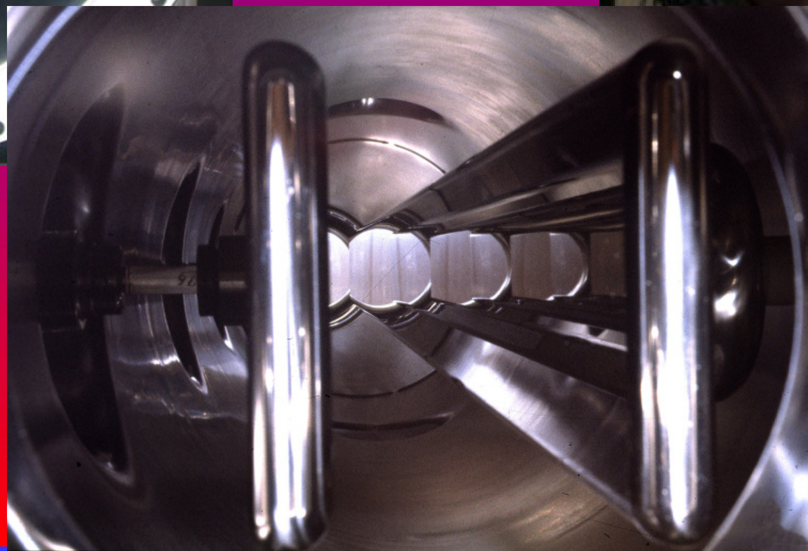
Electrode layout



LEP ZL separator

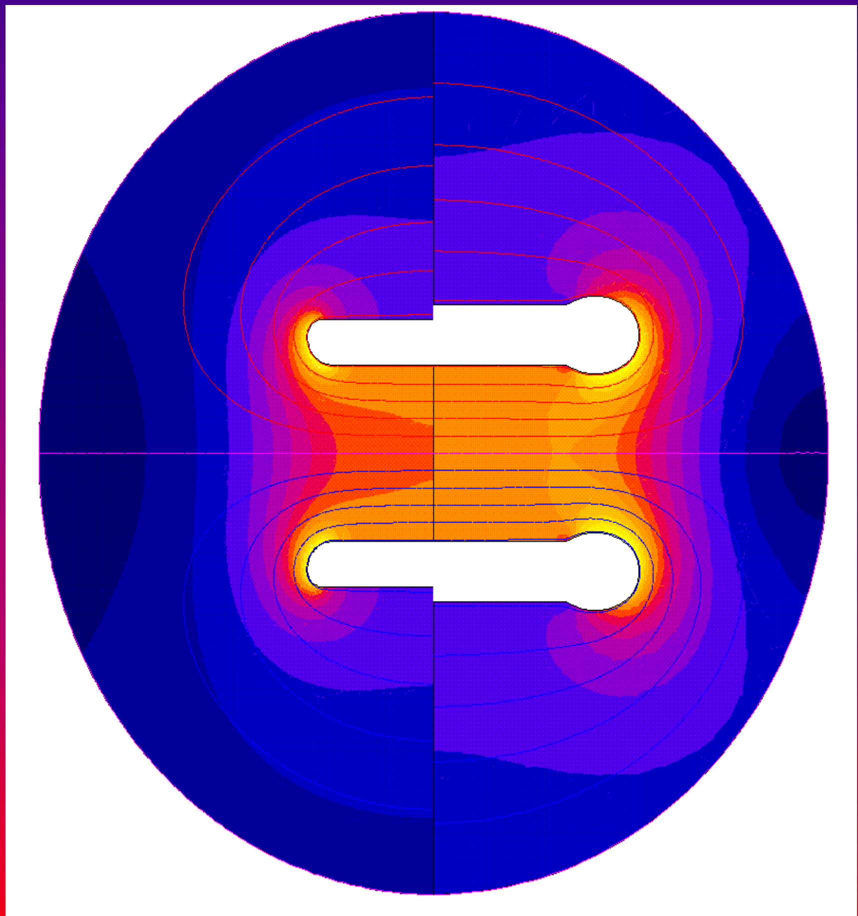


CESR separator

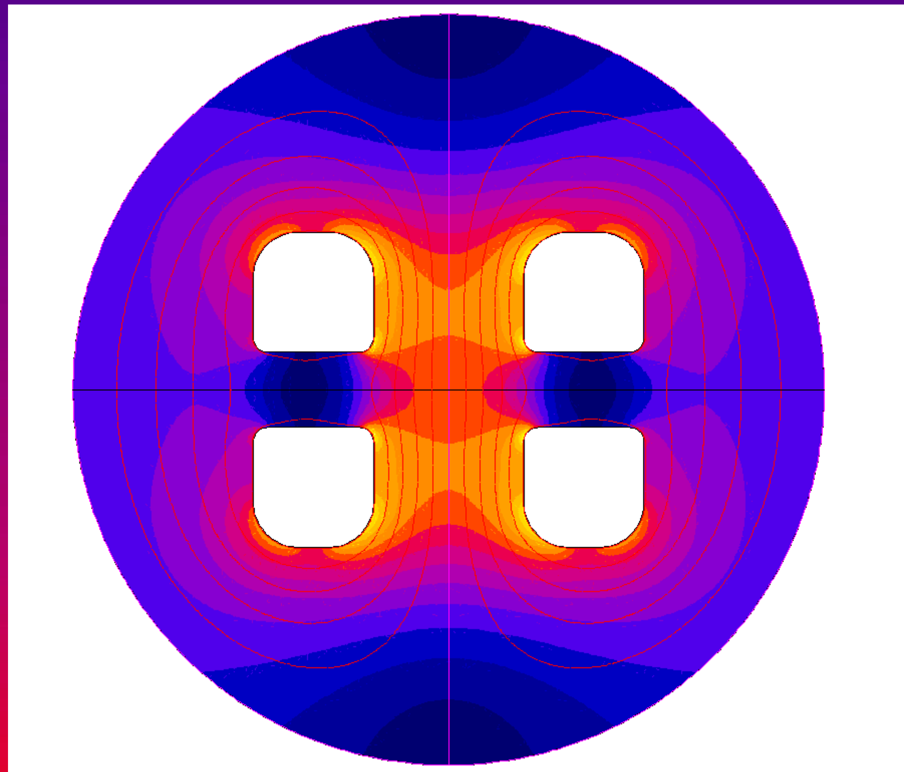


SPS ZX separator

Field distributions



ZX ZL

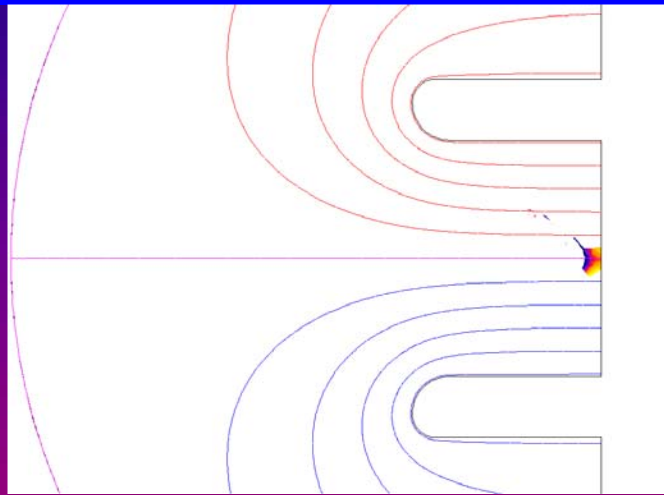


Split electrodes (50 mm)

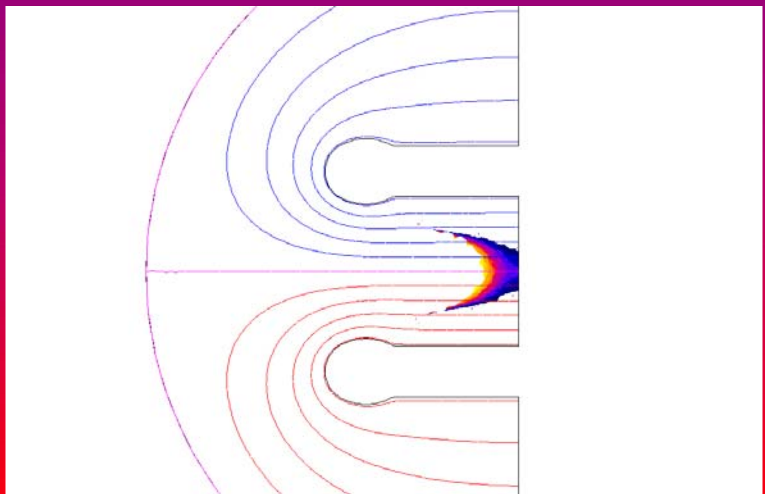
Field homogeneity

Requirements determine the electrode complexity and field enhancement factor

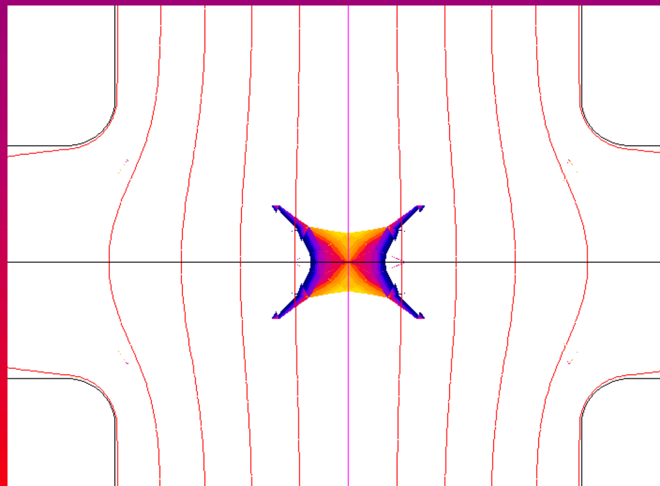
- material choice
- operational field strength
- spark rate
- reliability



ZX: 1‰ for 14 x 10 mm

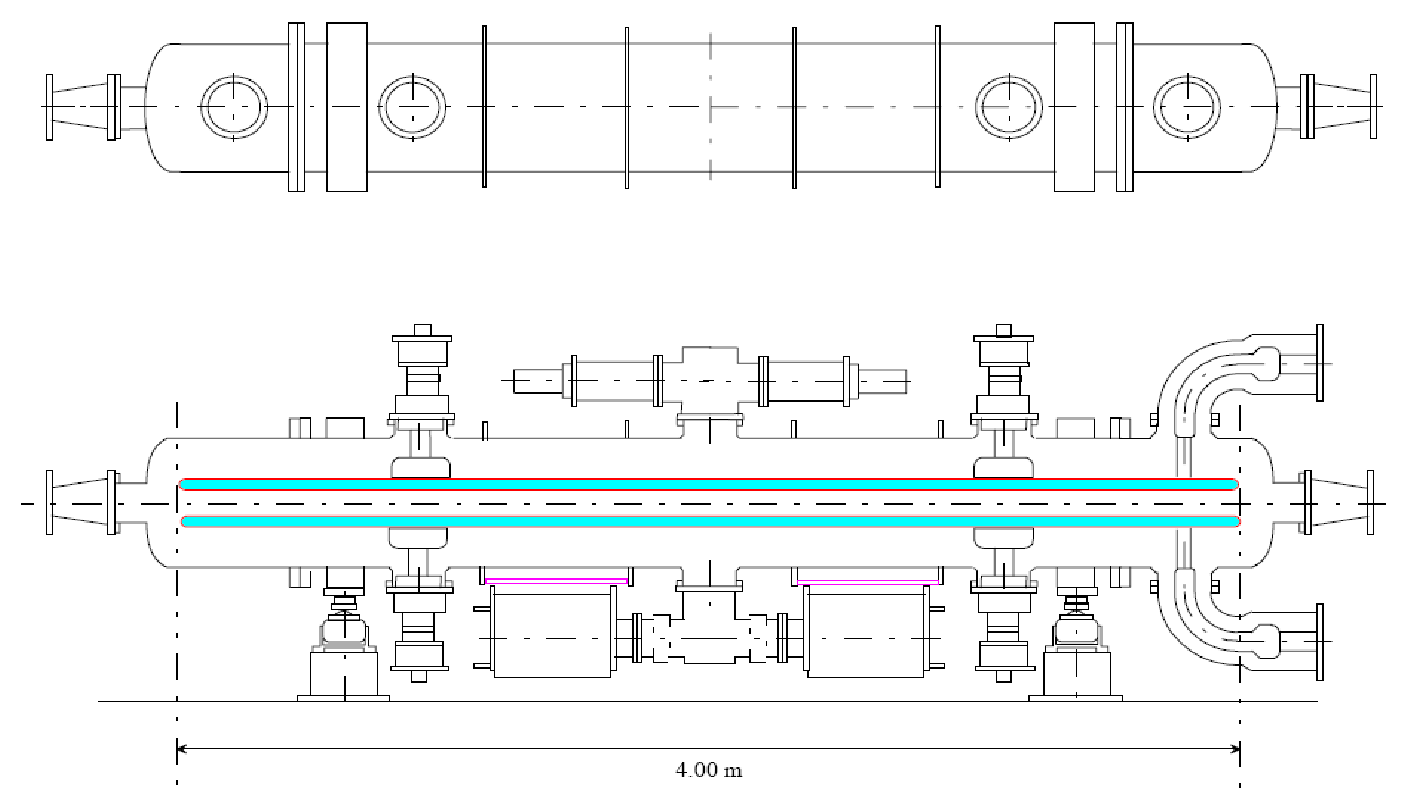


ZL: 1‰ for 25 x 13 mm



Split electrodes:1% for 6 x 7 mm

Installation length



- In SPS ZS septa: 3000 mm active length at 870 mm spacing
- LEP ZL: 4000 mm active length; 4500 mm device length; spacing > 650 mm

Note: Additional space would be needed for vacuum valves in case plug-in systems would be adopted to reduce down time in case of exchange due to failure

Design issues (cont.)

- Spark rate
  - Beam scattering on the electrodes

- Electrode supports (insulators)
  - Operation in hostile environment (e-, γ, p, …..)
  - Insulator treatments (ion implantation, ..), device glow discharge
- HV circuit
  - Recovery after sparking, HV resistors
  - Feedthrough
  - Cables and connectors
  - H.V. generator, Voltage margin for conditioning, Current margin to cope with dark current / beam loading / recovery after sparking
- Vacuum issues
  - Vacuum level (< 10^{-9} mbar)
  - Residual gas contents
  - Electrode cooling requirements
  - Operational constraints: venting (grounding of electrodes, vent direction), bake out (mechanical design constraint), …

Feedthrough

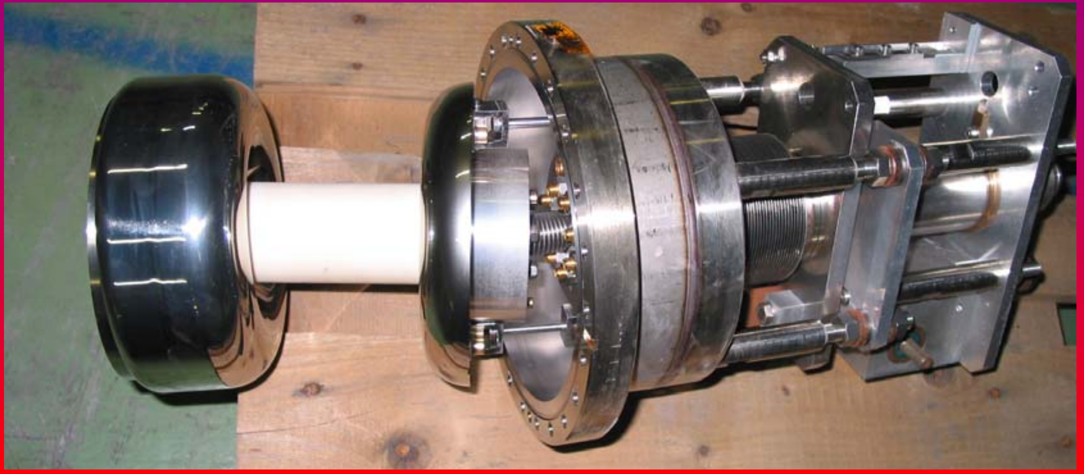
- Reliable design up to 300 kV available at CERN
- Modular: can be exchanged in case of failure without removal of separator from beam line
- Insulating liquid
  - 3M Fluorinert FC-77 with continuous "regeneration"

Electrode support

- Choice of insulator material
  - Pure insulator / slightly conductive
  - Some work on insulator treatments available at CERN
  - Glow discharge experience at KEK
- Little operational experience with insulators subject to strong radiation at CERN

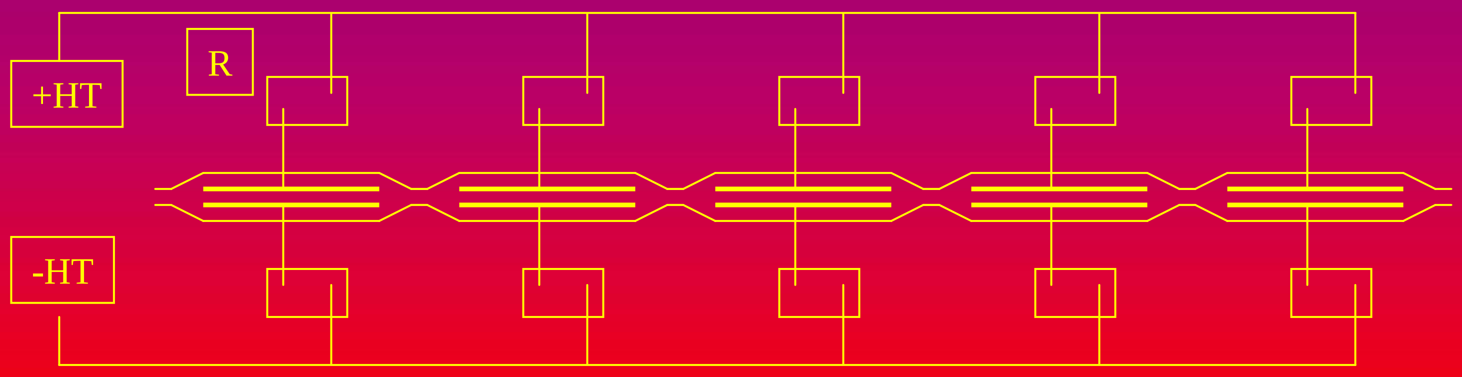
ZL electrode support mechanism:

- Electrode cooling liquid channel
- Remote displacement system

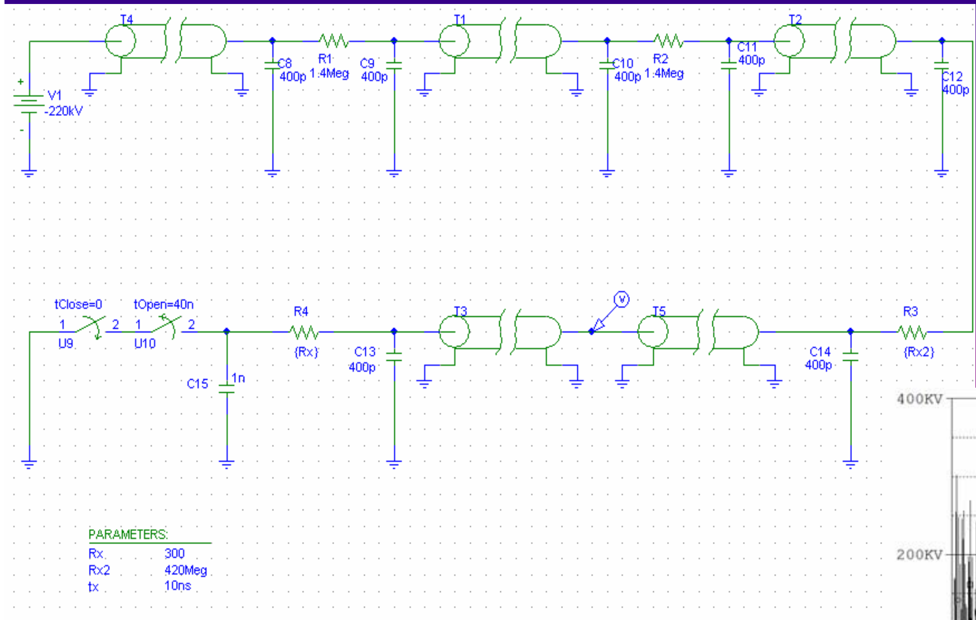


HV circuit

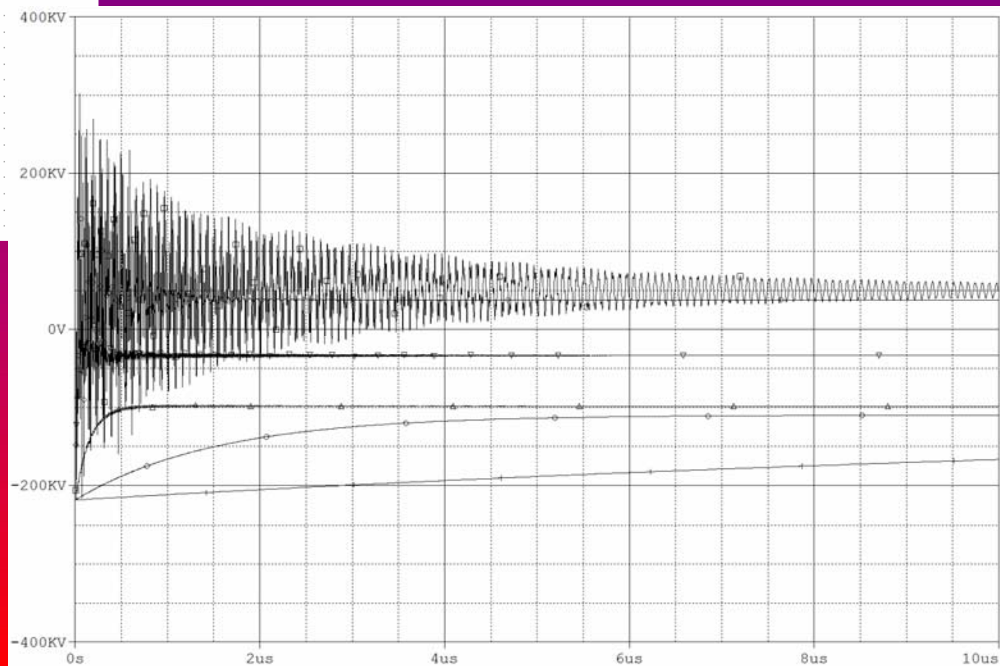
- Used in SPS septa
  - 400MΩ decoupling resistors, with short cable lengths to electrodes to limit discharge energy; decoupling of sparking
  - Single HT generator
- LEP separators:
  - bi-polar set-up with 1.2 MΩ decoupling resistors
  - Automatic conditioning system



HV circuit (cont.)



Decoupling of stored energy in coaxial cables from power supply by means of large series resistors (in SPS 400 MΩ)



Influence of the feedthrough resistor on reflections

Required ILC separator specifications [7]

- Active length: 25 m
- Total required deflection: 0.5 mrad
- Gap width: 100 mm
- Electric field: 5.0 MV/m
- Spark rate: *< 0.04 / hr ?*
- Field homogeneity: *10^{-3}?* in *5 x 5* mm^2

Proposal

- Low field amplification electrode shape in titanium
  – Titanium to obtain best performance for cathode, and obtain good local vacuum; cost impact to be studied; lightweight good for horizontal application to reduce stress on insulators
- 6 devices of 4 m spaced at 0.65 m
- Electrical field strength: 5.2 MV/m
- Bipolar: +/- 260 kV,
  – all devices electrically in parallel, decoupled with > 5 MΩ resistors
- Total installation length: 27.9 m
- Gap width 100 mm nominal, but adjustable 80 – 140 mm
  – For flexibility of operation and ease of conditioning
- Field homogeneity: 10^{-3} in 5 x 5 mm^2
  – Reasonably simple to obtain with flat electrodes
- HV power supplies: 300 kV, 3 mA
  – To provide required margins for conditioning and operation (U, I)

Required R & D

- **Optimal electrodes**
  - Length, width, cross section profile
  - Material and surface finish
  - Manufacturing techniques in case of hollow Ti
- **Coupling in the event of sparking**
  - Geometry effects (coupling of field, coupling via the beam / photons etc.)
  - Circuit effects
  - Recovery
- **Feedthrough & insulator support design**
  - (some work by CERN on insulator treatments available)
- **Performance under irradiation**
  - Evaluation of radiation in existing set-ups
  - Expected dose rates and profile
  - Tests with beam
- **System performance at 5.2 MV/m and beyond**
- **Impedance presented to the beam:**
  - Problem to the beam?
  - Problem to the separator (Parasitic mode damping needed?)

References

[1] V. Kovarik et al., "The modernization and improvement of the BNL short separators", NIMB 158, 1979

[2] T. Shintake et al., " electrostatic beam separation system of tristan main ring", PAC 1989

[3] K.P Koepke, "Status of the low beta and separator projects", EPAC 1992

[4] R. Bonvin et a;., "electrostatic deflectors for luminosity measurements at CERN pp collider", 10th ISDEIV 1982

[5] J.J. Welch et al., "Commissioning and performance of low impedance electrostatic separators for high luminosity at CESR", PAC 1999

[6] Y.D. Hao et al., "Design of low impedance electrostatic separators for BEPC II", APAC 2001

[7] O. Napoly et al., " Evaluation of the multi bunch kink instability in ILC head-on collisions", EUROTeV-report-2006-018