CLIC Post-Collision Line and Dump

Edda Gschwendtner, CERN

for the Post-Collision Team

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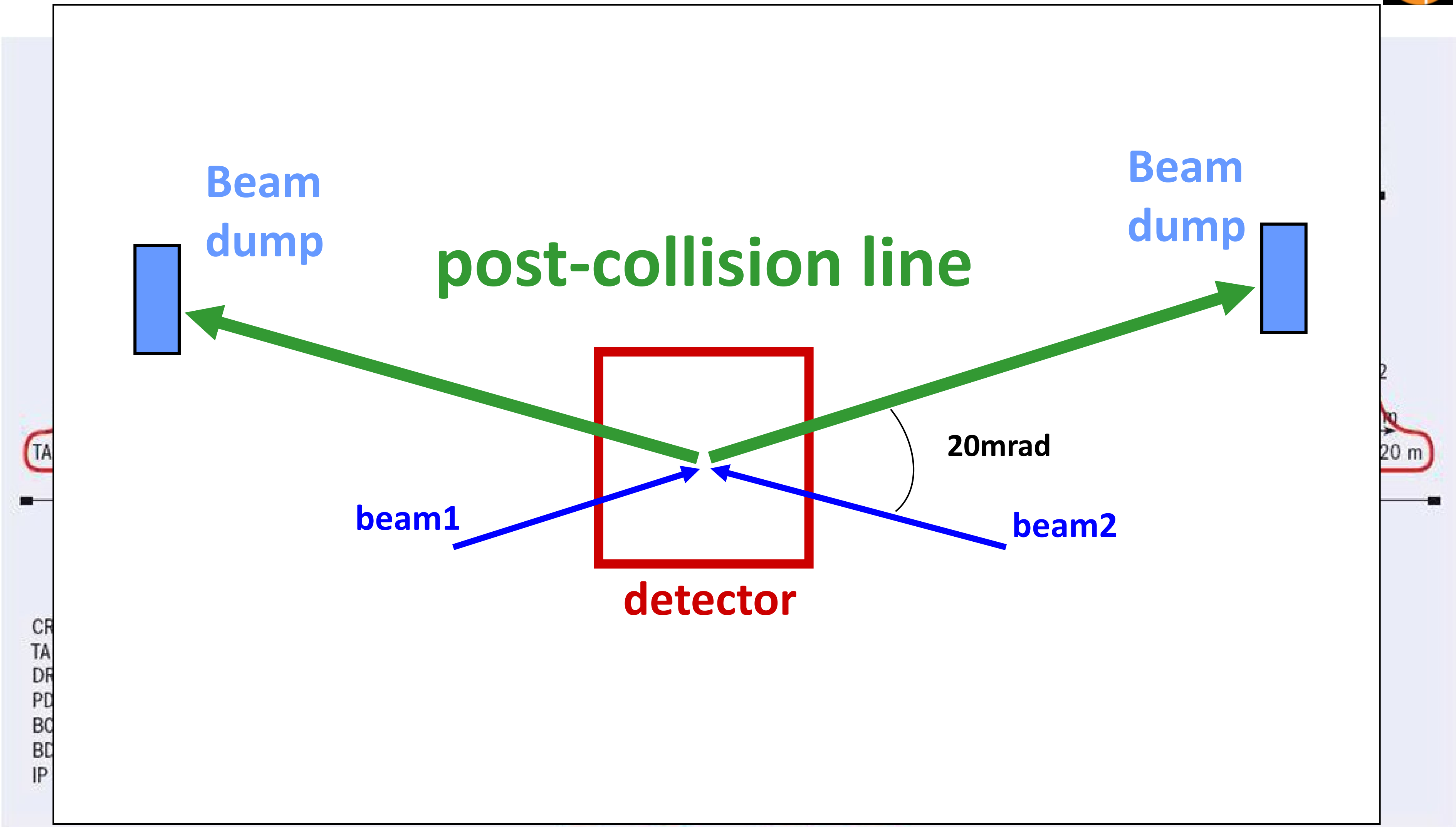
Outline

- Introduction
- Absorbers and Intermediate Dump
- Magnet System
- Background Calculations to the IP
- Main Beam Dump
- Luminosity Monitoring
- 500GeV/18.6mrad Option
- Summary

Post-Collision Line



Some Numbers

50 Hz repetition rate

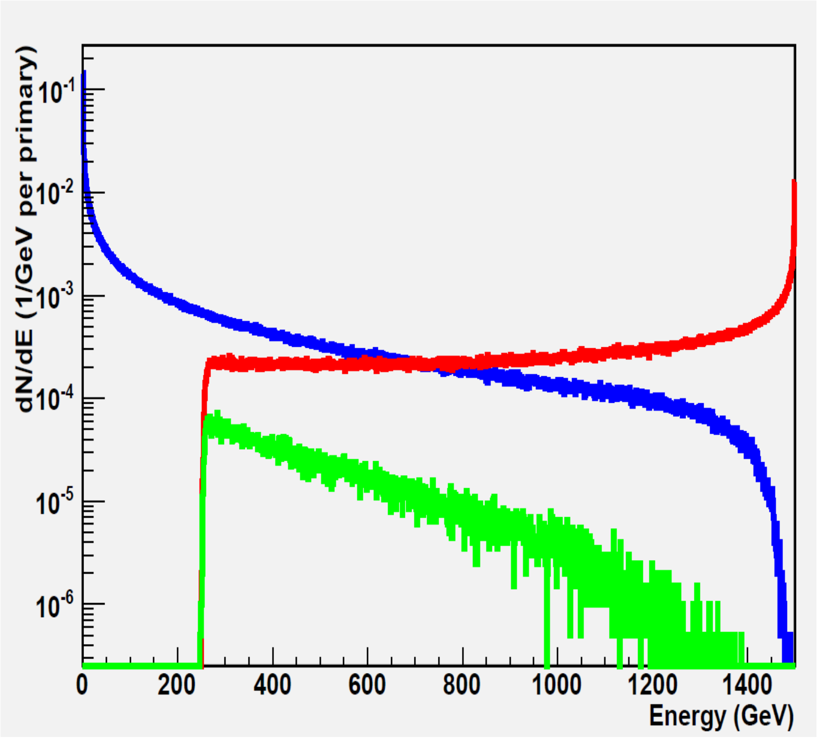
3.7E9 e/bunch

14MW beam power

156ns bunch train length

312 bunches/pulse

- e^+e^- collision creates **disrupted beam**
  - Huge energy spread, large x,y div in outgoing beam
    → total power of **~10MW**
- **High power divergent beamstrahlung photons**
  - 2.2 photons/incoming e+e-
    → 2.5 E12 photons/bunch train
    → total power of **~4MW**
- **Coherent e+e- pairs**
  - 5E8 e+e- pairs/bunchX
  → **170kW** opposite charge
- Incoherent e+e- pairs
  - 4.4E5 e+e- pairs/bunchX
    → 78 W



Design Considerations

- Transport particles of all energies and intensities from IP to dump
- Diagnostics (luminosity monitoring)
- Control beam losses in the magnets
- Minimize background in the experiments
- Stay clear of the incoming beam

Consequences

→ Large acceptance

→ Collimation system

→ Main dump

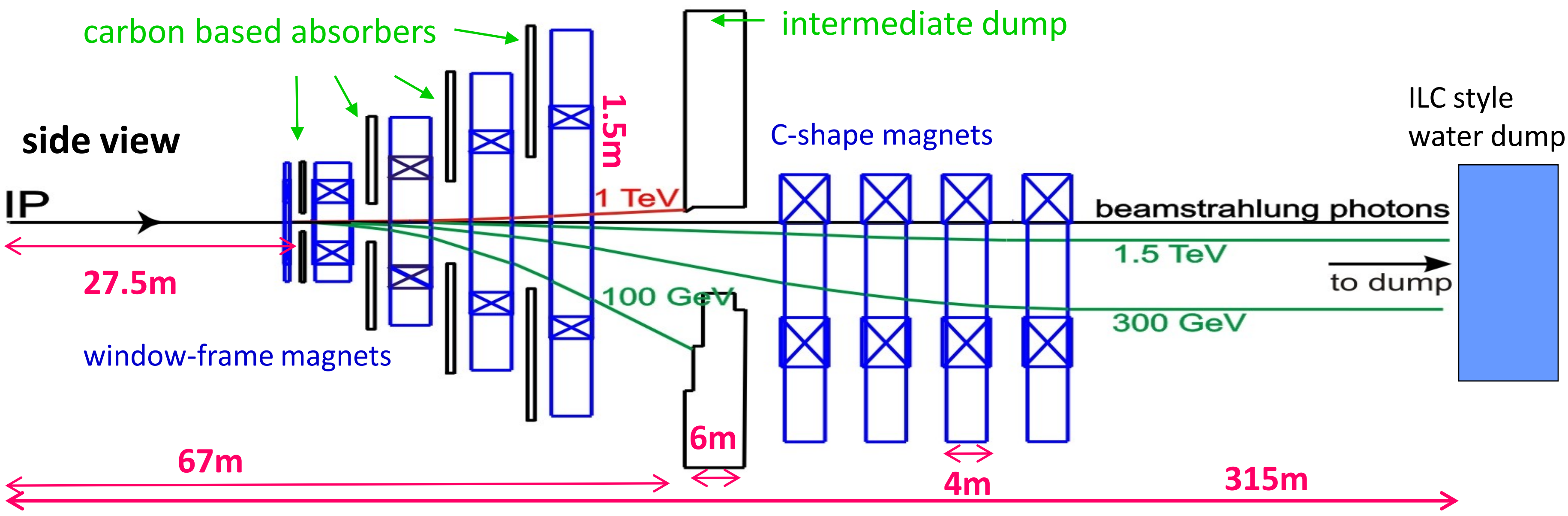
→ Beam diagnostic system

Baseline Design

*A. Ferrari, R. Appleby, M.D. Salt, V. Ziemann, PRST-AB **12**, 021001 (2009)*

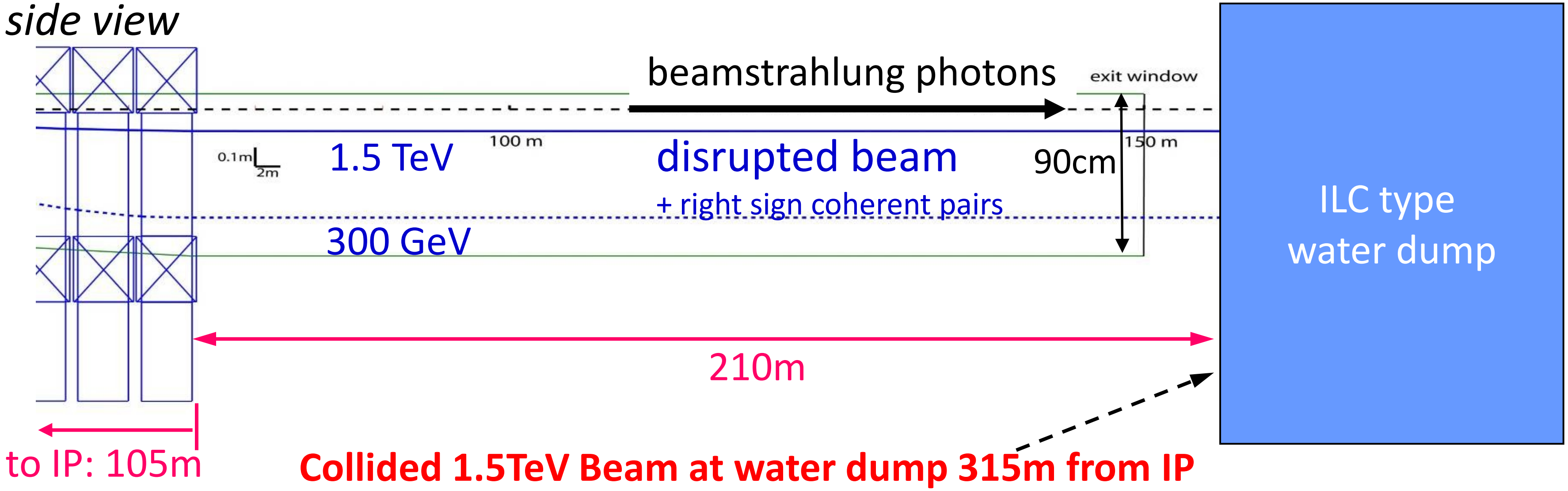
Vertical chicane

1. Separation of disrupted beam, beamstrahlung photons and right-sign charge particles from coherent pairs and particles from e+e- pairs with the opposite sign charge particles
   → Intermediate dumps and collimator systems
2. Back-bending region to direct the beam onto the final dump
   → Allowing non-colliding beam to grow to acceptable size

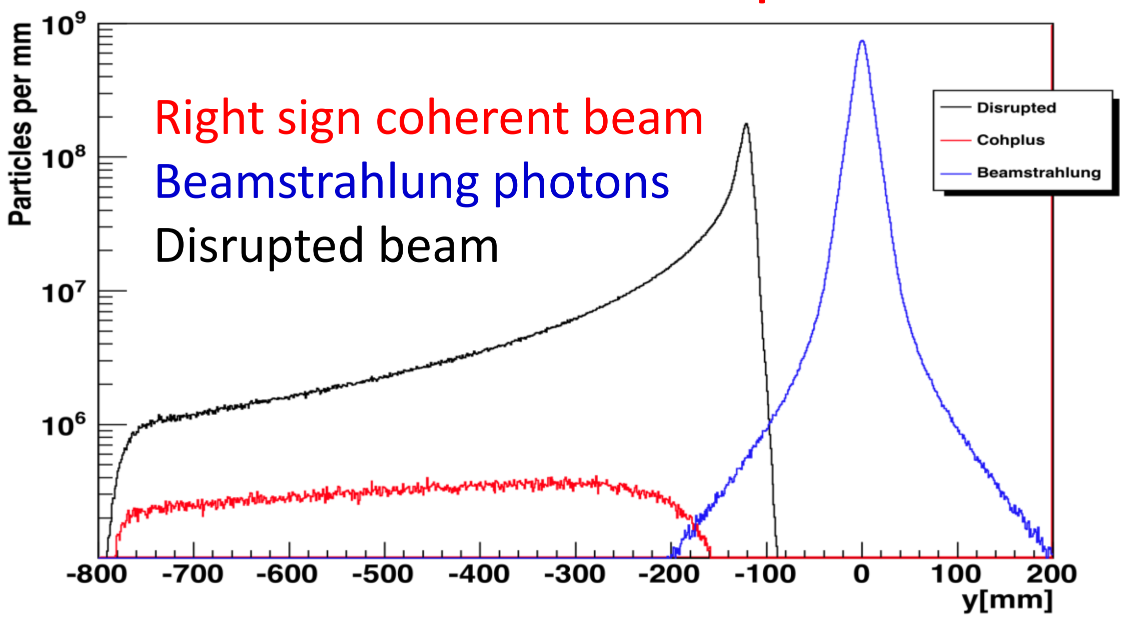


Baseline Design

side view

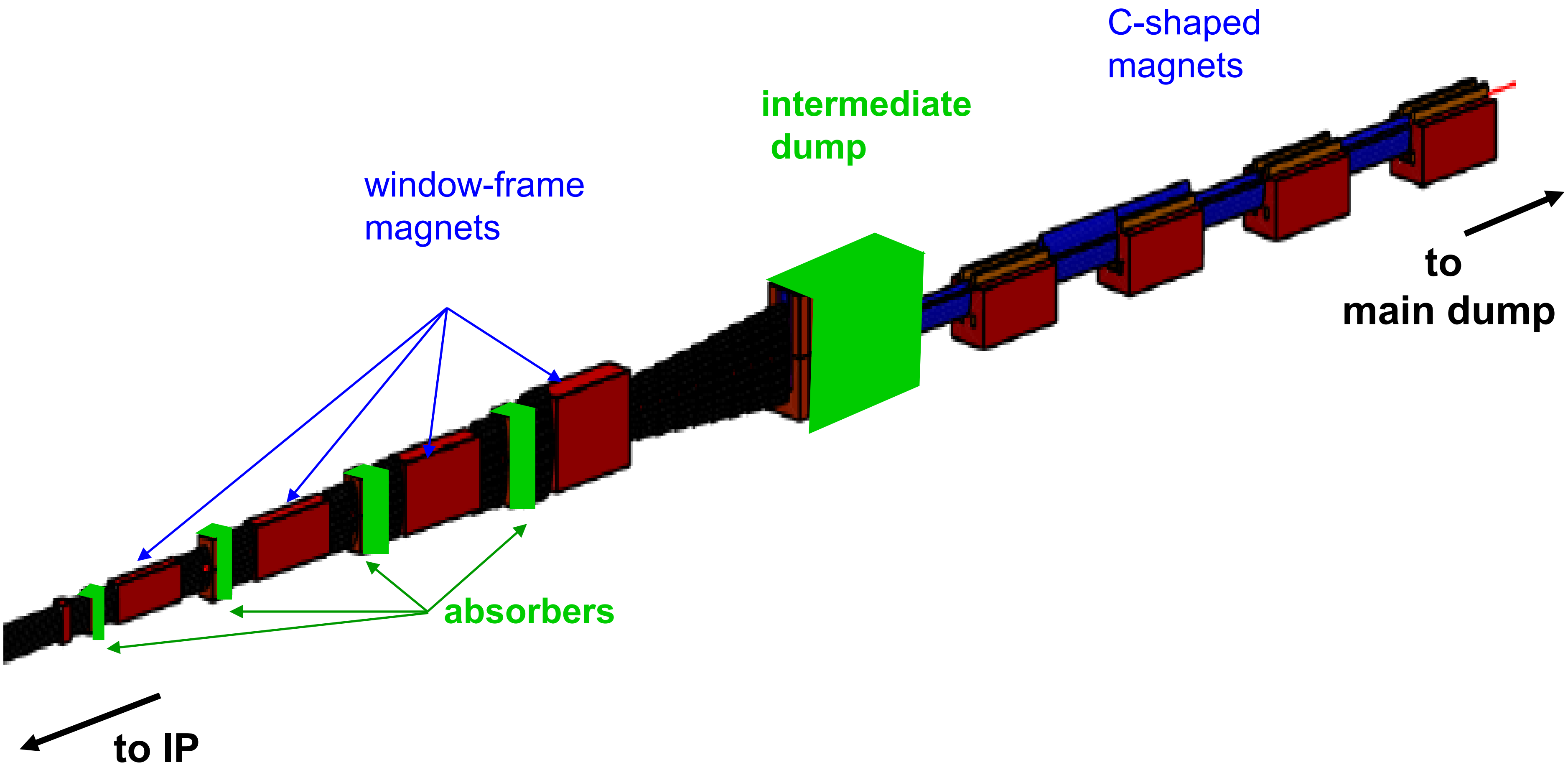


Collided 1.5TeV Beam at water dump 315m from IP



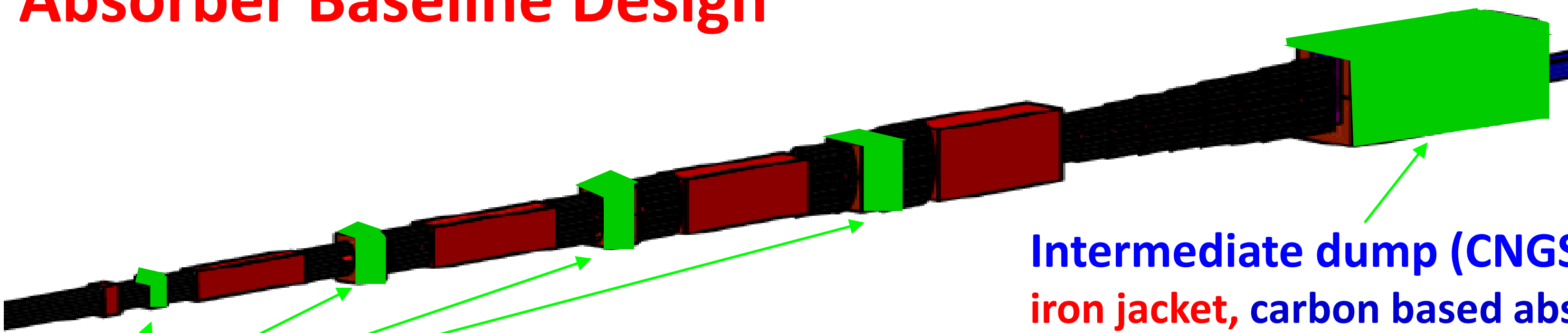
Baseline Design

Geometry fully implemented in SW tools



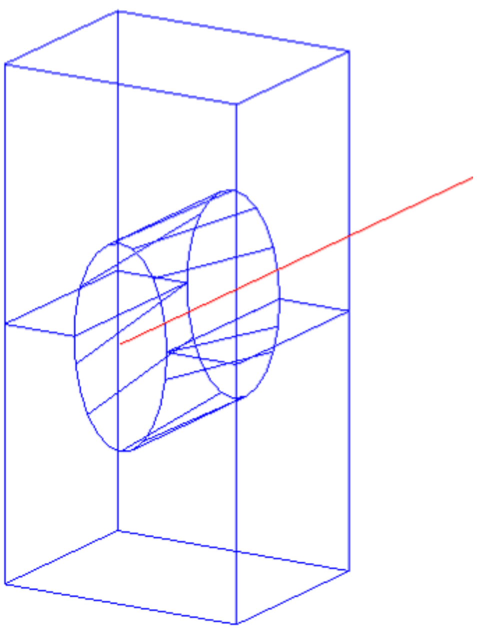
Magnet Protection Absorbers and Intermediate Dump

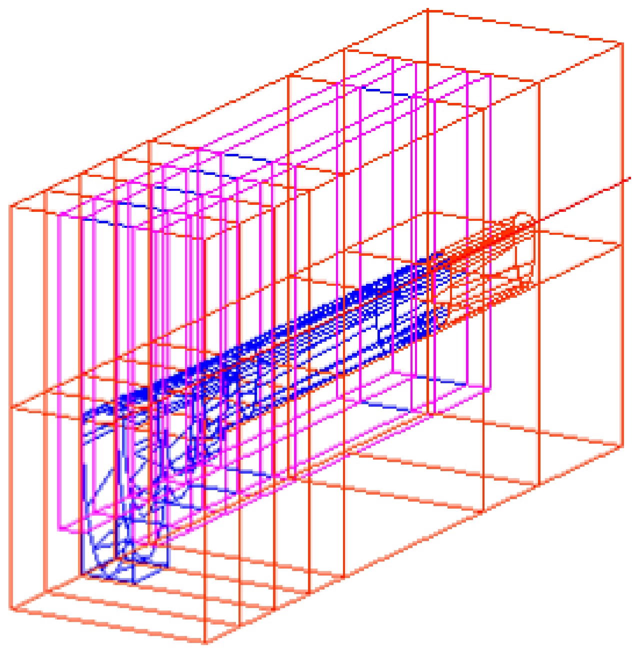
Absorber Baseline Design



Intermediate dump (CNGS style):
iron jacket, carbon based absorber, water cooled aluminum plates,
3.15m x 1.7m x 6m
→ aperture: X=18cm, Y=86cm

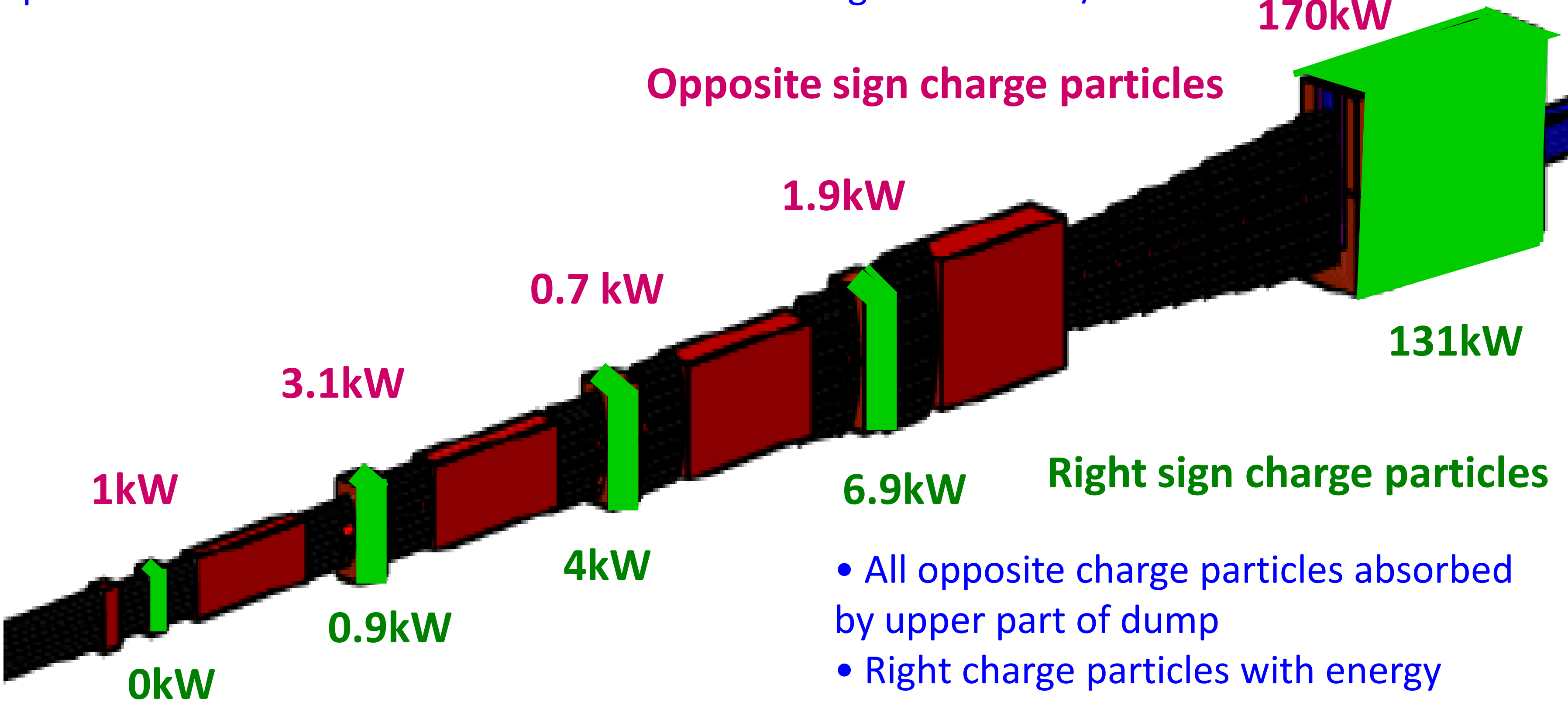
Magnet protection:
Carbon absorbers:
Vertical apertures between 13cm and 100cm





Absorber Baseline Design

Aperture dimensions tuned such that losses in magnets < 100W/m

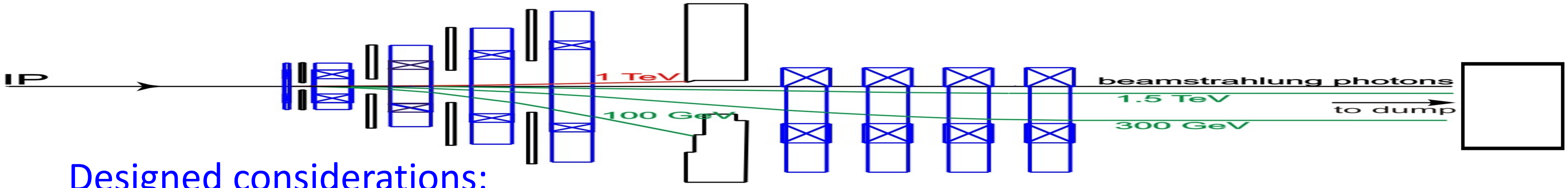


- All opposite charge particles absorbed by upper part of dump
- Right charge particles with energy >16% of nominal pass through

→ **Solutions for absorbers exist (see dumps in neutrino experiments: 4MW)**

Magnets

Post-Collision Line Magnets



Designed considerations:

- average current density in copper conductor < 5 A/mm^2.
- magnetic flux density in magnet core is < 1.5 T.
- temperature rise of cooling water < 20° K.

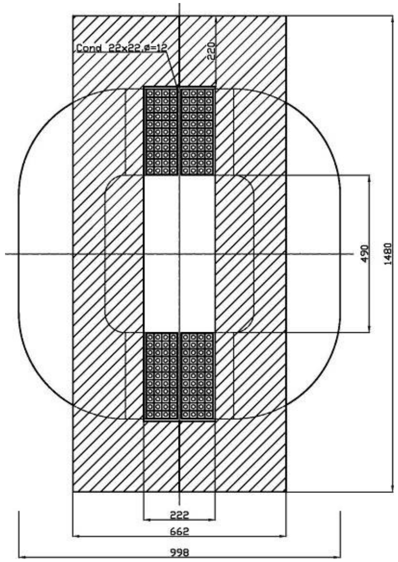
Dipole names	Magnetic length	Full magnet aperture horiz. / vert. [m]	Full magnet dimensions horiz. / vert. [m]	Power consumption
Mag1a1b	2m	0.22 / **0.57**	1.0 / 1.48	65 kW
Mag2	4m	0.30 / **0.84**	1.12 / 1.85	162.2 kW
Mag3	4m	0.37 / **1.16**	1.15 / 2.26	211 kW
Mag4	4m	0.44 / **1.53**	1.34 / 2.84	271 kW
MagC-type	4m	0.45 / **0.75**	1.92 / 1.85	254 kW

→ All magnets strength of 0.8 T
→ In total 18 magnets of 5 different types
→Total consumption is 3.3MW

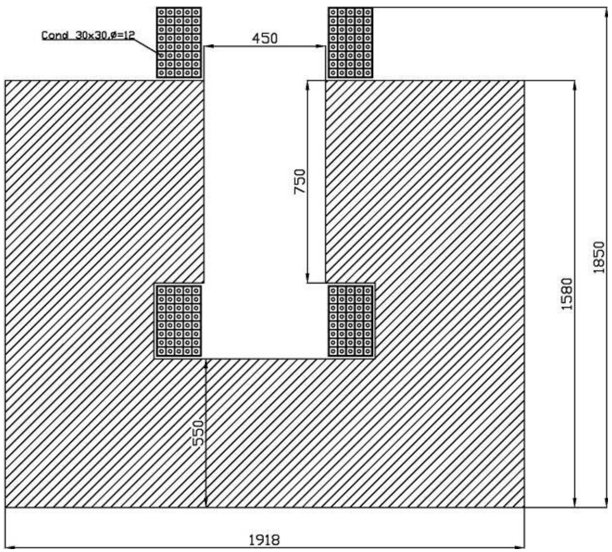
M. Modena, A. Vorozhtsov, TE-MSC

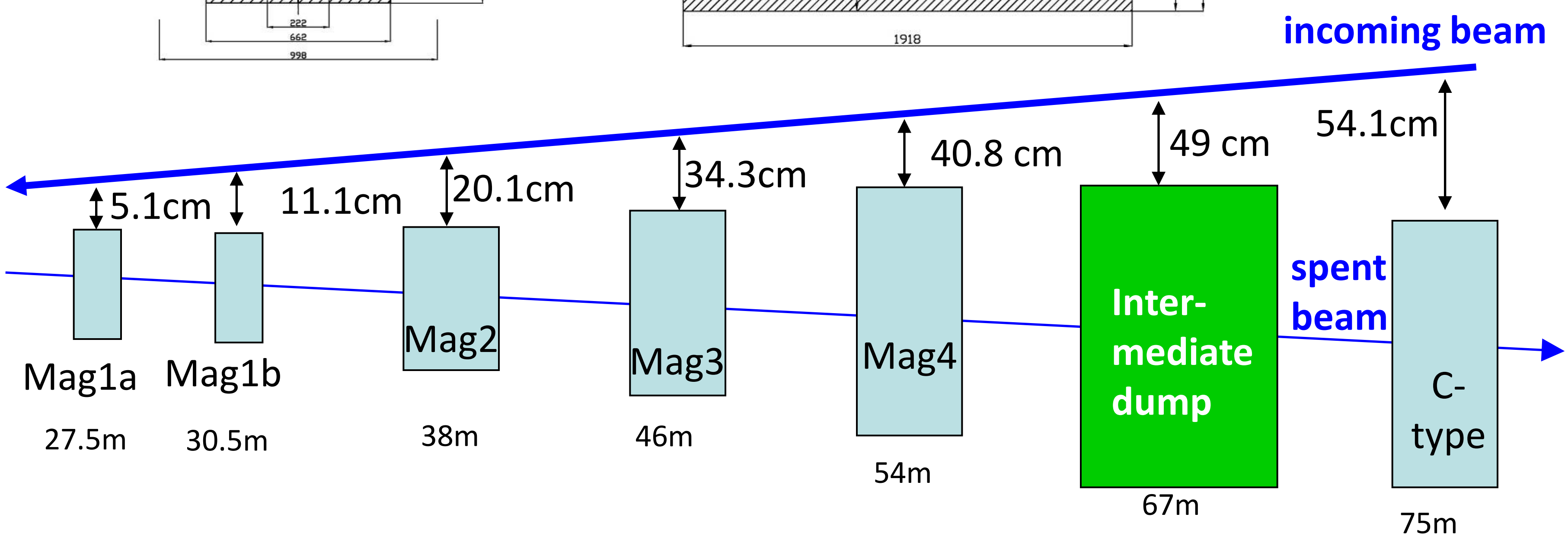
Magnets

Mag1a (window frame type)



C-type

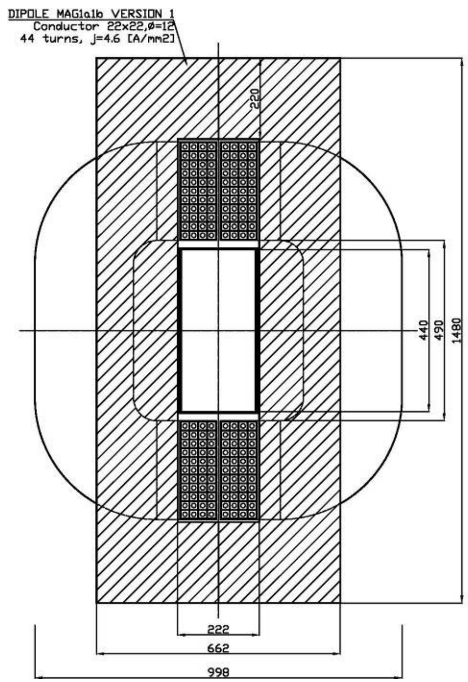


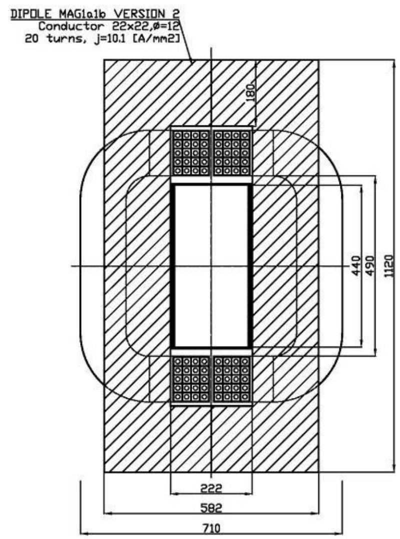


Window Frame Type Magnets Mag1a1b

4.6A/mm^2
280kCHF
65kW

5.1cm distance to incoming beam





10A/mm^2
198kCHF
143kW

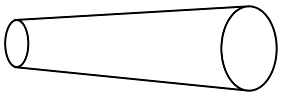
19.5cm distance to incoming beam

M. Modena, A. Vorozhtsov, TE-MSC

Vacuum System

Vacuum System

elliptical vacuum tube



- Less demanding pressure requirement in the medium vacuum range (required pressure TBC),
  - allowing for a conventional un-baked system design.
- Requires a high pumping speed due to the large surface area and beam-induced outgassing.
  - A combination of sputter-ion, turbo-molecular and mechanical pumps will be used.
- stainless steel vacuum chambers in stepped or conical forms inside the magnetic and absorber elements.
- Absorbers are outside the vacuum chambers
  - windows upstream of the intermediate dump absorbers
  - exit window separating the collider vacuum system from the main dump body
    - Large diameter (~1m).

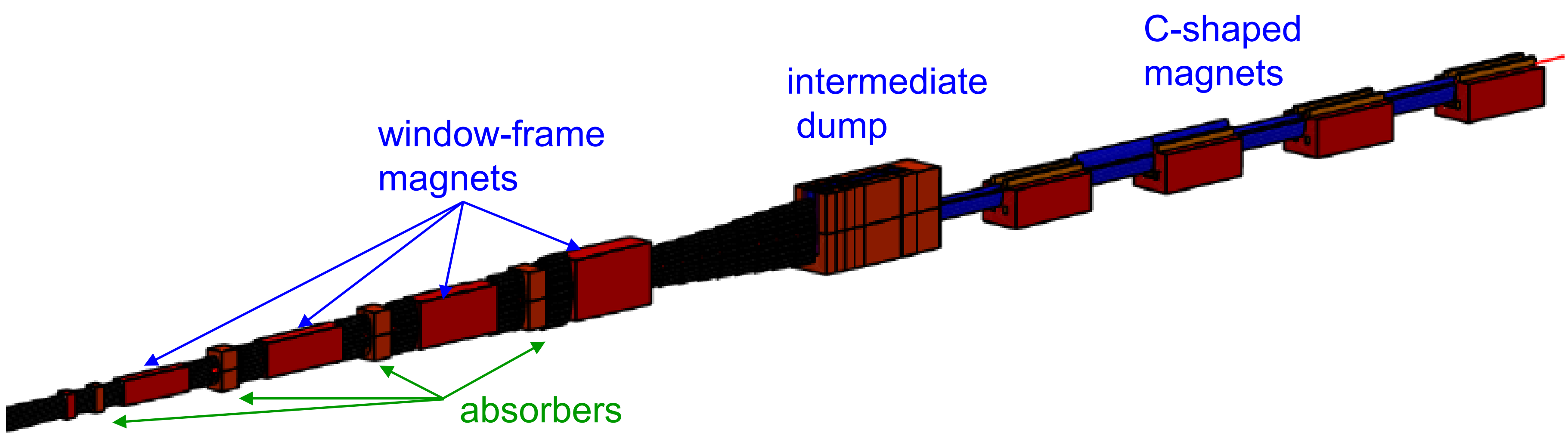
R. Veness, TE-VSC

Background Calculations to IP

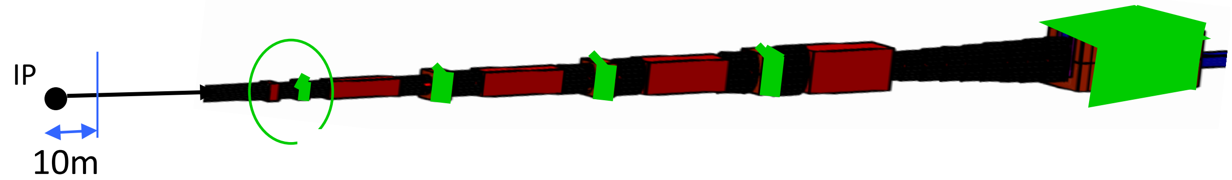
Background Calculations from Post-Collision Line to IP

- Entire Post-collision line geometry implemented
- Using Geant4 on the GRID
  - Neutron and photon background from absorbers and intermediate dump
  - Neutron and photon background from main beam dump

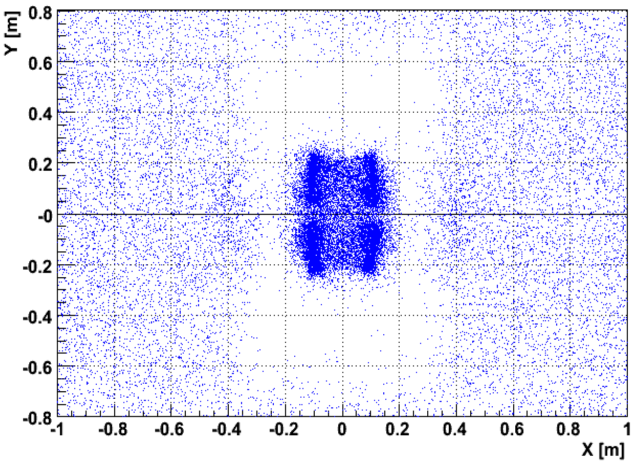
    → Ongoing: M. Salt, Cockcroft Institute

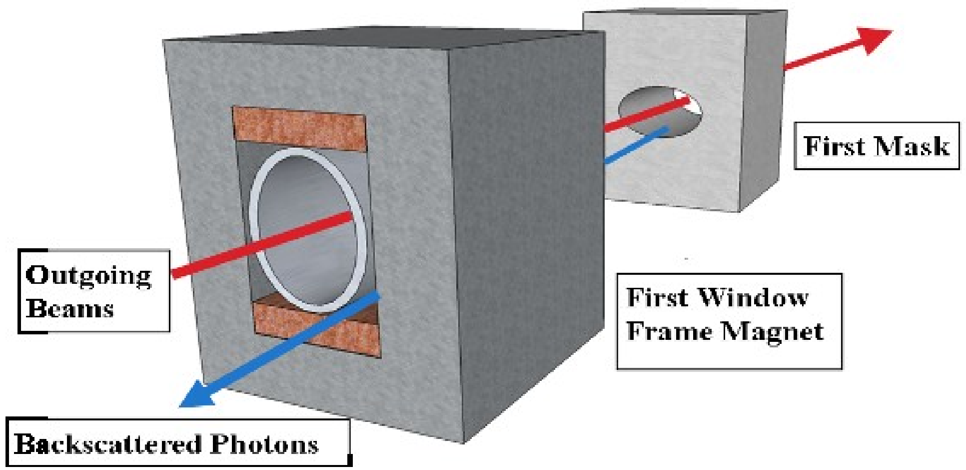


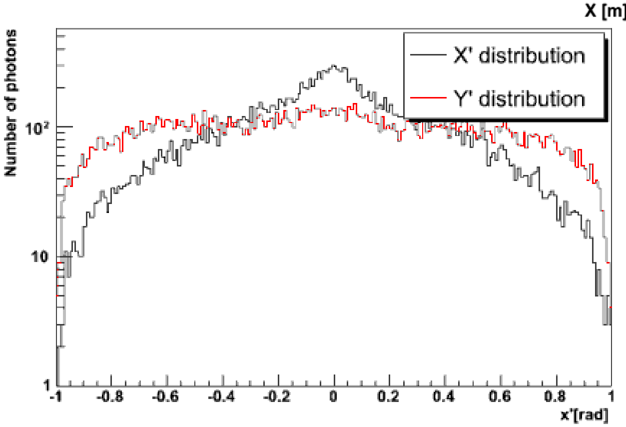
Photon Background from First Absorber to IP

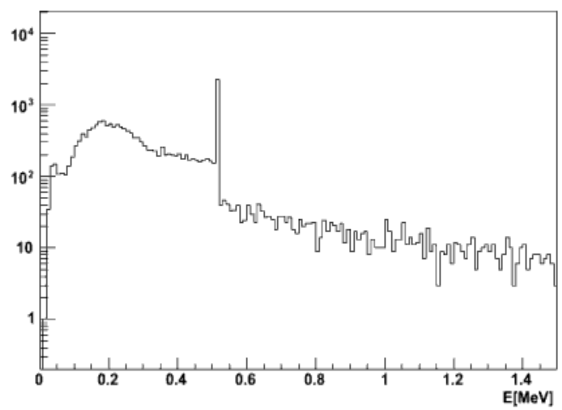


Backscattered photons at the entrance to the first magnet (s = 27.5 m)







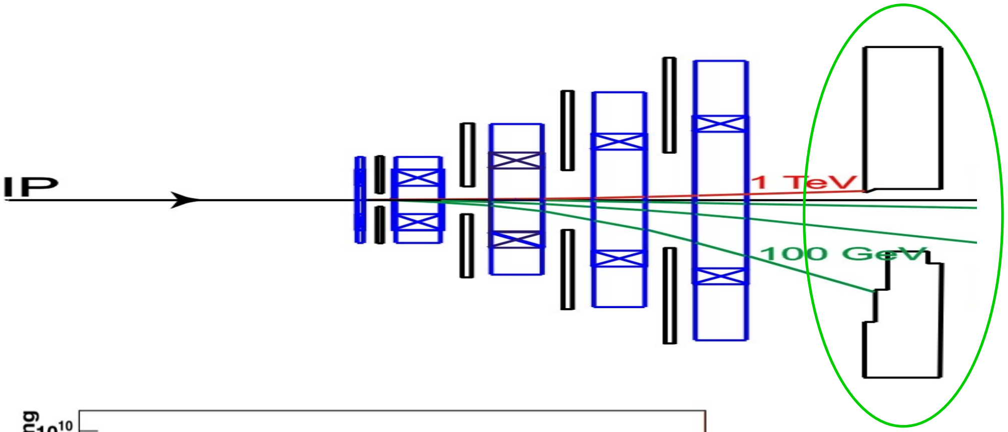


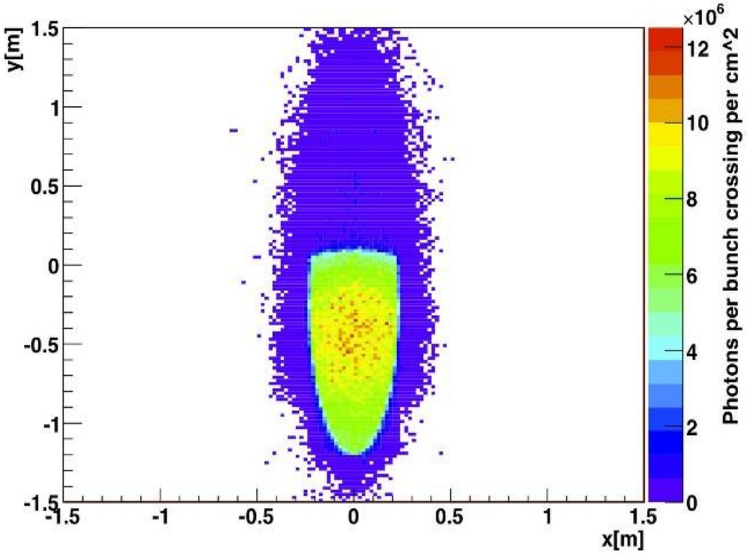
From first absorber:

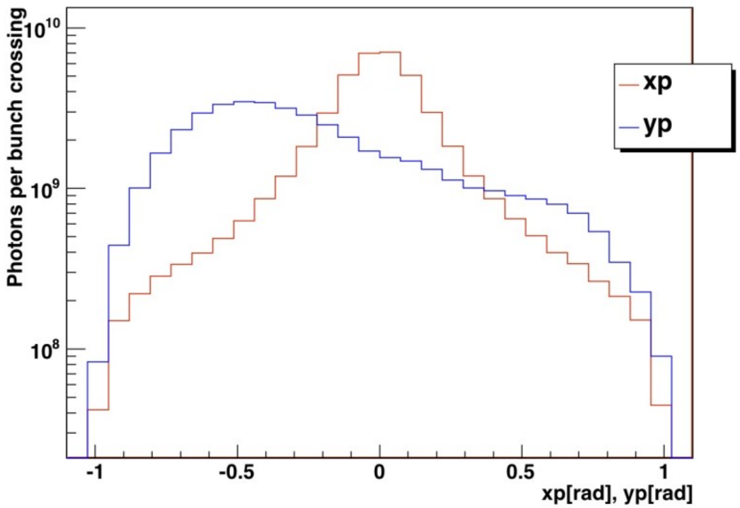
0.73 ± 0.05 photons/cm^2/bunchX

M. Salt, Cockcroft Institute

Photon Background from Intermediate Dump to IP







From intermediate dump:

7.7 ± 2.6 photons/cm^2/bunchX

(without absorbers: 530 ± 20 photons/cm^2/bunchX)

→Intermediate dump contributes significantly to IP background

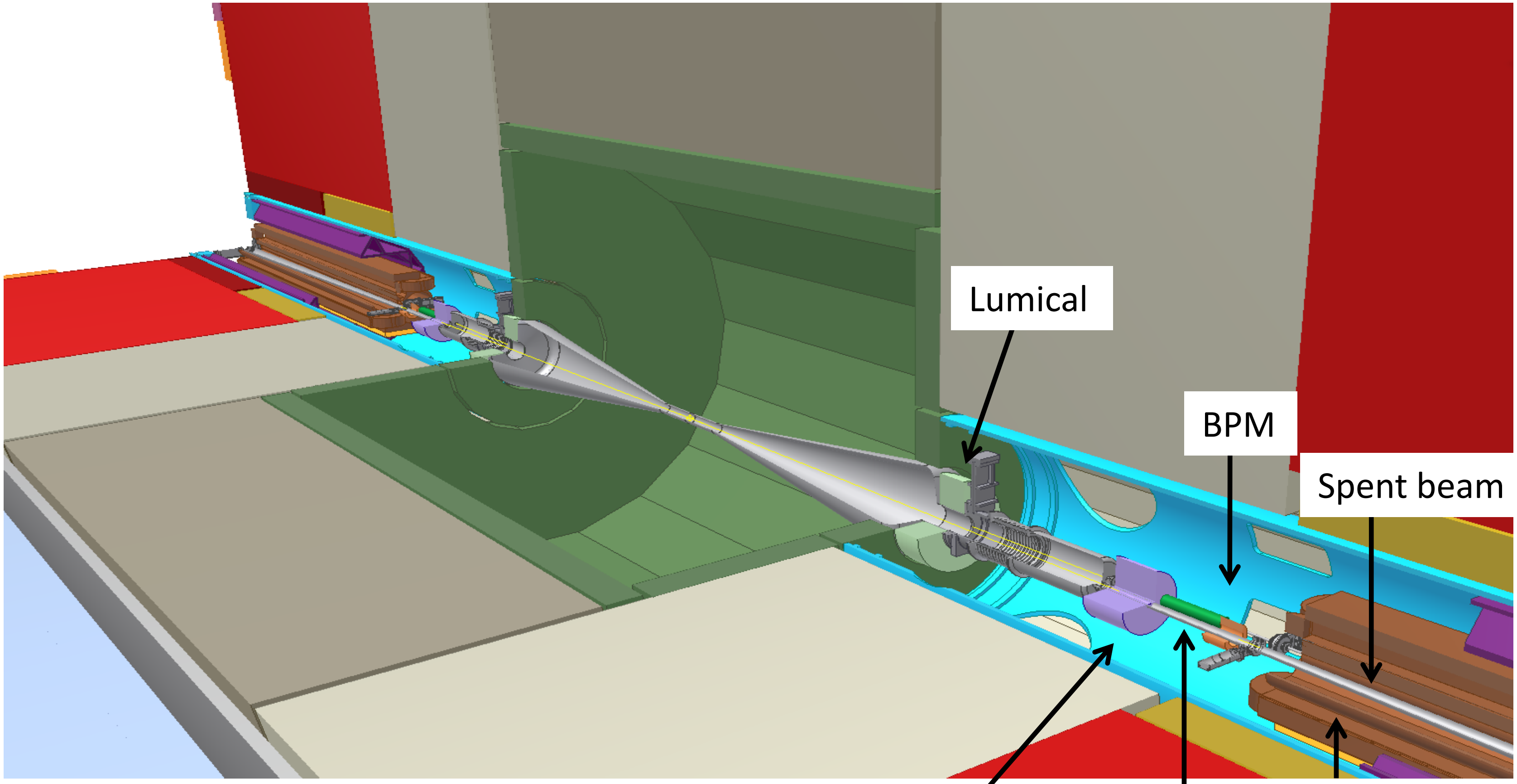
→**But** 98% attenuation thanks to aperture restriction in the chicane

M. Salt, Cockcroft Institute

Background Calculations to IP

→Preliminary results show that background particles at 'outer edge' of the LCD is low. The detector yoke and calorimeter will further shield the vertex and tracker against hits from background photons.

→Even if additional absorbers are needed, space is available in the forward region between the detector (6m) and the first post-collision line magnet (27m) .

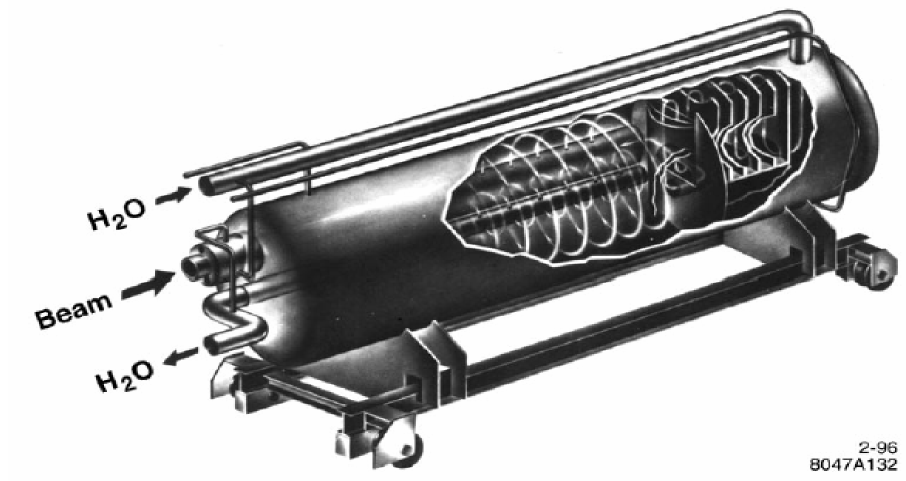


N.Siegrist, H.Gerwig

Main Beam Dump

Main Dump

- 1966: SLAC beam dump
  - 2.2 MW average beam power capacity
  - Power absorption medium is water



- 2000: TESLA
  - 12 MW beam power capacity
  - Water dump

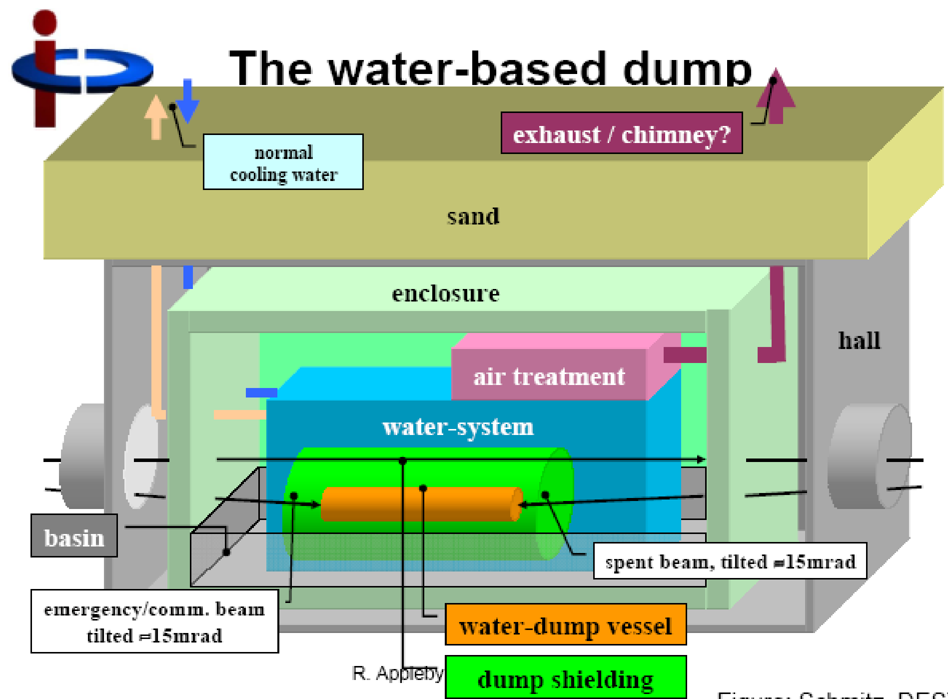
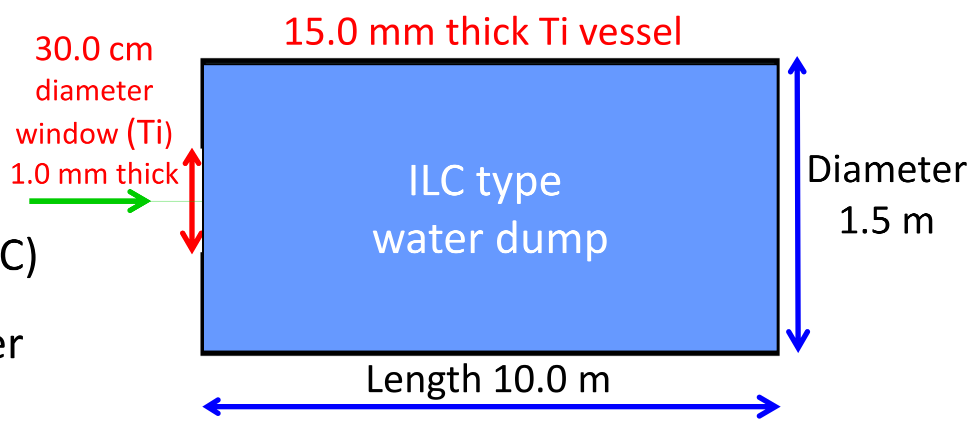


Figure: Schmitz, DESY

Baseline Main Dump Design

	CLIC	ILC
Beam energy	1500 GeV	500 GeV
# particles per bunch	3.7×10^9	2×10^{10}
# bunches per train	312	2820
Duration of bunch train	156 ns	950 μs
Uncollided beam size at dump σ_x, σ_y	1.56 mm, 2.73 mm	2.42 mm, 0.27 mm
# bunch trains per second	50	5
Beam power	14 MW	18 MW

- 2008: ILC 18 MW water dump
  - Cylindrical vessel
  - Volume: $18m^3$, Length: 10m
  - Diameter of 1.8m
  - Water pressure at 10bar (boils at 180C)
  - Ti-window, 1mm thick, 30cm diameter



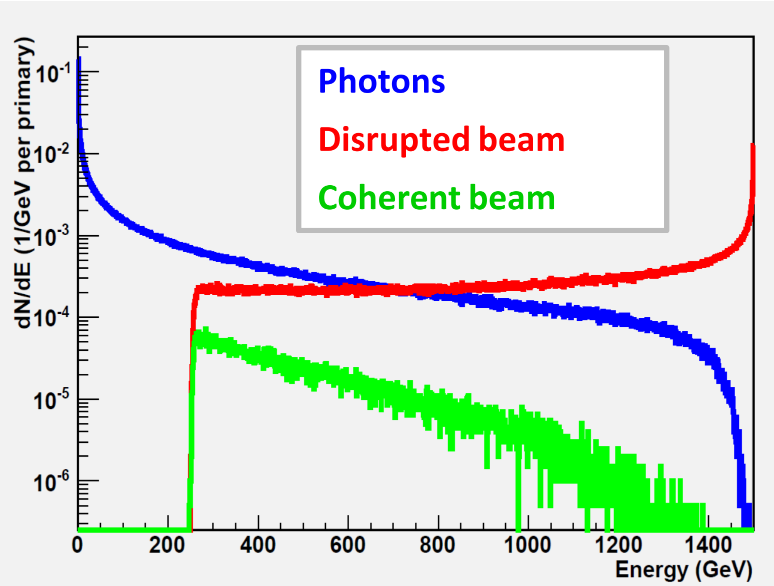
→ **baseline for CLIC 2010 main dump**

CLIC Main Beam Dump

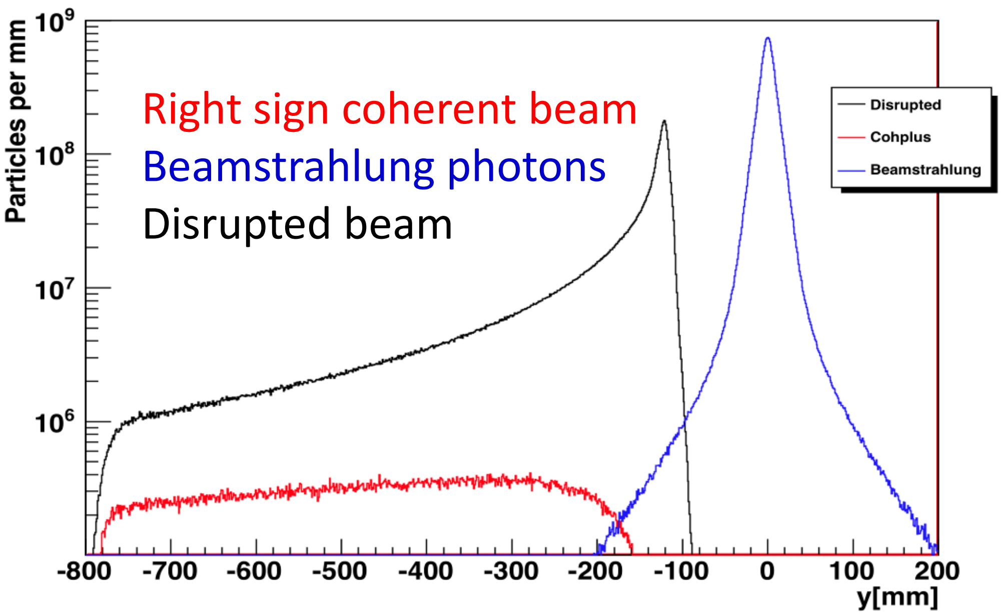
- Uncollided beam:

$\sigma_x = 1.56\text{mm}, \sigma_y = 2.73\text{mm} \rightarrow \mathbf{5.6mm^2}$

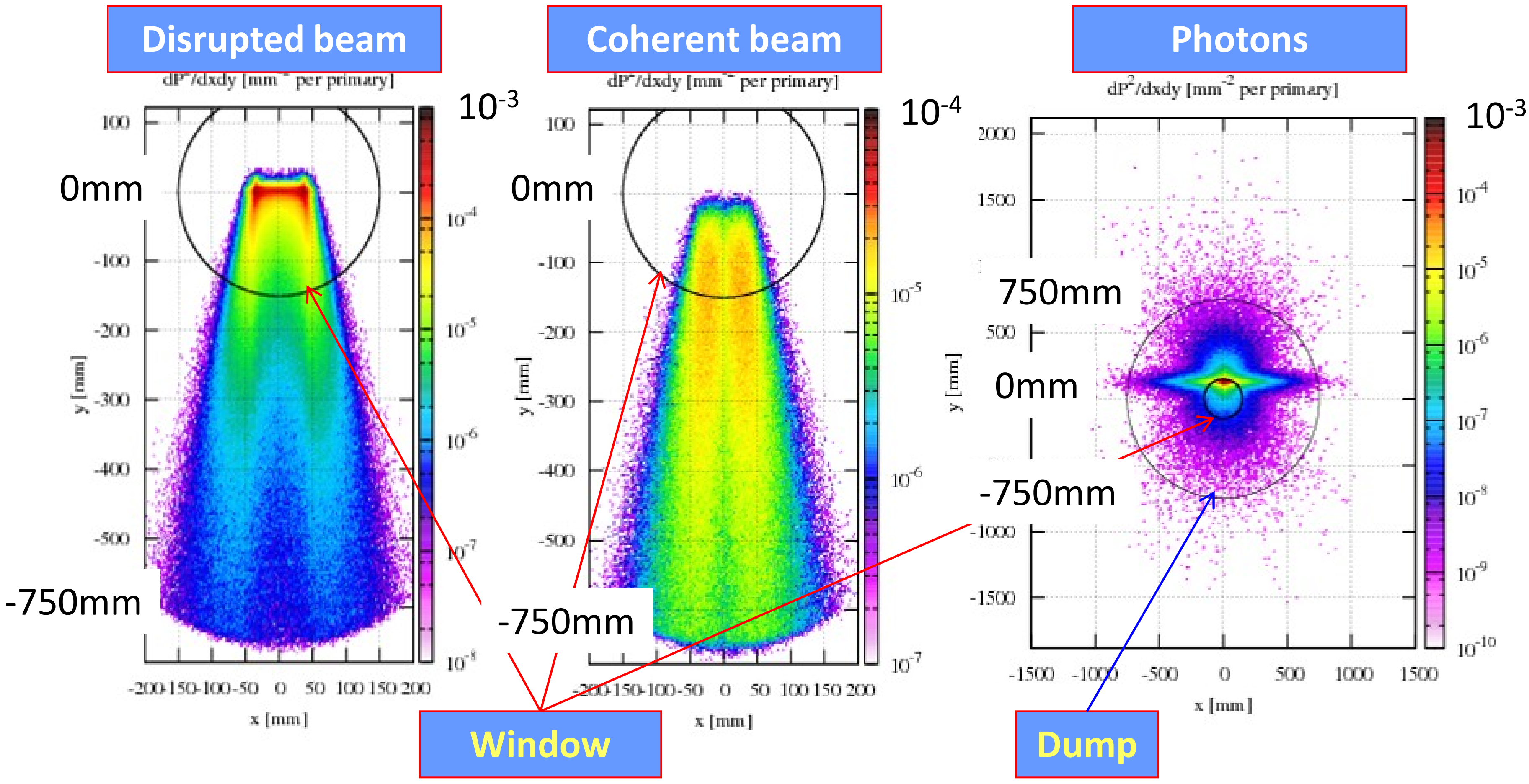
- Collided beam:



Collided 1.5TeV Beam at water dump 315m from IP

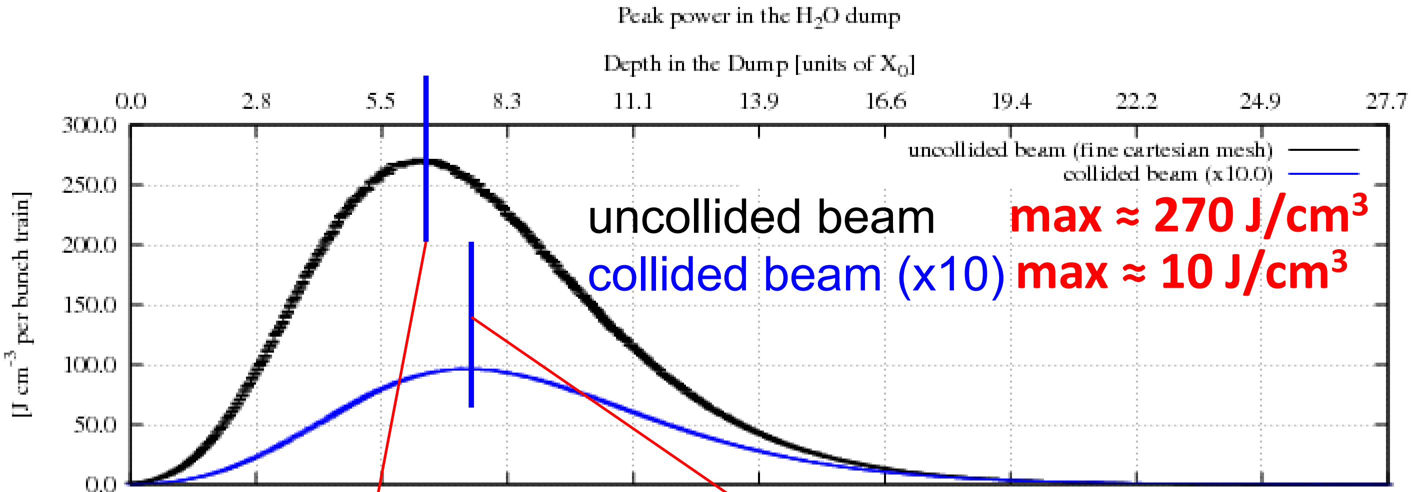


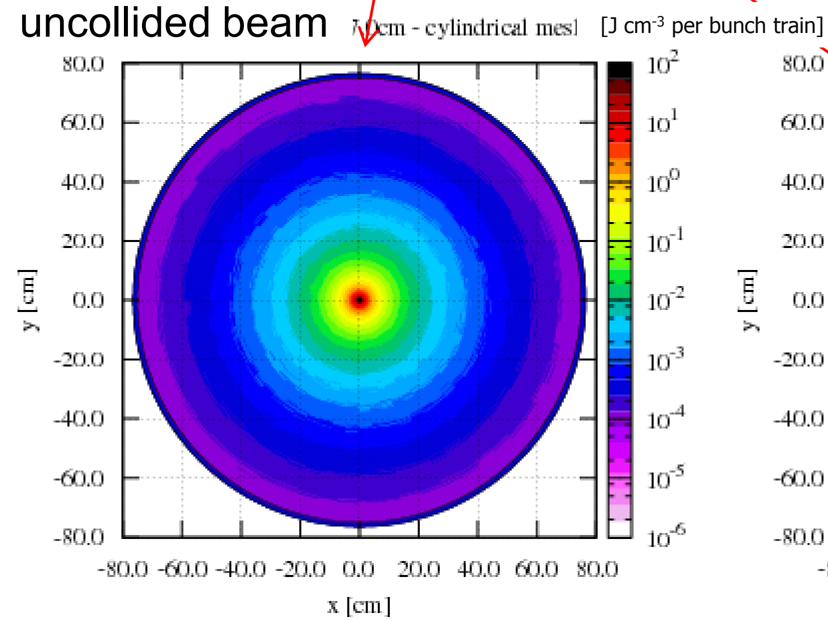
Particle Distribution at the Beam Dump Entrance

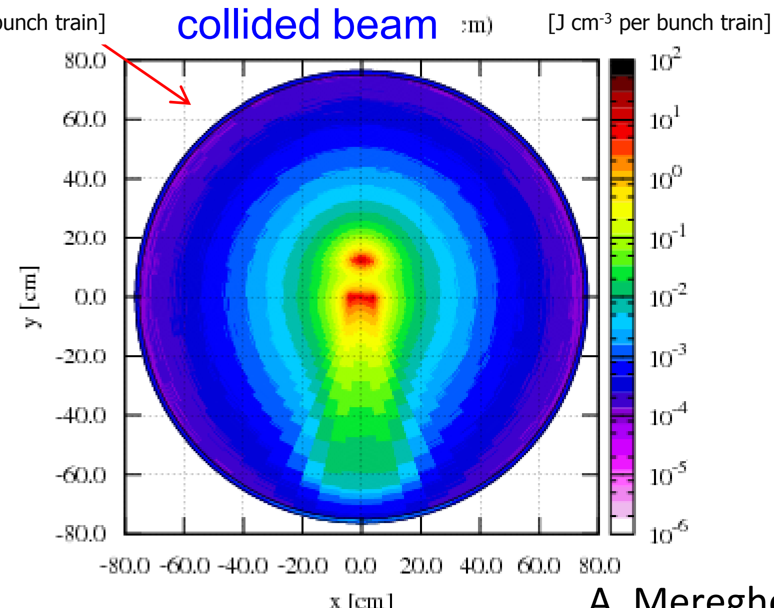


A. Mereghetti, EN-STI

Energy Deposition in Main Dump







A. Mereghetti, EN-STI

Main Dump Issues

- Maximum energy deposition per bunch train: **270 J/cm^3**

  → ILC: 240 J/cm^3 for a 6 cm beam sweep

- Remove heat deposited in the dump
  - Minimum water flow of 25-30 litre/s with v=1.5m/s
- Guarantee dump structural integrity
  - Almost instantaneous heat deposition generate a dynamic pressure wave inside the bath!
  - Cause overstress on dump wall and window (to be added to 10bar hydrostatic pressure).

    → dimensioning water tank, window, etc..
- Radiolytical/radiological effects
  - Hydrogen/oxygen recombiners, handling of ^{7}Be, ^{3}H

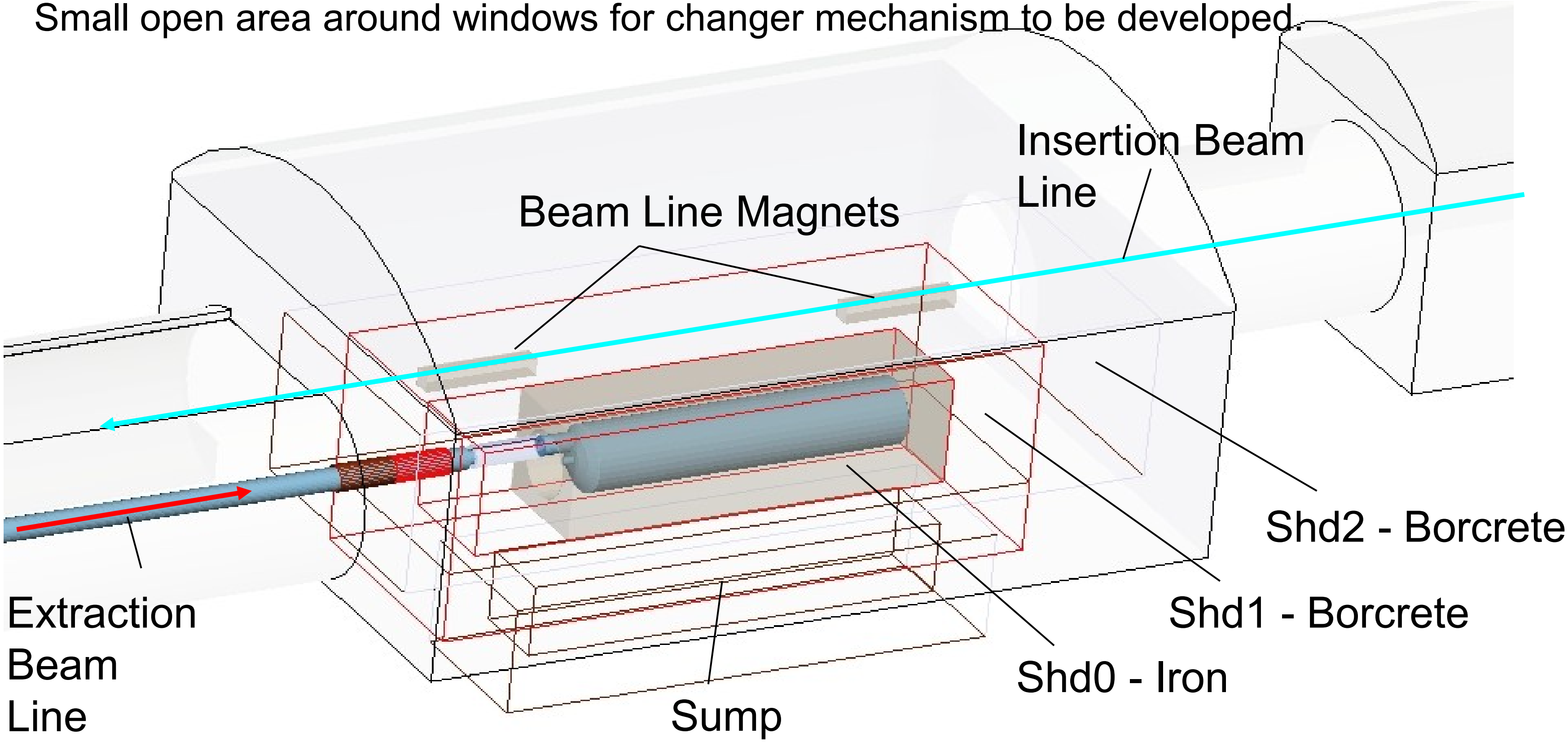
→ Calculations ongoing

ILC Beam Dump

Dump Hall - Tank - Geometry Version 2

Surround Dump Tank with 50 cm Iron + ~200 cm Borcrete (Concrete + 5% Boron).
Minimize volume of activated air.
Tail Catcher inside Dump Tank.
Small open area around windows for changer mechanism to be developed.

This plan can work.



Energy Deposition in CLIC Beam Dump Window

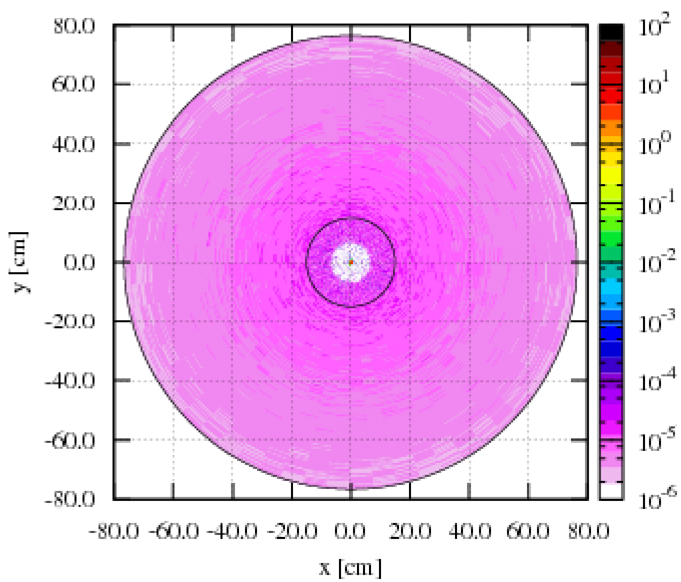
Titanium window:

1mm thick, 30cm diameter, cooling on internal surface by dump water at 180°C

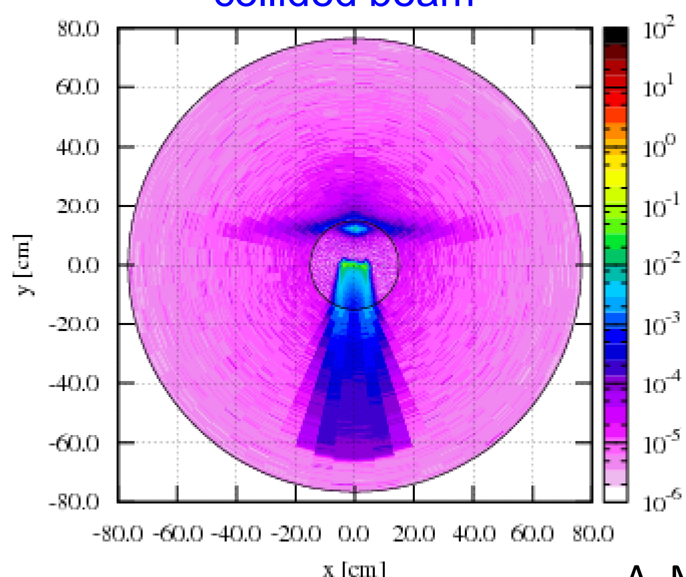
→ Total deposited Power: **~6.3W**

uncollided beam	**max ≈ 4.3 J/cm³**
collided beam	**max ≈ 0.13 J/cm³**

uncollided beam

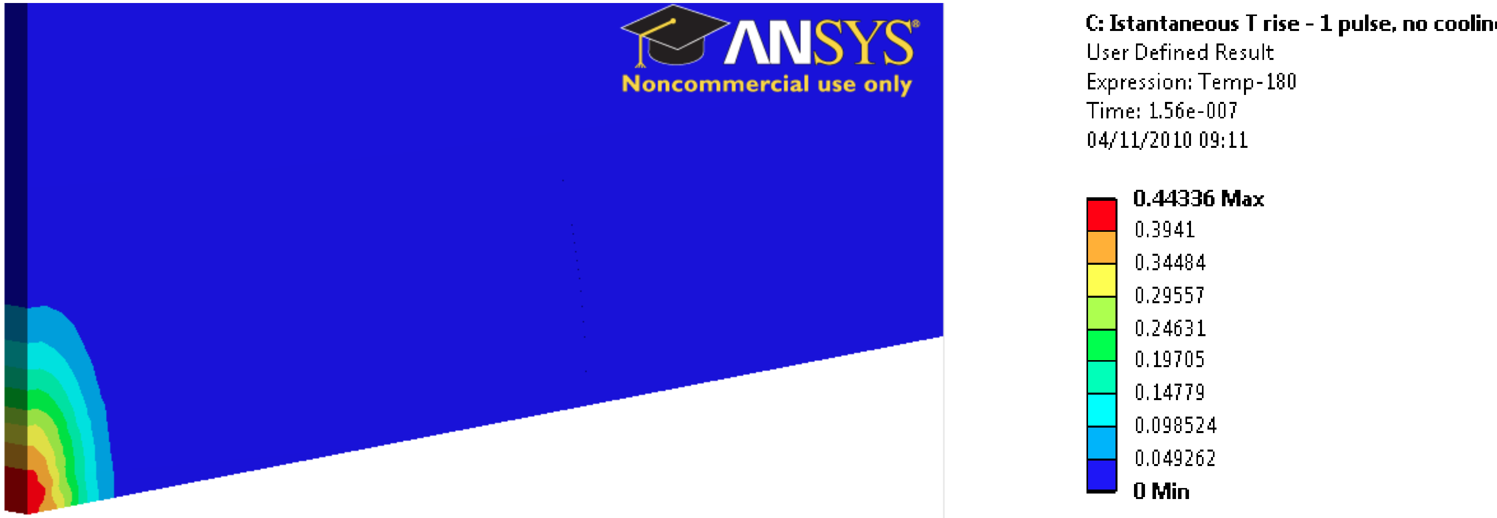


collided beam

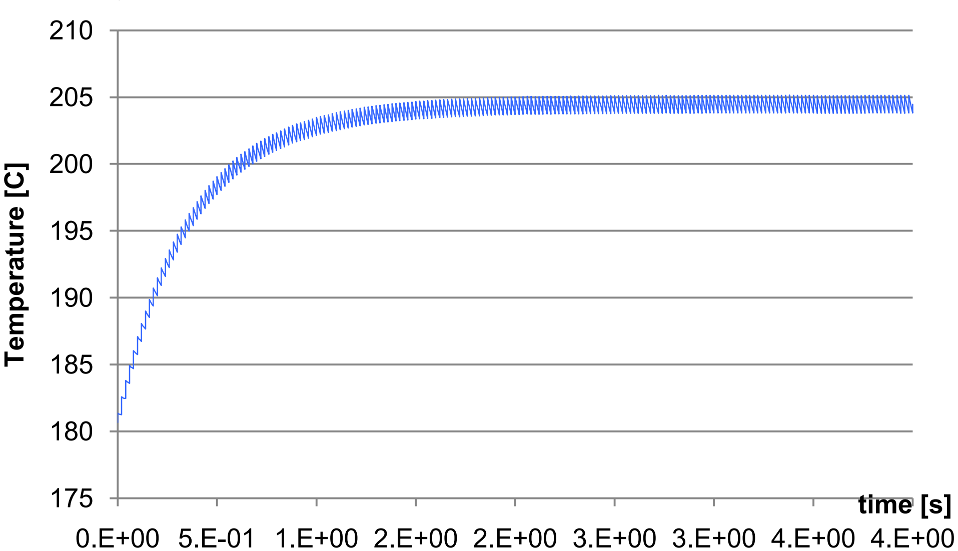


A. Mereghetti, EN-STI

Temperature Rise in CLIC Beam Dump Window



- → Temperature rise per 1 pulse: ΔT=0.44°C
- → Stable temperature after 3-4 sec with ΔT=24°C

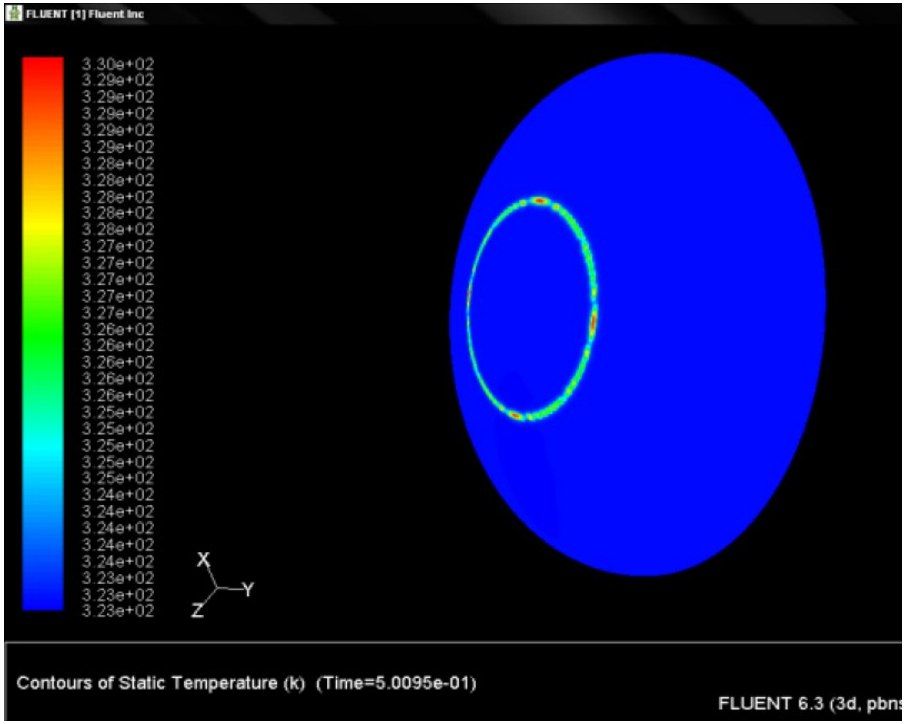


C. Maglioni, EN-STI

ILC Beam Dump Window

Titanium window:

hemispherical shape, 1mm thick, 30mm thick, single jet cooling



→ Maximal total power of **25 W** with **21 J/cm³**

→ Maximum temperature rises to 57°C

Other Main Dump Window Issues

- Beam dump window needs stiffener, double/triple parallel window system, symmetric cooling, etc… to withstand
  - Hydrostatic pressure of 10bar
  - Dynamic pressure wave
  - Window deformation and stresses due to heat depositions

→ **Calculations ongoing**

Luminosity Monitoring

Luminosity Monitoring

e+e- pair production

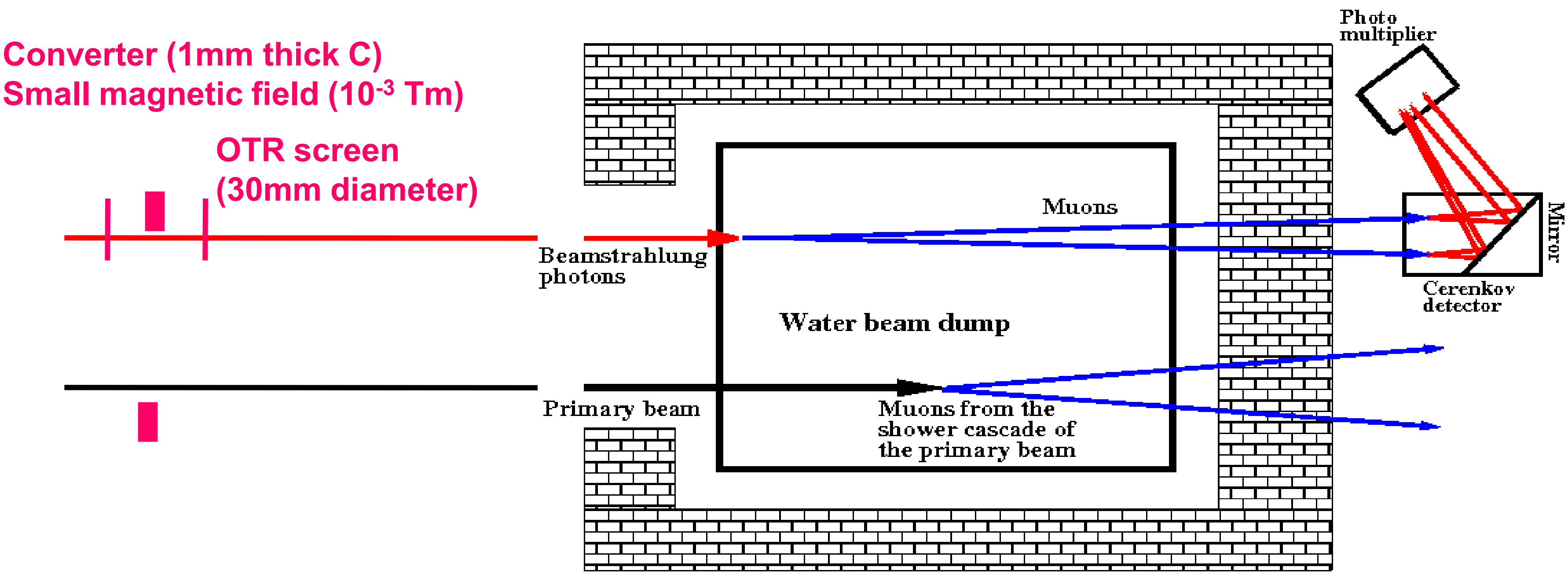
Beamstrahlung through converter → Produce charged particles → Optical Transition Radiation in thin screen → Observation with CCD or photomultiplier

V.Ziemann – Eurotev-2008-016

$\mu+\mu-$ pair production

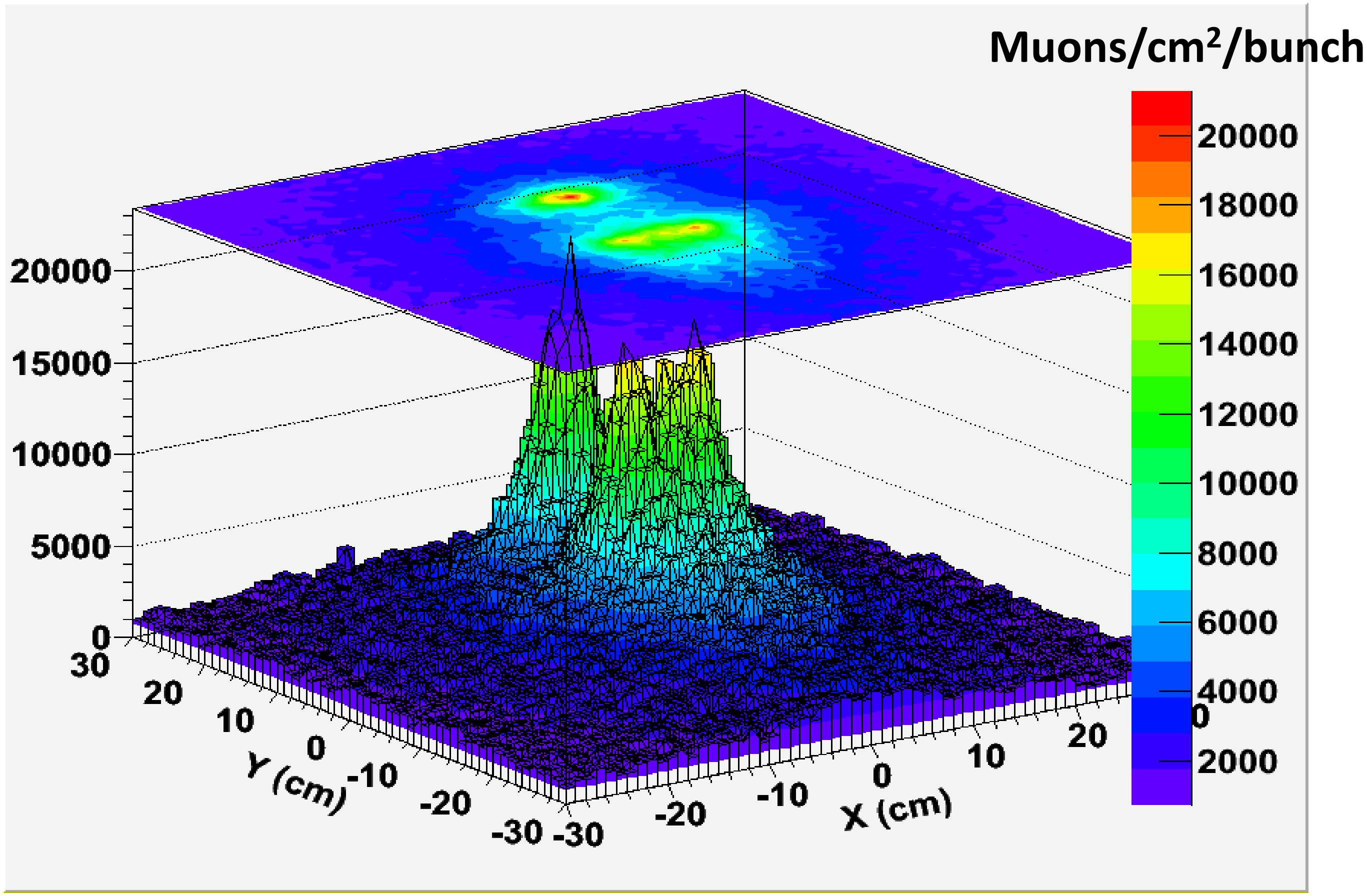
Main dump as converter→ muons → install detector behind dump

- With a Cherenkov detector: 2 E5 Cherenkov photons/bunch



First Results

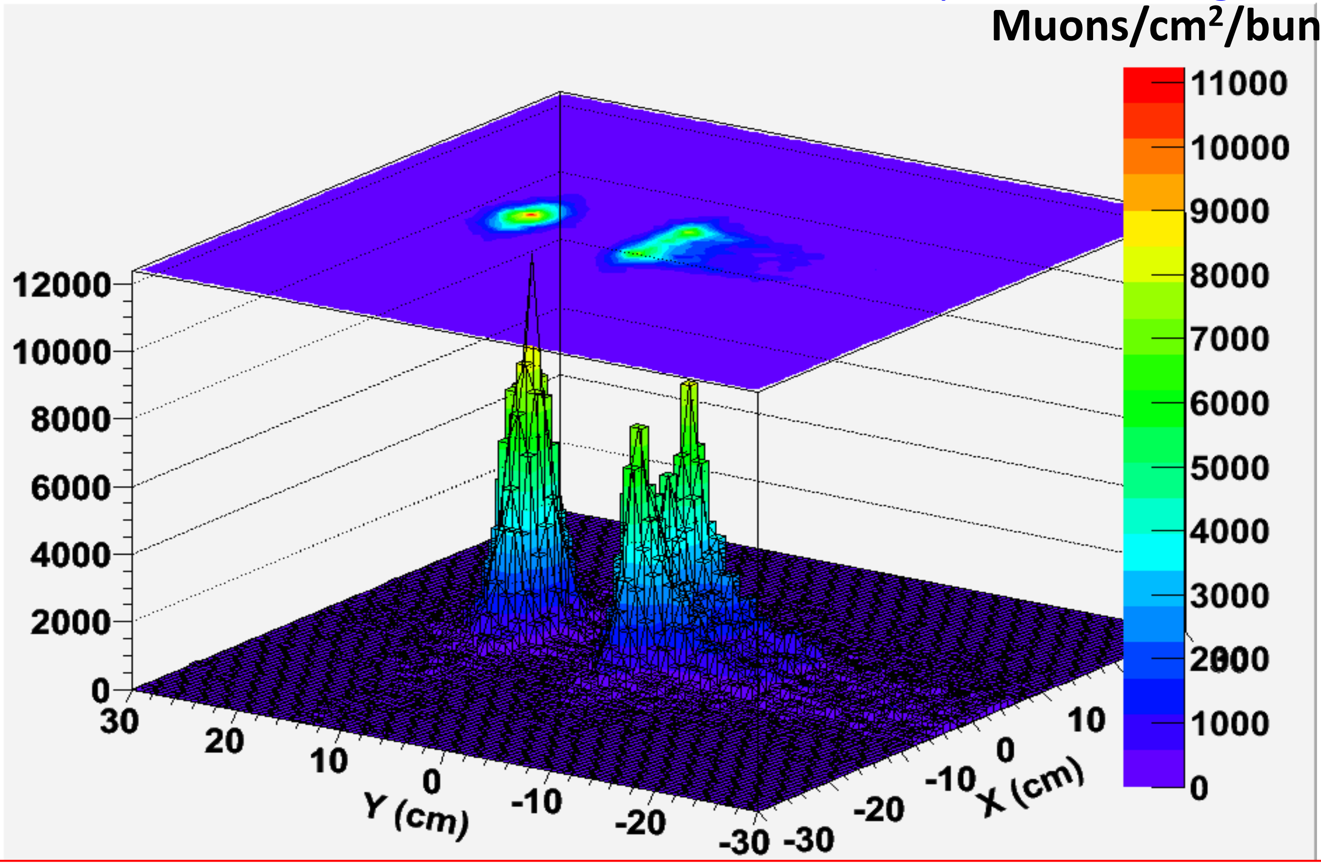
Muon distribution with **E> 212MeV** behind the beam dump and shielding



A. Apyan, EN-MEF

First Results

Muon distribution with **E> 50 GeV** behind the beam dump and shielding



A. Apyan, EN-MEF

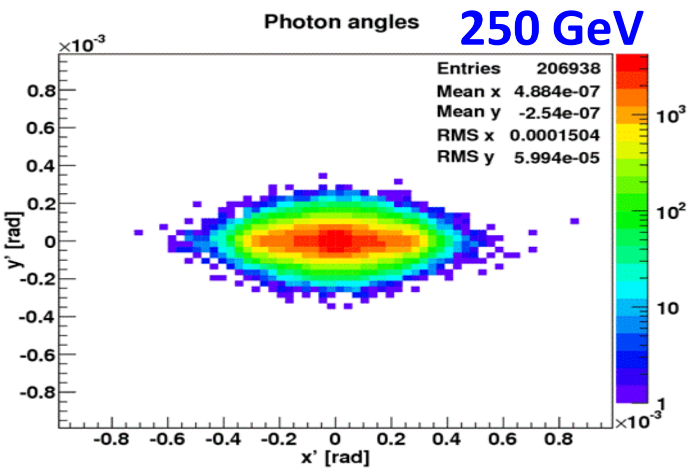
Calculations ongoing:

→ **Include Cherenkov counters in simulations**

→ **produce non-perfect collisions and track particles through post collision line to see variations in luminosity detectors**

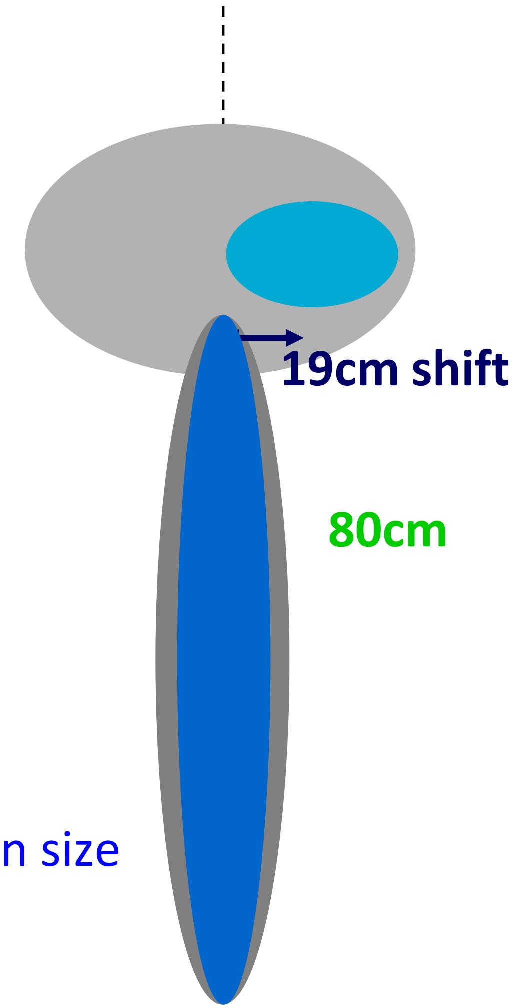
500 GeV c.m. Scenario

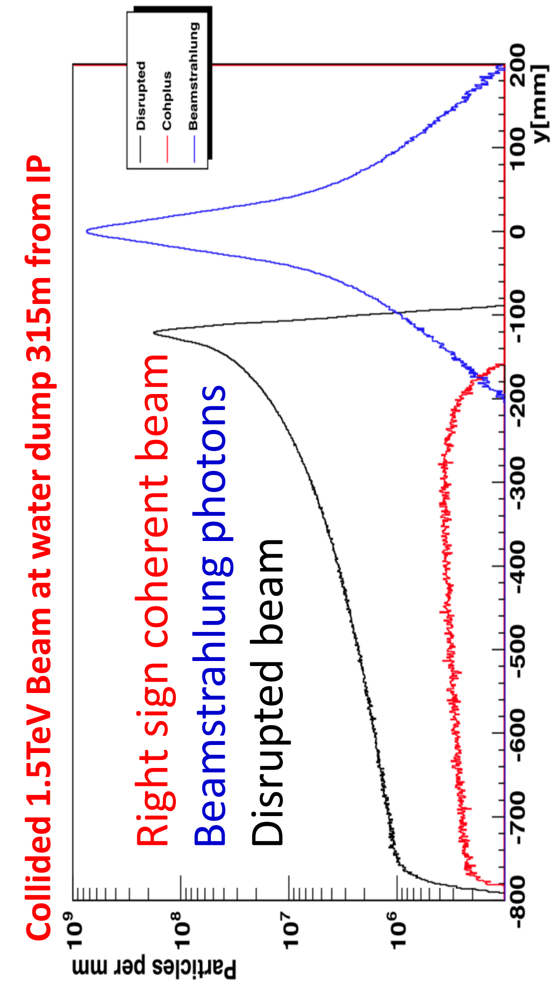
500 GeV c.m. /18.6mrad Option versus 3000 GeV c.m. / 20mrad Option



$x'_{max} = \pm 0.6mrad$

$y'_{max} = \pm 0.3mrad$





Photons:
19cm horizontal shift, but reduced in size

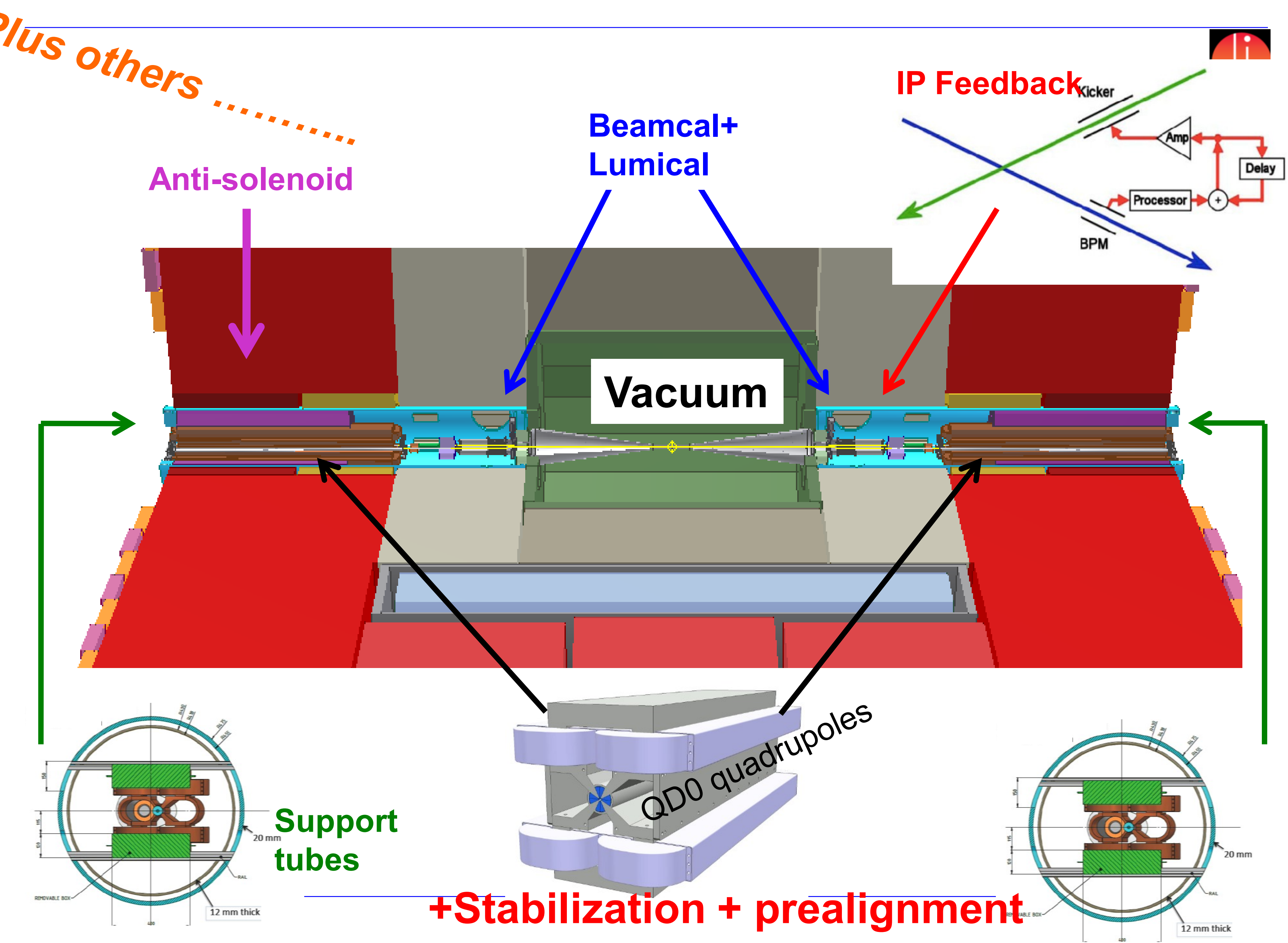
→ Proof of principle

Impact of 500GeV c.m. scenario on post-IP design is minimal

Summary

- Many new results achieved since last year
- Conceptual design of the CLIC post-collision line exists:
  - Magnets
  - Intermediate dumps
  - Background calculations to the IP
  - Luminosity monitoring: First promising results
  - Beam dump: first results, calculations ongoing
    - →Improve design on beam dump
    - →Collaboration with ILC: ILC-CLIC working group on dumps?

- Additional Slides


Plus others ....
IP Feedback
Kicker
Amp
Delay
Processor
BPM
Beamcal+
Lumical
Anti-solenoid
Vacuum
Support
tubes
QD0 quadrupoles
20 mm
12 mm thick
+Stabilization + prealignment

Summary of Energy Deposition in Main Dump

	max [J cm-3 per bunch train]		tot [W]	
	un-collided	collided	un-collided	collided
H_2O	271	9.7	13.8 M	13.1 M
Ti window	5.7	0.13	6.40	4.76
Ti vessel (side)	0.001341	0.00292	15.5 k	17.0 k
Ti vessel (upstr. face)	0.000037	0.001993	7.3	45.0
Ti vessel (dwnstr. Face)	0.254852	0.044544	1.1 k	905.0

Prompt Energy Deposition - J/cm³/hour - Geometry V2

Even the rocks get hot!