LPC and 5 TeV Parameters

LHC Programme Coordination LPC, chaired by Massimiliano Ferro-Luzzi (CERN / PH)

web page http://lpc.web.cern.ch/lpc/

meetings on indico http://indico.cern.ch/categoryDisplay.py?categId=1607

weekly meetings June - October 2008

so far single information **meeting this year on 7 May 2009**

with a presentation and discussion on LHC parameters for the first run

copy of this shown here + one slide on follow up

Run scenario and plans to increase intensity and luminosity in 2009-2010

- Wha t limitations can we expect ?
- How do we go from 1e28 to 1e32 ?
- How could the run look like ?

With much help from
Ralph Assmann, Roger Bailey,
Helmut Burkhardt, Werner Herr,
Mike Lamont, Jorg Wenninger

Input from experiments (*pp* running)

- ATLAS and CMS: highest possible lumi, even if pile-up of 7 (which we very probably never exceed in 2010)

- ALICE: a couple of different running modes with typically very low lumi (1e28 to 1e30) and low pile-up per crossing (~ 0.1 or smaller)

- LHCb: "low lumi" ~ few e32 (so, as much as ATLAS and CMS for this run), but keep pile-up at reasonable level (nominally ~1, but may try working with higher pile-up)

- TOTEM and LHCf: will try to fit in special requests for short runs (typically of order 1 day)

What max intensity for LHC Year 1 ?

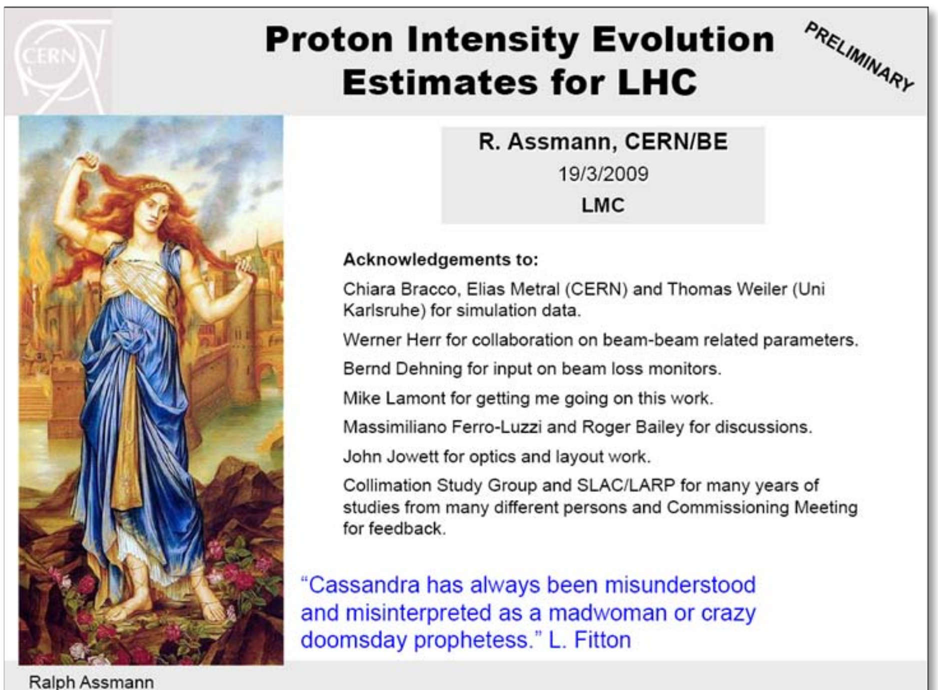
See Ralph Assmann at LMC_6d

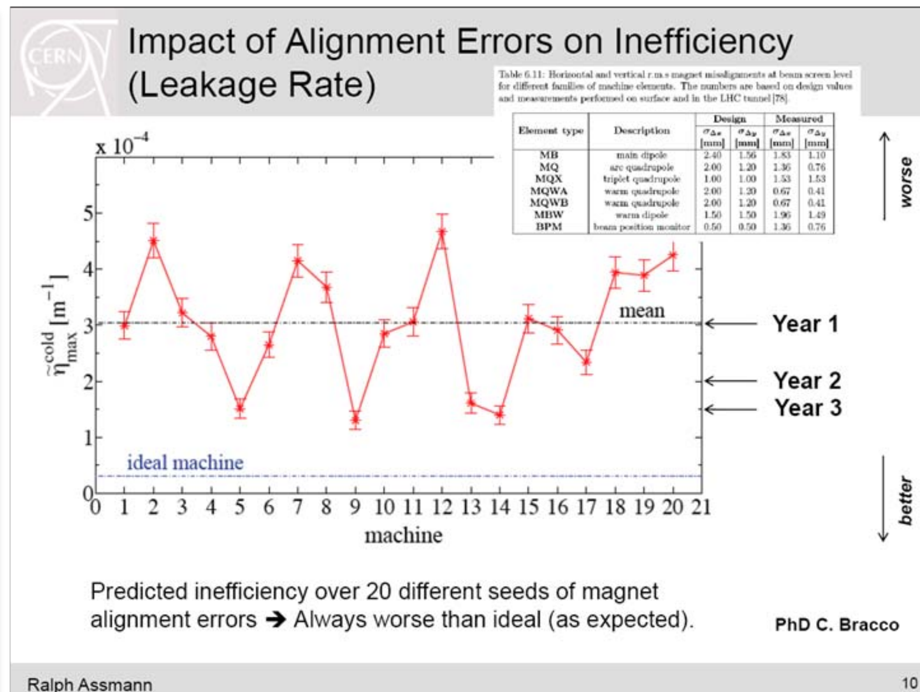
- LHC design report (2004)

> Even though detailed performance estimates are not yet possible, it is hoped that the design goals for cleaning efficiency can be met. The collimation system is designed to support up to 40% of design intensity with nominal β^* in phase 1. The phase 2 collimation system should allow nominal and possibly even ultimate running conditions.

for an ideal machine

- Detailed performance estimates were made (2009, C. Bracco' s thesis)

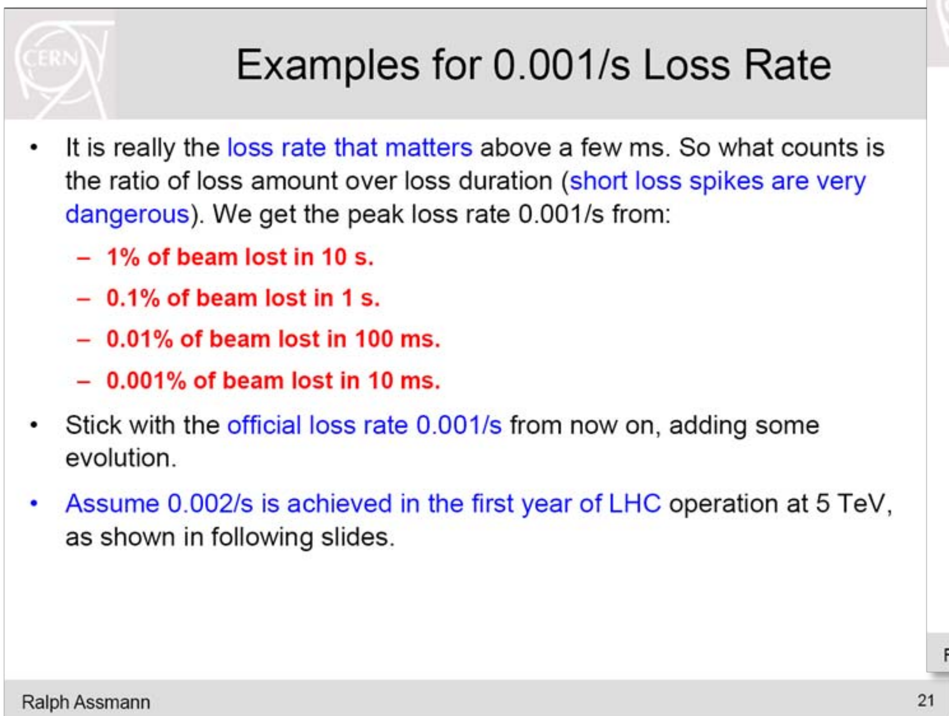




Element type	Description	Design $\sigma_{\Delta x}$ [mm]	Design $\sigma_{\Delta y}$ [mm]	Measured $\sigma_{\Delta x}$ [mm]	Measured $\sigma_{\Delta y}$ [mm]
MB	main dipole	2.40	1.56	1.83	1.10
MQ	arc quadrupole	2.00	1.20	1.36	0.76
MQX	triplet quadrupole	1.00	1.00	1.53	1.53
MQWA	warm quadrupole	2.00	1.20	0.67	0.41
MQWB	warm quadrupole	2.00	1.20	0.67	0.41
MBW	warm dipole	1.50	1.50	1.96	1.49
BPM	beam position monitor	0.50	0.50	1.36	0.76

Expected maximum intensity

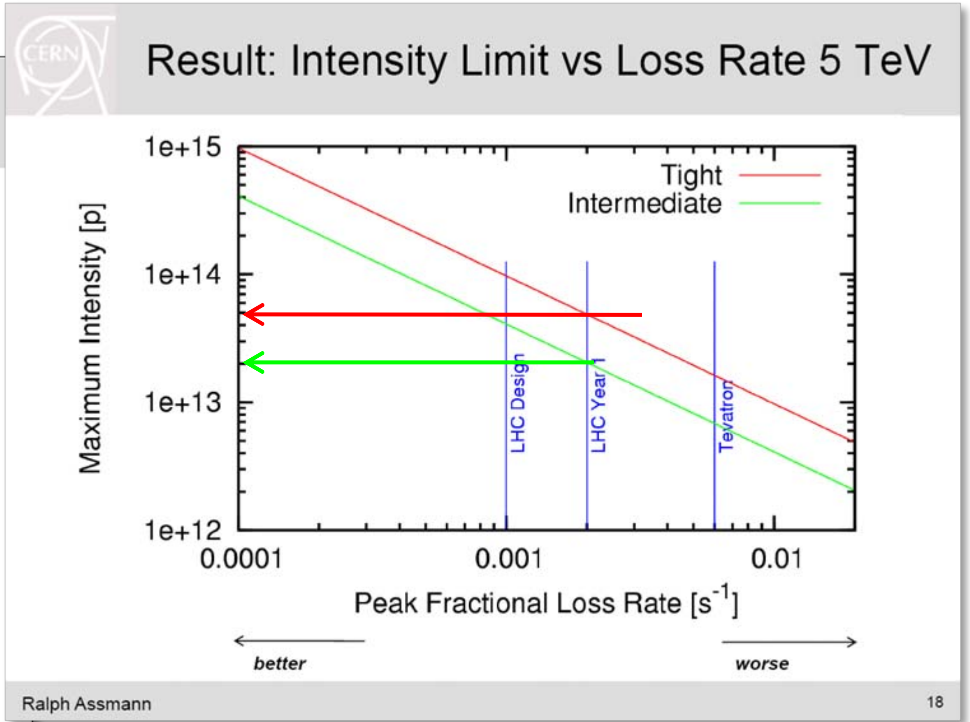
- Max intensity driven by loss rate and quench limit (~ 5 W/liter)
- Ex: 10^{13} *p* x 0.002 s^{-1} loss rate at 5 TeV (Year 1) => 16 kW



Examples for 0.001/s Loss Rate

- It is really the loss rate that matters above a few ms. So what counts is the ratio of loss amount over loss duration (short loss spikes are very dangerous). We get the peak loss rate 0.001/s from:
  - **1% of beam lost in 10 s.**
  - **0.1% of beam lost in 1 s.**
  - **0.01% of beam lost in 100 ms.**
  - **0.001% of beam lost in 10 ms.**
- Stick with the official loss rate 0.001/s from now on, adding some evolution.
- Assume 0.002/s is achieved in the first year of LHC operation at 5 TeV, as shown in following slides.

Ralph Assmann 21



- Year 1:
  - Intermediate (start of physics run): I < 2e13 *p*
  - Tight (towards end of run ?): I < 5e13 *p*

Optimum number of bunches for lumi

Simple-mindedly:

- given a max intensity I_{max} and a max bunch charge N_{max}, the number of bunches for maximizing luminosity is

$$k_b^{opt} = \frac{I_{max}}{N_{max}}$$

For illustration:

Imax	Nmax	kbopt
2e13 *p*	5e10 *p*	400
	9e10 *p*	222
5e13 *p*	5e10 *p*	1000
	9e10 *p*	555

At the beginning, we are likely to have optimum at ~200-400 bunches

Fill schemes

- Start with 2x2
  - each IP gets 1 colliding pair and 1 non-colliding bunch/beam

Then move on with equidistant schemes

- 43x43
  - 43 / 4 / 43 / 19 colliding pairs in IP1 / 2 / 5 / 8
- 156x156
  - 156 / 4 / 156 / 72

⇐ that's about the maximum number of "equidistant" bunches (which is driven by the length of the common pipe section ~120m)

Move on to crossing angle schemes

- many possibilities: 75 ns, 50 ns, 25 ns spacing (100 ns ? 150 ns ? ...)
- NB1: the short spacing introduces long-range encounters in IR => reduced reach in bunch charge ?
- NB2: the crossing angle reduces the aperture in triplet => reduced reach in β^*

=> we most probably loose lumi with these schemes for the same intensity as in156x156!! Will require higher intensity to recover lumi as in 156x156

With crossing angle: why 50 ns ?

- Allows to distibute lumi over 4 IP in very flexible and optimal manner
- Allows starting with 144 bunches with the full long range effects
- Adding further "trains" should not change beam-beam effects
- when reaching close to 50% nominal intensity and 100% nominal bunch charge (in 2011?), it should gives the highest possible luminosity (while waiting for phase 2 collimation system)

Physics run modes

* expt magnet ON means at full nominal field (as for 14 TeV)

900 GeV

toroids & solenoids ON*, spectr. dipoles OFF

2x2
5e10
10-11m

10 TeV

toroids, solenoids & spectr. dipoles ON*

2x2
5e10
10-11m

2x2
5e10
2m

43x43
5e10
2m

156x156
5e10
2m

Dominated by beam commissioning

Lumi goes over 1e32

Dominated by physics

156x156
9e10
1m

50ns/432
9e10
3m

develop 50 ns, truncated

introduces crossing angle

short physics runs at 50 ns and go back to best luminosity (156x156) for mass lumi production

until 50ns breaks even (then stay at 50 ns)

try also 25 ns at the end

Steps for luminosity increase during the 2009-2010 LHC pp run

	900 GeV	first high-energy coll.		Pilot physics run							
				no external crossing angle			with external crossing angle				
step	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	...	units
fill scheme	2x2	=	=	43x43	156x156	156x156	50ns@144	50ns@288	50ns@432	...	
E	**0.45**	**5**	=	=	=	=	=	=	=	...	TeV
k_b	2	=	=	**43**	**156**	=	**144+12**	**288+12**	**432+12**	...	bunches
N	5	=	=	=	=	**9**	=	=	=	...	10^{10} p/bunch
N_{Alice}	5	=	=	=	=	=	1	=	=	...	10^{10} p/bunch
β^*(IP1,5)	11	=	**2**	=	=	**1**	3	=	=	...	m
β^*(IP2)	10	=	=	=	=	=	3	=	=	...	m
β^*(IP8)	10	=	**2**	=	=	**3**	4	=	=	...	m
I/I_{nom}	0.031	=	=	0.67	2.42	4.3	4.05	8.1	12.1	...	%
E_{stored}	0.0072	0.08	=	1.72	6.24	11.1	10.5	20.8	31.2	...	MJ
α_{net}(IP1,5)	0	0	=	=	=	=	300	=	=	...	μrad
α_{net}(IP2)	0	200	=	=	=	=	300	=	=	...	μrad
α_{net}(IP8)	0	380	=	=	=	=	620	=	=	...	μrad
n_{bb}(IP1,5)	1	=	=	43	156	156	144	288	432	...	colliding pairs
n_{bb}(IP2)	1	=	=	4	=	=	12	=	=	...	colliding pairs
n_{bb}(IP8)	1	=	=	19	72	=	138	276	414	...	colliding pairs
L(IP1,5)	0.0026	0.029	0.16	6.9	24.9	161.5	48.3	96.5	145	...	10^{30} cm^{-2}s^{-1}
L(IP2)	0.0029	0.032	=	0.13	=	=	0.05	=	=	...	10^{30} cm^{-2}s^{-1}
L(IP8)	0.0029	0.032	0.15	2.8	10.8	23.7	32.7	65.4	98.1	...	10^{30} cm^{-2}s^{-1}
μ(IP1,5)	0.012	0.19	1.07	=	=	6.9	2.24	=	=	...	
μ(IP2)	0.013	0.21	=	=	=	=	0.028	=	=	...	
μ(IP8)	0.013	0.21	1.0	=	=	2.3	1.58	=	=	...	
Time for physics	~shifts	~days		~weeks		~months					

Definitions: μ = average number of inelastic interactions per crossing
n_{bb} = number of colliding pairs at given IP
α_{net} = net crossing angle

Assumptions: Longitudinal emittance $\epsilon = 0.5$ nm $\cdot$ 7 TeV/E
Inelastic cross section: $\sigma_{\text{inel}} = 52$ and 75 mb for $\sqrt{s} = 0.9$ and 10 TeV

Estimates: Beam commissioning time* for reaching step 6 $\approx$ six weeks
Beam commissioning time* to go from step 6 to step 7 $\approx$ two weeks
Total expected physics running time: of the order of $5 \cdot 10^6$ s

* with machine available

Run scenario 2009-2010 (see Mike Lamont at LMC_12c)

"*The CERN Management today confirmed the restart schedule for the Large Hadron Collider resulting from the recommendations from the Chamonix workshop.*
The new schedule foresees first beams in the LHC at the end of September this year, with collisions following in late October.
A short technical stop has also been foreseen over the Christmas period. The LHC will then run through to autumn next year, ensuring that the experiments have adequate data to carry out their first new physics analyses and have results to announce in 2010.
The new schedule also permits the possible collisions of lead ions in 2010."

- Chamonix Baseline
  - 1 month commissioning
  - 10 month proton physics
  - 1 month Lead Ions
  - Shutdown – end September 2010
  - Built in slip potential

Winter stop 2009-2010

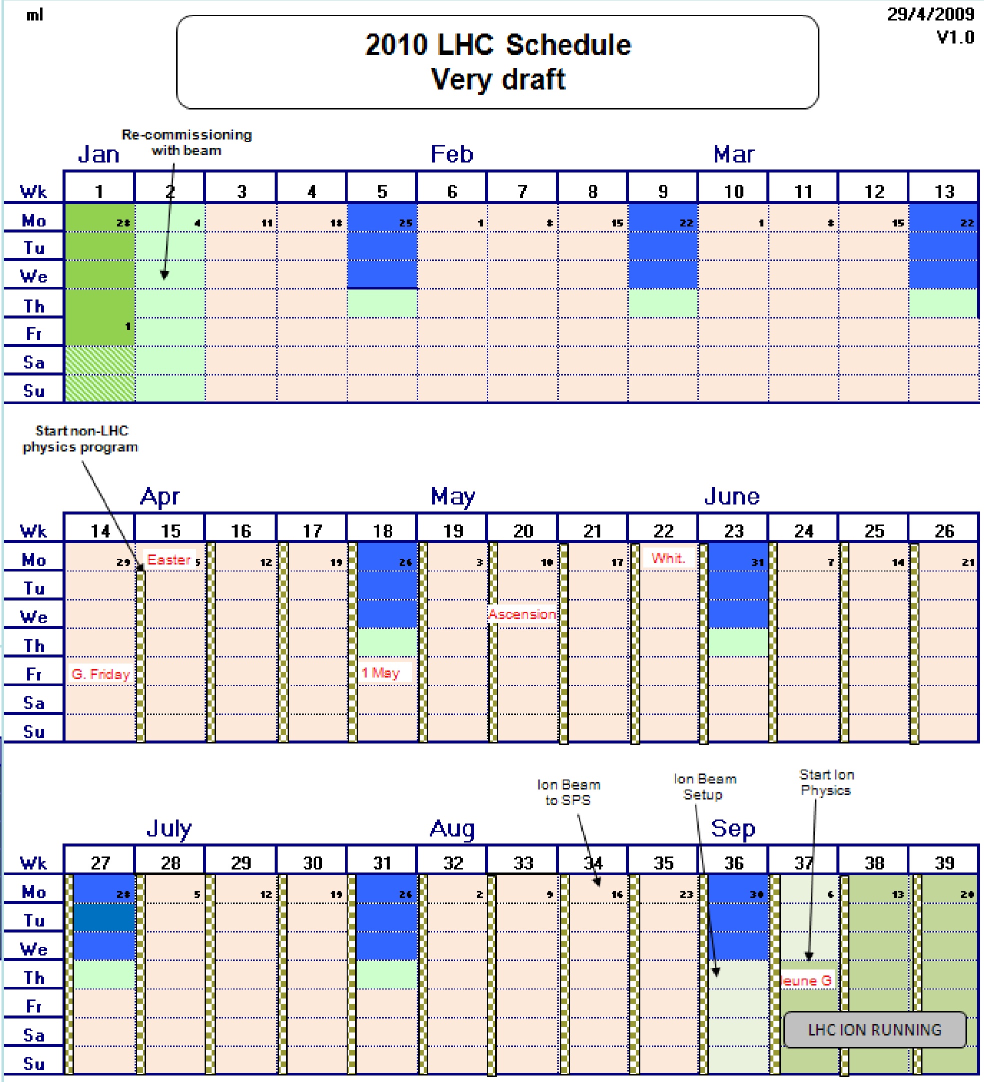
- Unusual for CERN to run through winter
- Assessed cost at Chamonix, decided to run through
- Technical consequences and modalities being assessed
  - Main constraints from machine sector seem to be:
    - manpower coverage (including burn-out risks)
    - injector source maintenance (requiring a 3 week stop) => run until it breaks or do maintenance if a 3-week stop occurs for other reasons
  - Expts: no need for shutdown, nor scheduled stop (of more than 2-3 days) . Only issue: cooling towers (CERN-wide issue)
- Proposal made at LMC (see LMC_12c):
  - Stop LHC with beam ~19th December 2009
  - Earliest restart ~ 4th January 2010
  - Could possibly use weekends either end =>12 days stop
- Experiments and machine to assess difference in manpower investment for a no-stop scenario and a 2-week stop (standby) scenario (coming LMC)

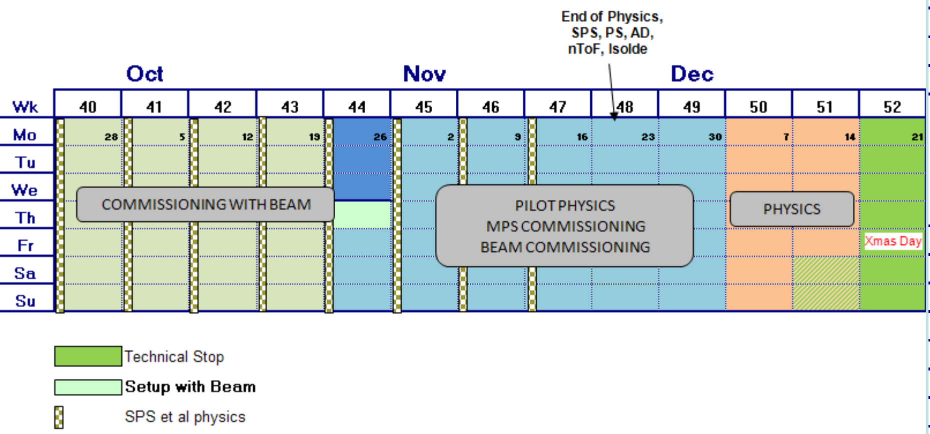
Monthly Technical Stop

- Programmed
- 3 days including recovery and re-closure of ring
  - QPS plus power converters, controls, R2E etc.
  - Cool-down will become an issue
- Mon – Wed allowing weekday time for re-setup with beam
- Followed by one day set-up with beam and systematic checks of machine protection system
- Clearly if major breakdowns occur at other times – advantage will be taken.
- Injector maintenance in parallel is an option
- [Have not considered scheduling of MD…]

Very draft LHC schedule for 2009-2010

- First draft produced by Mike
- For discussion





Follow up on parameters

Idea is to update

"LHC BEAM PARAMETERS FOR FIRST PHYSICS RUN AT 5 TEV", LHC-OP-ES-0011, EDMS 931921, https://edms.cern.ch/document/931921

- **include parameters with crossing angle**
- **starting from the table edited by Massi**
- **add short explanations in the text, including intensity limits - Ralph**
- **pre-collisions parameters**
- **$\beta^* = 3$ m with crossing angle is conservative to be careful with luminosity estimates**
- **try to go lower towards $\beta^* = 1$ m - use this for conservative background simulations**
- **clarify choice of IP2 parameters - interest by ALICE for squeeze with protons, $\beta^* \sim 3$ m to get smaller vertex distribution and sufficient luminosity**