Phase rotation and charge separation

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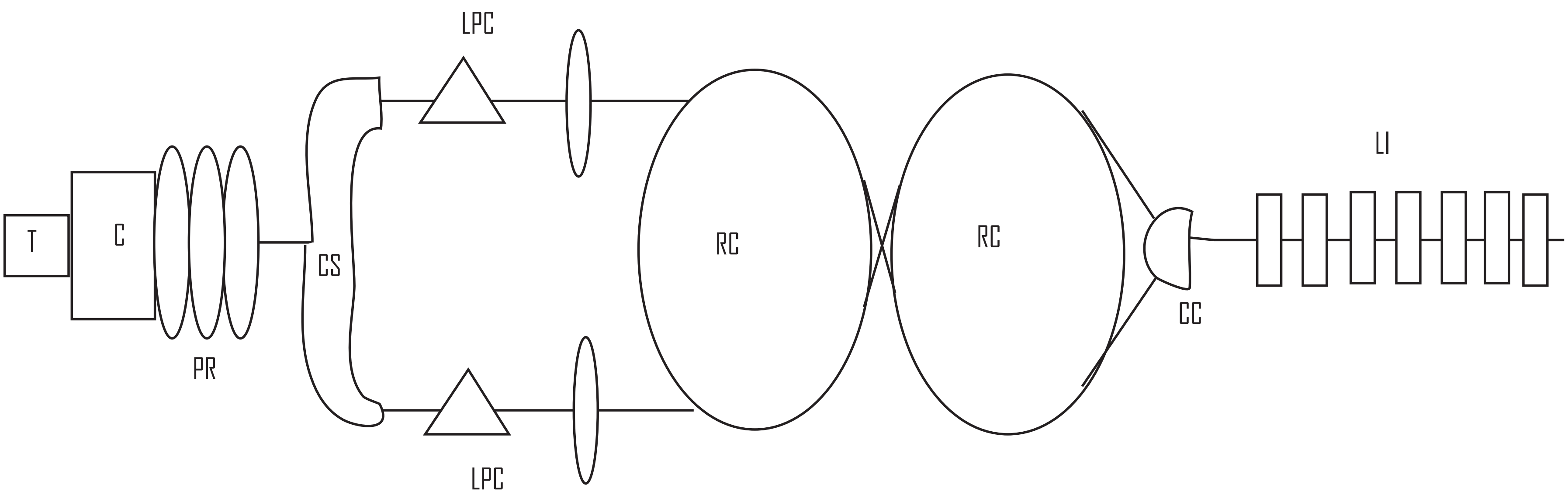
Reference parameters for beam

	out PR	in BCR	in RFOFO	HF	
ε_{TN}	20	18	12	0.29	mm
ε_{LN}	1225	450	19	2.0	mm
ε_{6N}	$5\ 10^5$	$2\ 10^5$	2840	0.17	mm^3
<p>	228	193	219	$50\ 10^3$	MeV/c
σ_X	9.5	8.4	4.2	0.0295	cm
$\sigma_{X'}$	97	125	139	2.1	mr
σ_Z	190	50	12	14	cm
σ_P/p	0.41	0.19	0.18	$3\ 10^{-5}$	
β_T	97	70	30	14	cm

Front end scenario

- many possible configurations
- choose "single-bunch" from target



Phase rotation

- Compare phase rotation designs [MC-302]
  - Same initial beam distribution (MARS 24 GeV on Hg)
  - Same simulation code (ICOOL)
  - Same assumptions about radii, windows, etc
  - Did survey with simplified simulation model
- Single bunch designs for p ~ 200 MeV/c
  - (1) Snowmass 1996
  - (2) Status report 1999
  - (3) Start of PJK NF
  - (4) Start of CERN NF
  - (5) V. Balbekov (MC-272)

Phase rotation survey summary

	B1	f	G	LROT	Tr	Tr
	[T]	[MHz]	[MV/m]	[m]	100-300	200-400
VB	1.75	36.37	6.37	20	0.277	0.334
	1.75	36.37	6	25	0.302	0.341
	1.75	40.25	6	25	0.303	0.344
PJK	1.25	60-30-45	8-5-7	43	0.257	0.277
	1.75	66-30-42	8-5-7	43	0.286	0.324
CERN	1.75	44	2	30	0.179	0.240
	1.75	44	4	30	0.180	0.258
SR	5	60-30-60-37	5-4-4-4	42	0.268	0.301
Snow	5	90-50-30	4-3-2	42	0.227	0.273

Transmissions include 6 m bunchlength cut

Balbekov design

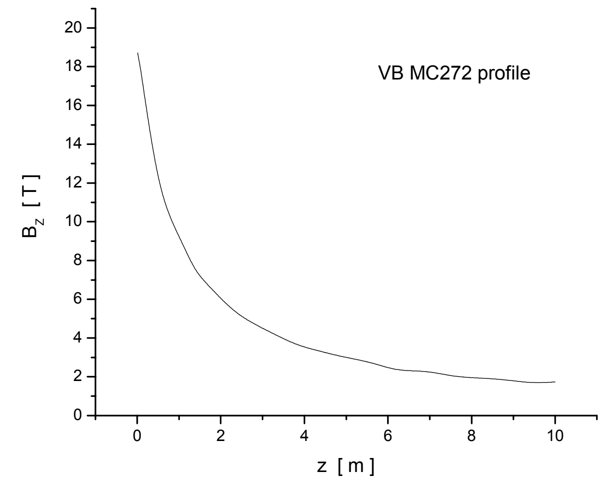
Balbekov MC-272

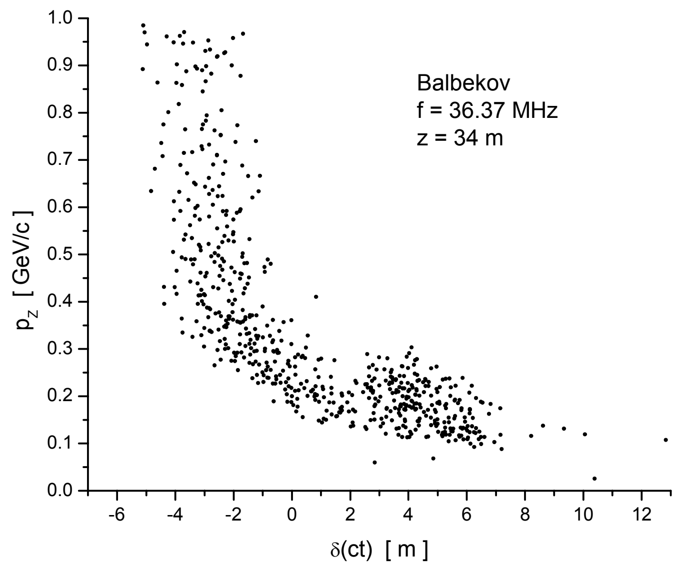
target

drift	RF 36	RF 36	drift

z = 0 4 10 24 34 m

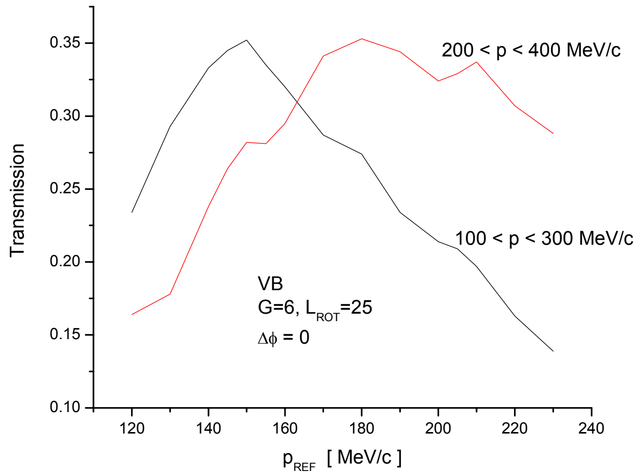
B = 20 3.5 1.75 1.75 T

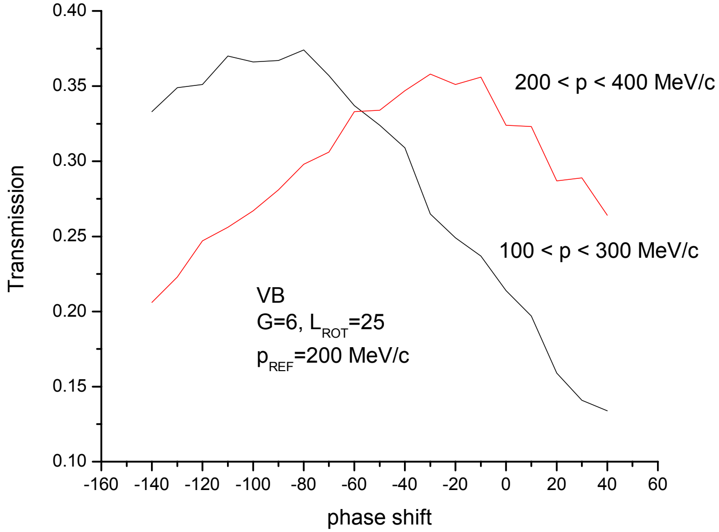


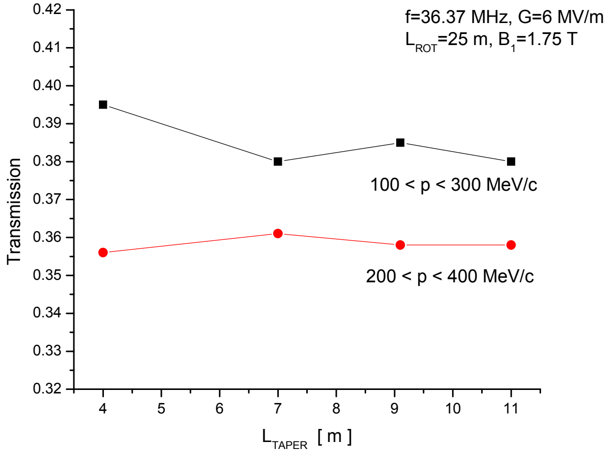


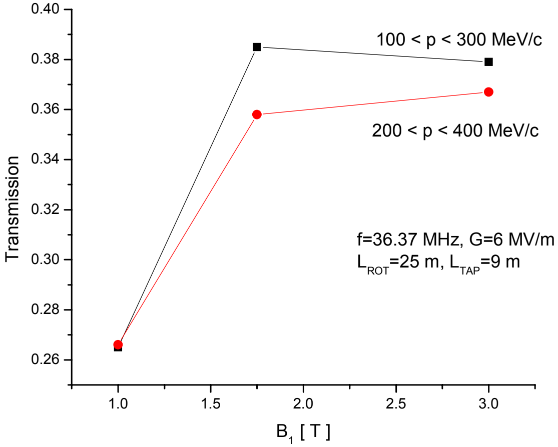
- Most recent
- Simplest – 1 frequency
- Shortest – 34 m
- Low solenoid field

Parameter variation (1)

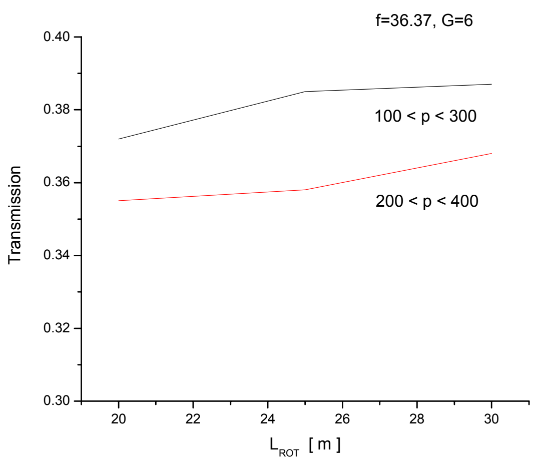


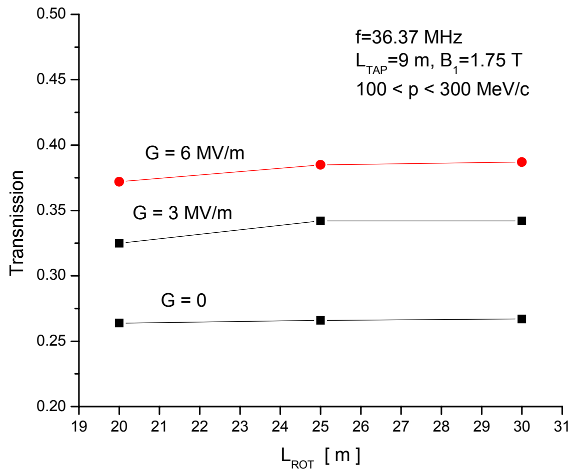


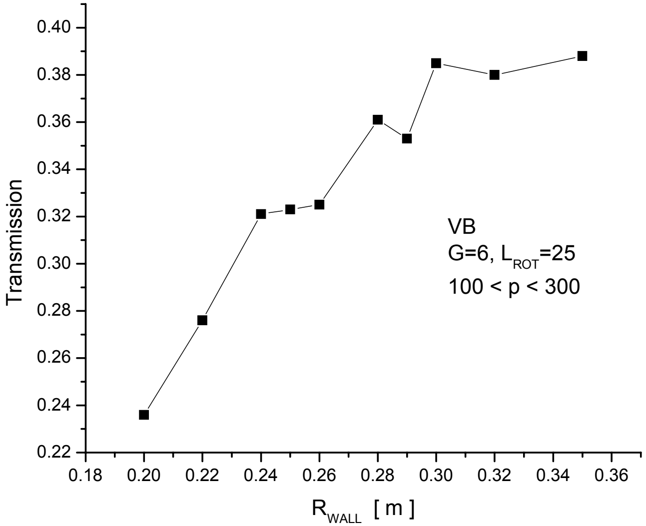


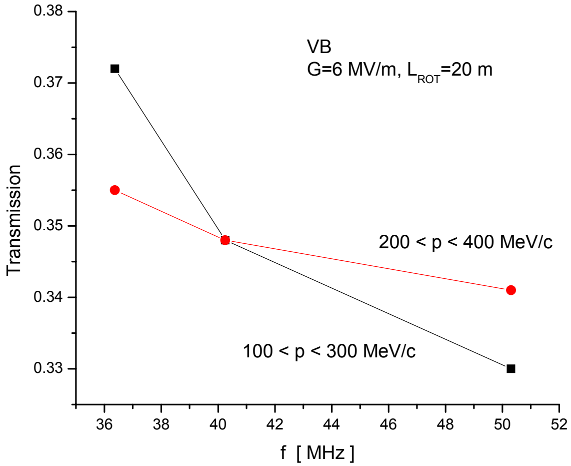


Parameter variation (2)







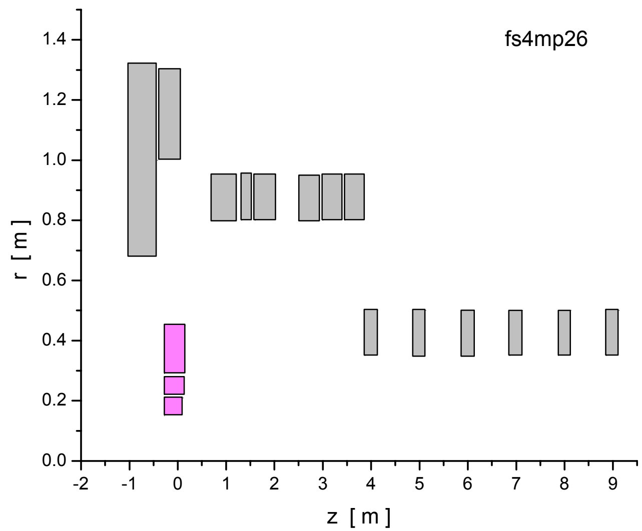


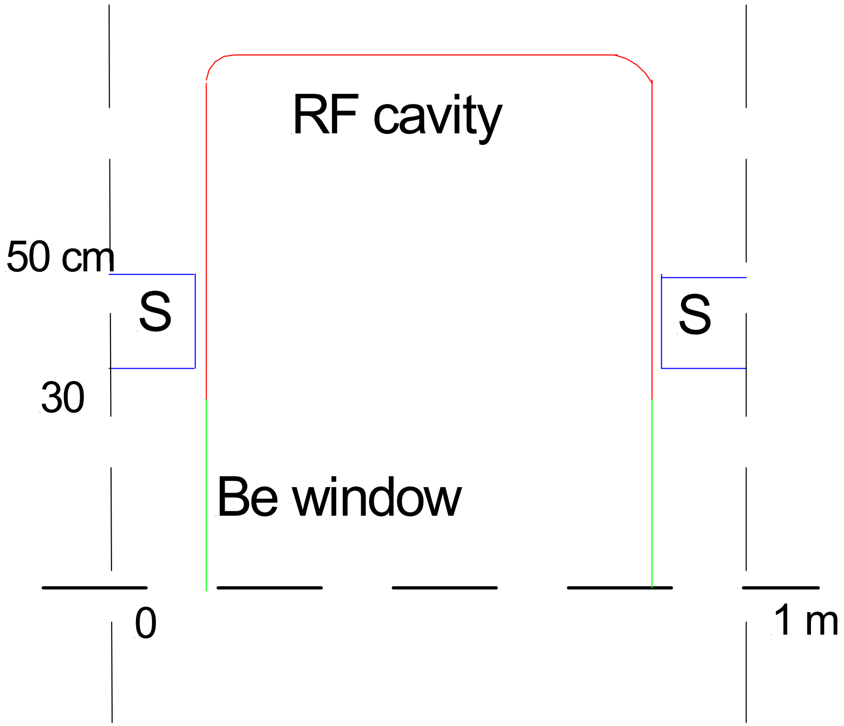
Realistic design

L_{TAP}	4 m
B_1	1.75 T
f	40.25 MHz
G	6 MV/m
L_{ROT}	25 m
L_{DRIFT}	10 m

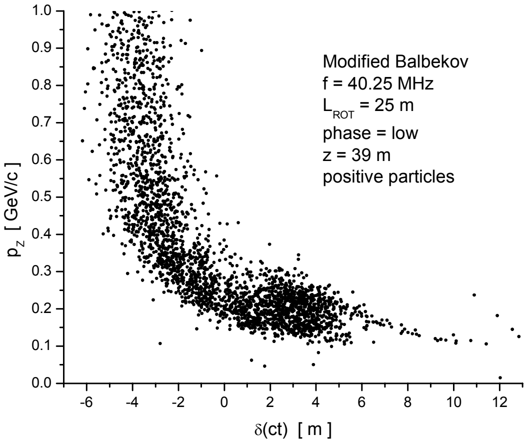
- Tapered wall
- Be window after target
- extended rf cavities
- Be windows on rf cavities
- Periodic solenoid channel

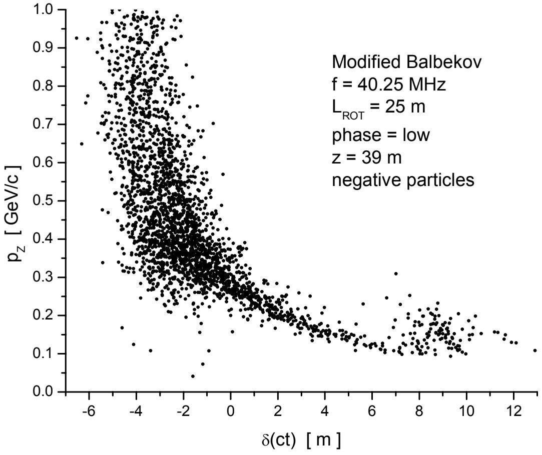
Design details

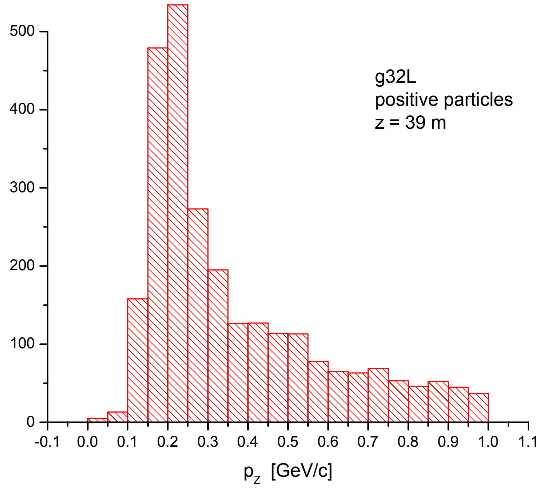


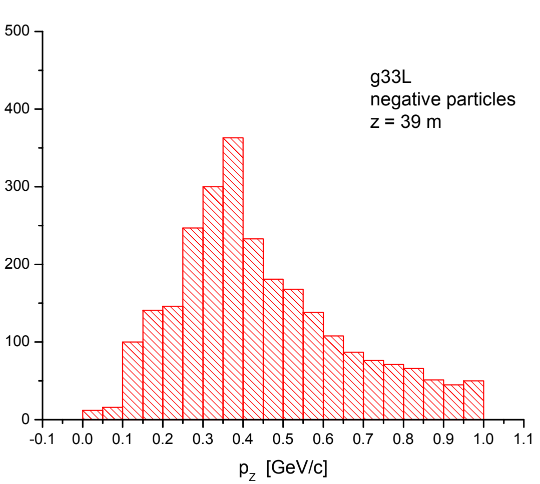


Effect of particle charge









Performance summary

case	sign	Δp [MeV/c]	μ / p
1	+	100-300	0.39
2	-	100-300	0.12
3	-	250-450	0.32
4	+	200-400	0.47
5	-	200-400	0.20
6	-	300-500	0.23

All cases use 6 m bunch cut

Muon Collaboration

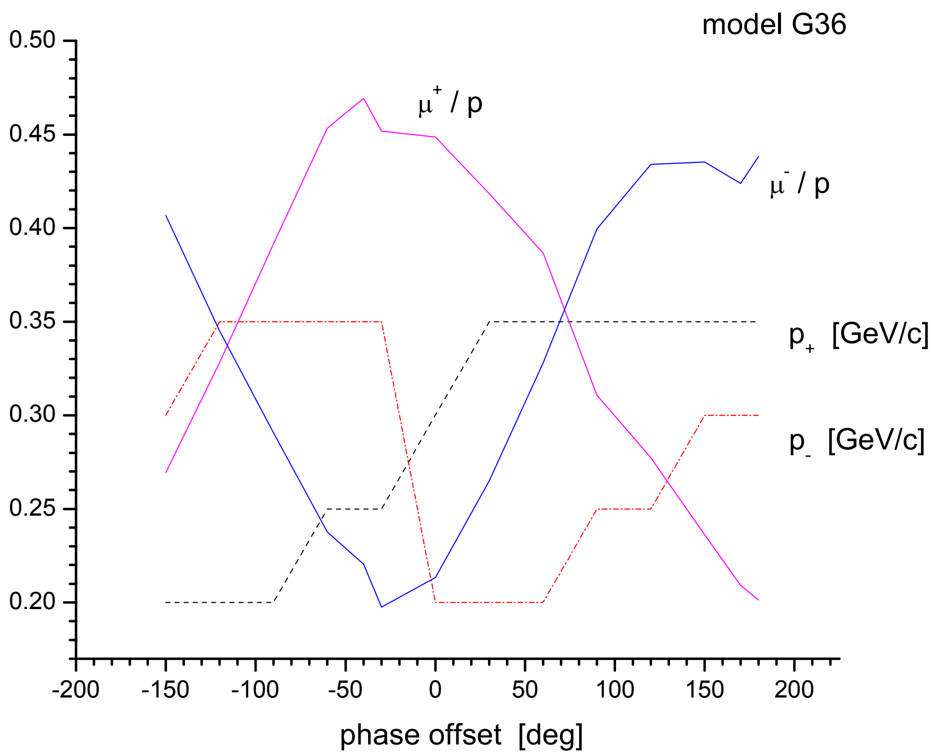
Bunch length dependence

BROOKHAVEN NATIONAL LABORATORY

- standard MARS beam files have $\sigma_t = 3.2$ ns
- decrease bunch length to 1 ns
- use realistic model
- transmissions in longitudinal phase space box
    - increases 21% for $100 < p < 300$ MeV/c
    - increases 13% for $200 < p < 400$ MeV/c
- not used in subsequent analysis

Equalize intensities

- find rf phase that gives $N_+ = N_-$



Equalized bunches have
different momenta
80% of peak positive intensity

Collider luminosity

- $L = N_+ N_- f / 4 \pi \sigma^2$
- status report

  $L \sim 1 \times 1 \times 0.5 \sim 0.5$
- this scheme with unequal bunch intensities

  $L \sim 1 \times 0.8 \times 1 \sim 0.8$
- this scheme with equal bunch intensities

  $L \sim 0.8 \times 0.8 \times 1 \sim 0.64$

Charge separation

- want to separate charges before 6D precooling
- geometric constraints

  2 parallel beams (±)

  ~5 m apart (6D cooling needs low frequency rf)

  in plane of accelerator
- some possible configurations

  (1) dipole chicane in horizontal plane

  (2) double bent solenoid in vertical plane

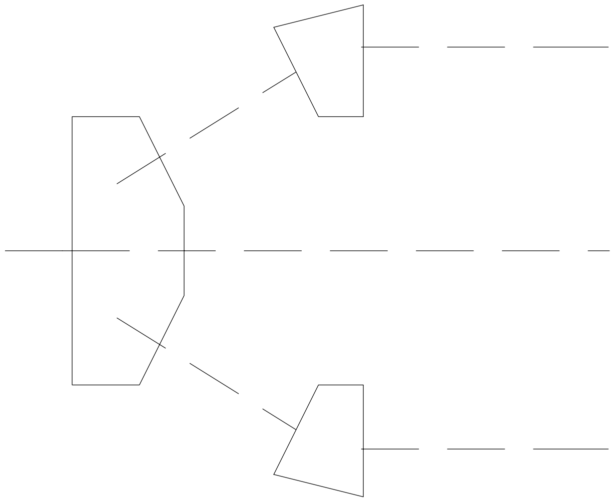
  → horizontally separated beams

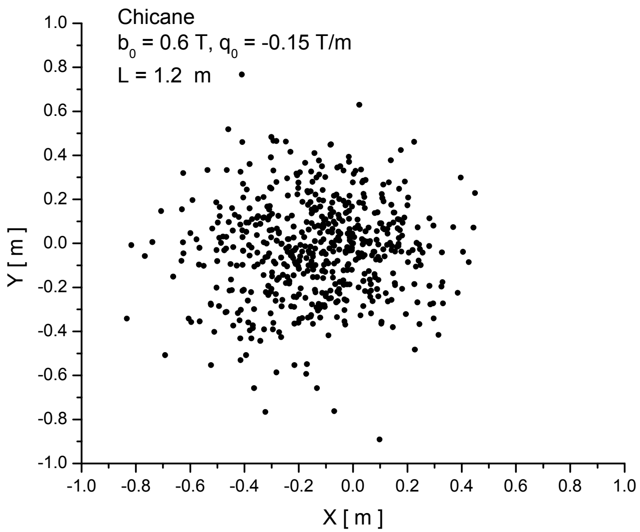
  (3) 90^{o} bent solenoid in horizontal plane (Juan Gallardo)

  → vertically separated beams

Chicane

- problems
  - clean separation of charges
  - growth in transverse beam size





after first dipole:

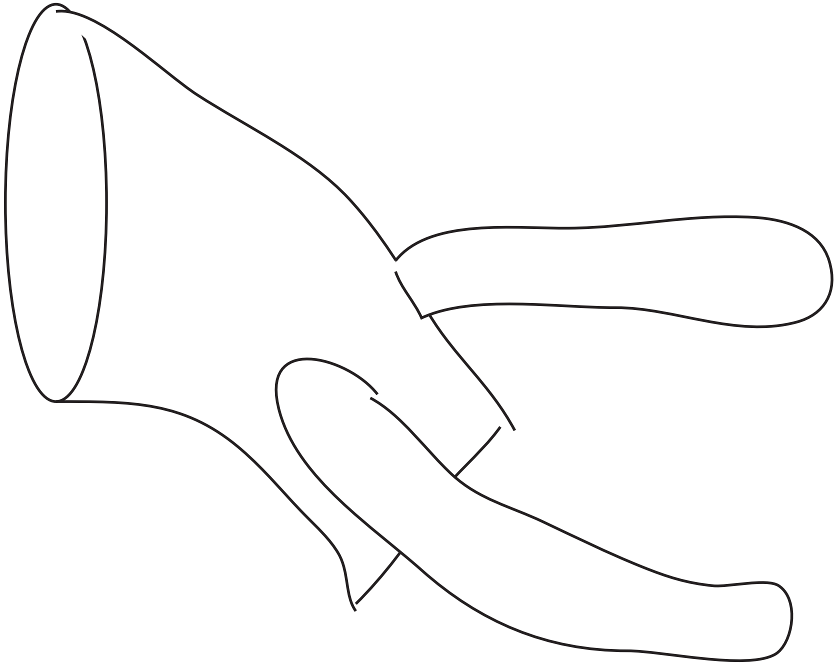
$b_0 = 0.6$ T, L = 1.2 m

centroids moves to $x = \pm 41$ cm

$\sigma_X = 21$ cm, $TR_{band} = 93\%$

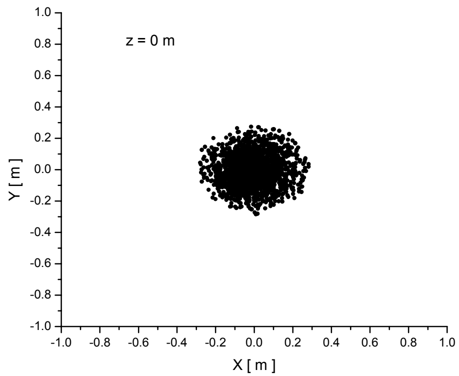
Separation with double bent solenoid

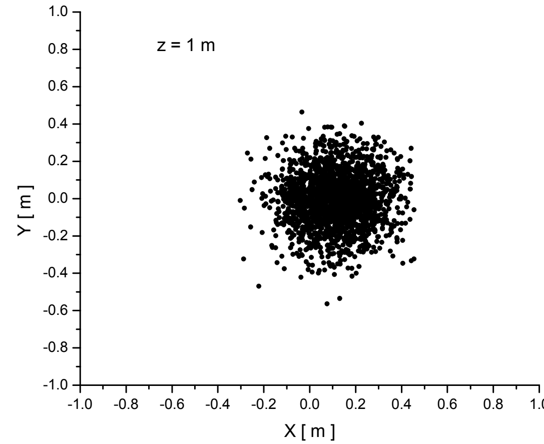
- B_S = 1.75 T
- B_D = 0
- BSOL(1) with edge focusing
- use beam from exit of phase rotator

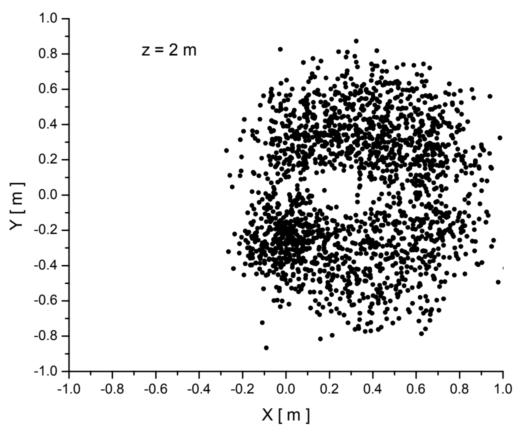


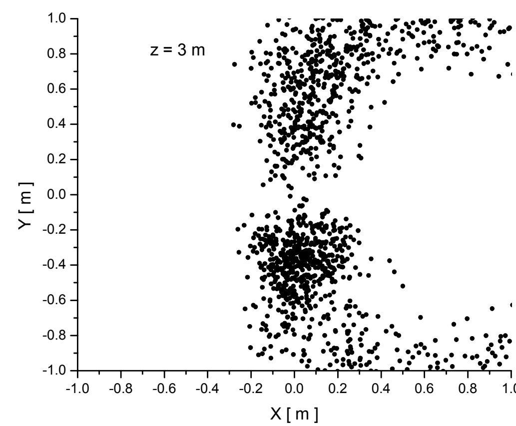
Single bent solenoid

- Cross section vs distance
- good separation at 2 m



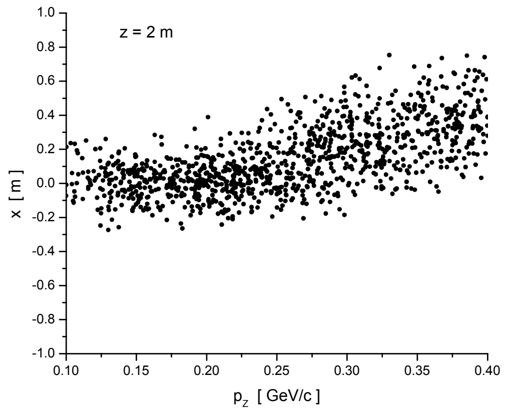


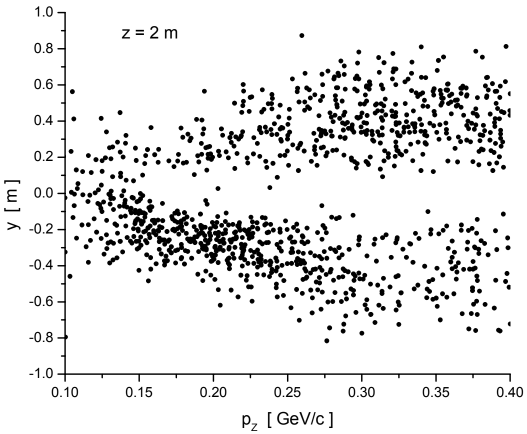


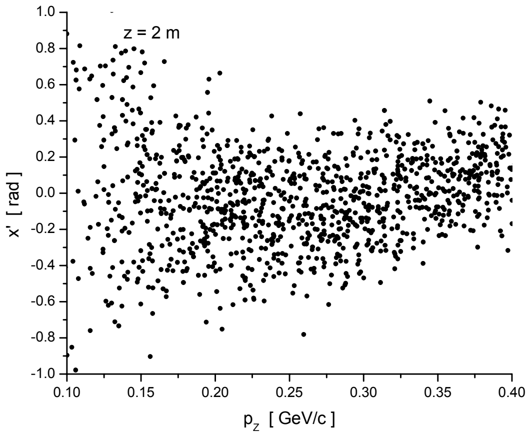


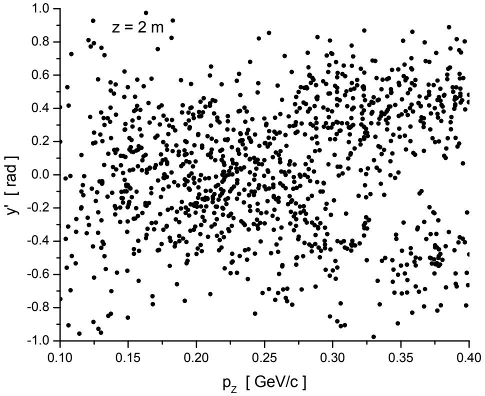
Single bent solenoid

- Dispersions at 2 m
- bend angle = 0.6 rad



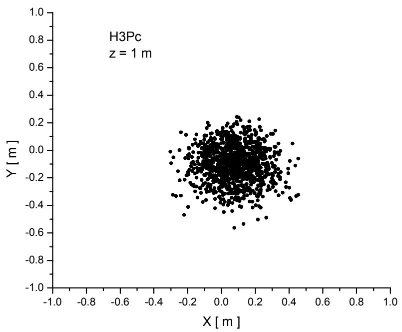


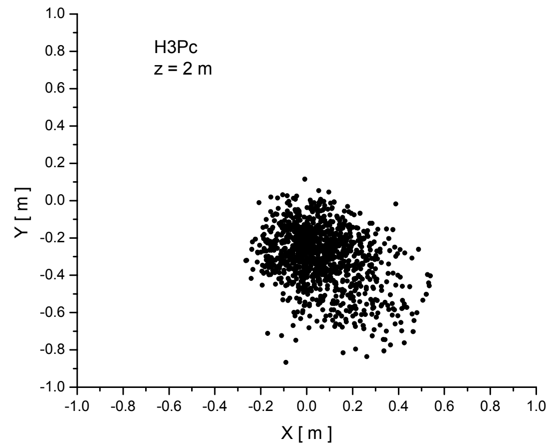


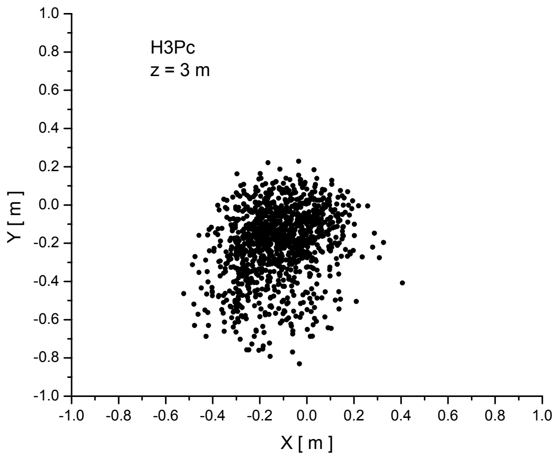


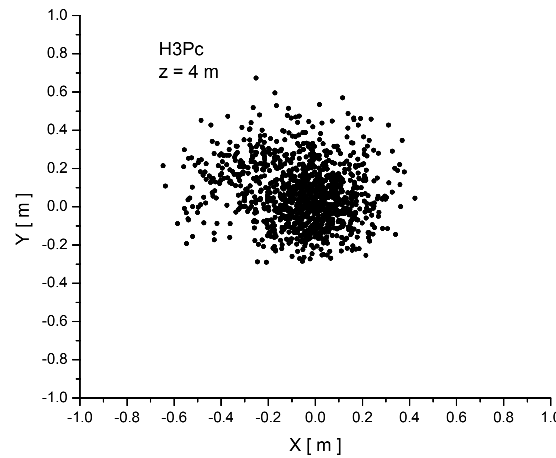
Double bent solenoid

- positive charges only
- apply 100 < p < 400 MeV/c cut



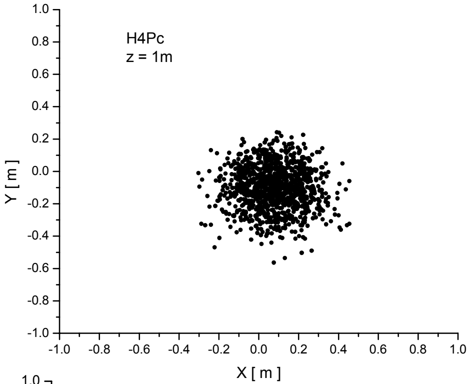


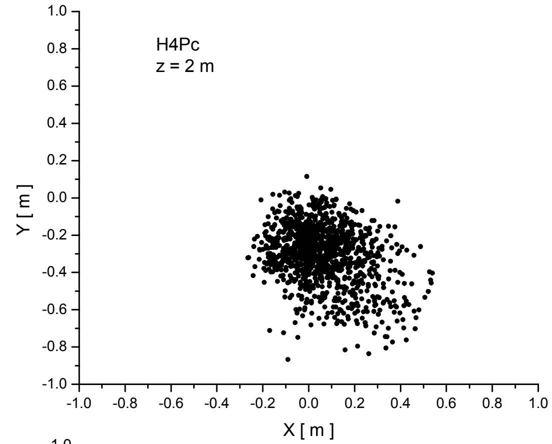


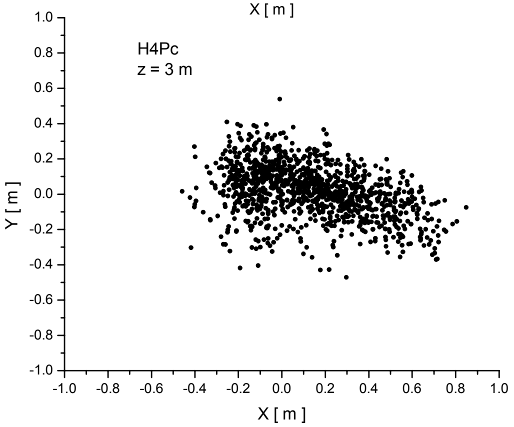


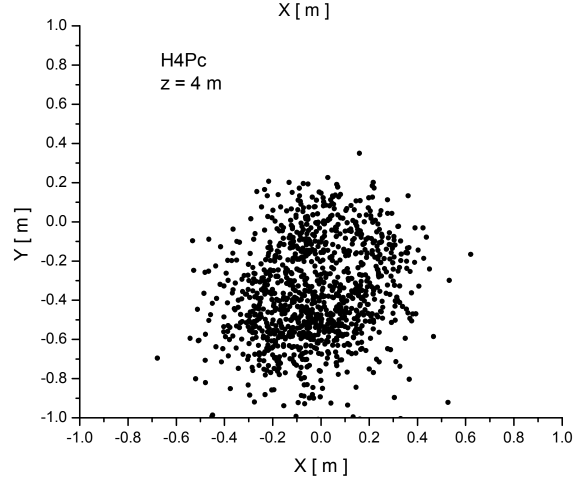
Double bent solenoid with B_S flip

- apply 100 < p < 400 MeV/c cut
- positive charges only
- 10 cm drift between bent solenoids









Double bend summary

- positive charges with $100 < p < 400$ MeV/c only
- leave $-0.01 < y < 0.01$ m free for charge separation
  large enough?
- $TR_{box} \sim 0.23$ for double-bend
- $TR_{box} \sim 0.27$ for double-bend with flip
  cf. $TR_{box} \sim 0.32$ after phase rotation
- introduces lots of correlations in beam

Status

- single-frequency phase rotation works well
- using both signs offers potential increase in luminosity
  ~30% for equal bunch intensities
- now studying charge separation systems
- results are encouraging so far