CLIC Post-Collision Line and Dump

Edda Gschwendtner, CERN

for the Post-Collision Working Group

Rob Appleby (CERN & Cockcroft Institute), Armen Apyan (CERN), Barbara Dalena (CERN), Konrad Elsener (CERN), Arnaud Ferrari (Uppsala University), Thibaut Lefevre (CERN), Cesare Maglioni (CERN), Alessio Mereghetti (CERN), Michele Modena (CERN), Mike Salt (Cockcroft Institute), Jan Uythoven (CERN), Ray Veness (CERN), Alexey Vorozhtsov (CERN)

Outline

- Introduction
- Background Calculations to the IP
- Absorbers and Intermediate Dump
- Magnet System
- Main Beam Dump
- Luminosity Monitoring
- Summary

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 protection system

→ Beam diagnostic system

Some Numbers

50 Hz repetition rate

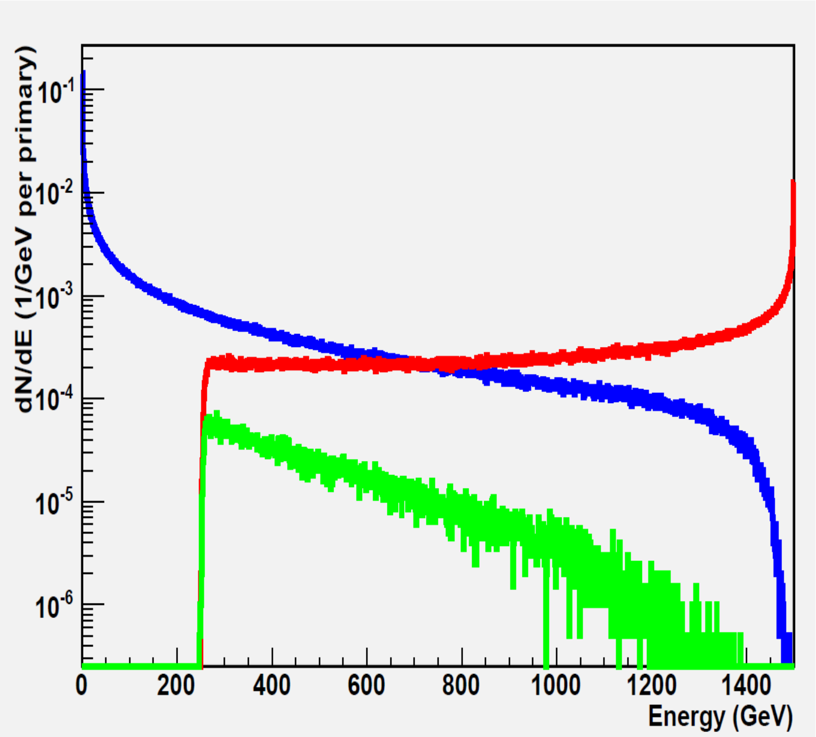
3.7E9 e/bunch

14MW beam power

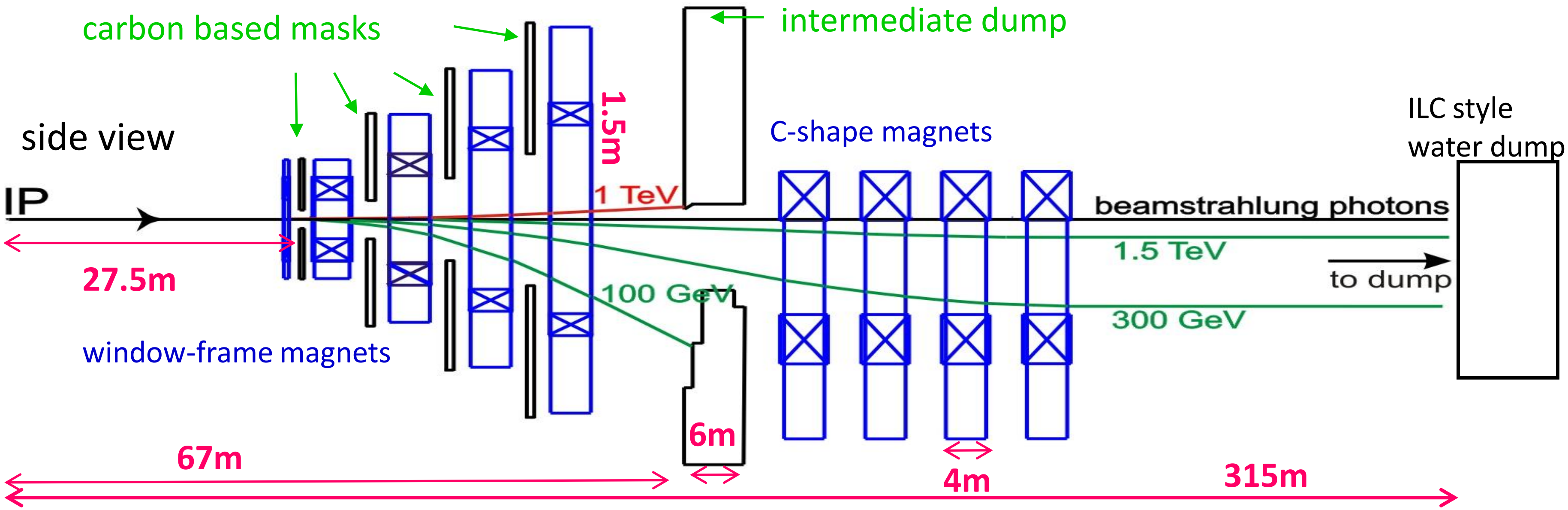
156ns bunch train length

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



Baseline Design



1. Separation of disrupted beam, beamstrahlung photons and particles with opposite sign from coherent pairs and particles from e+e- pairs with the wrong-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

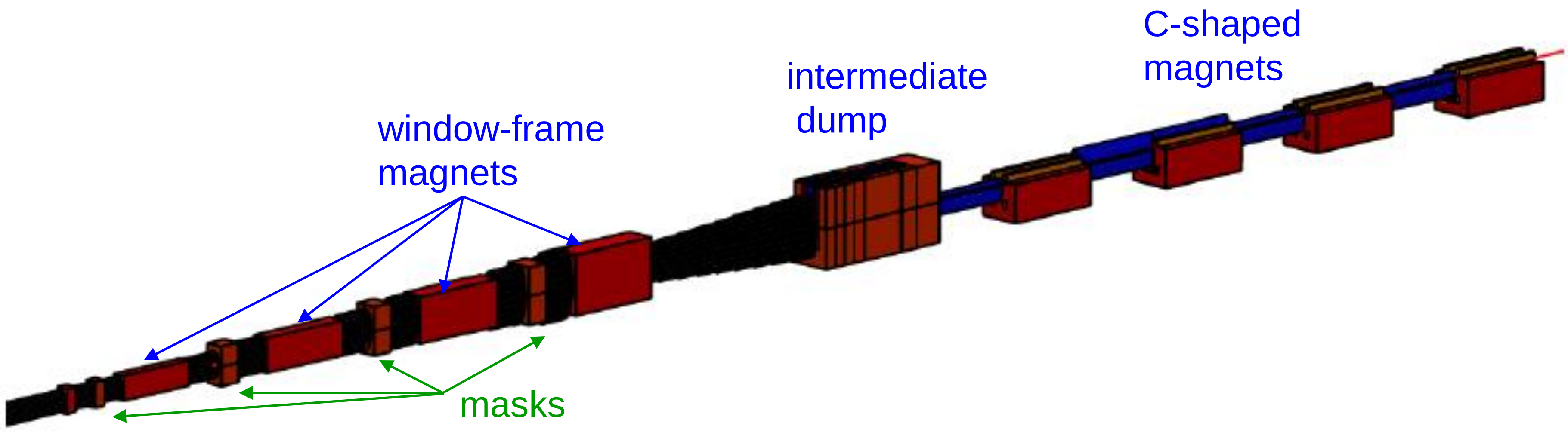
Background Calculations to IP

Background Calculations from Main Dump to IP

- Entire Post-collision line geometry implemented
- Using Geant4 on the GRID

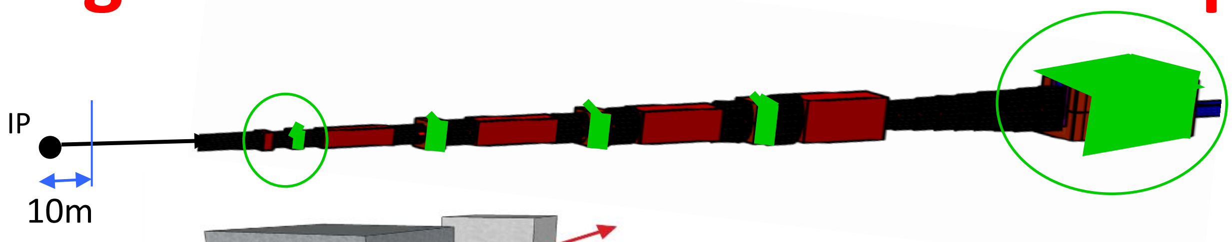
→ **Ongoing: M. Salt, Cockcroft Institute**

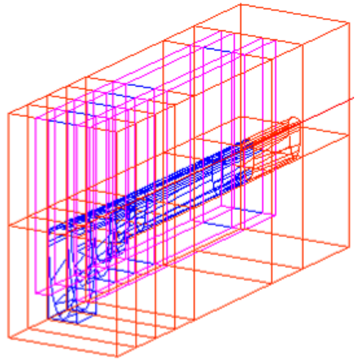
– Neutron and photon background from main beam dump

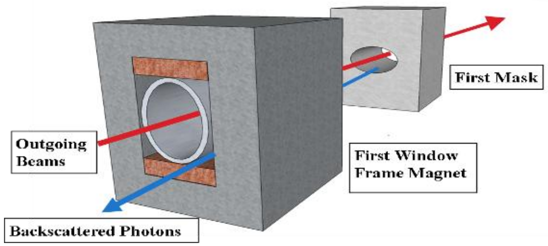


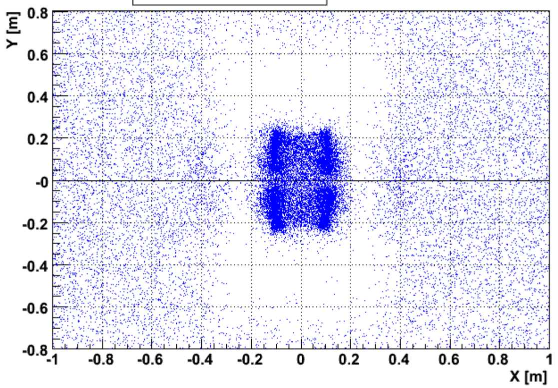
→Preliminary results show that background particles at 'outer edge' of the LCD is low and detectors should absorb large fraction of particles.
→Even if additional absorbers are needed, space is available in the detector forward region.

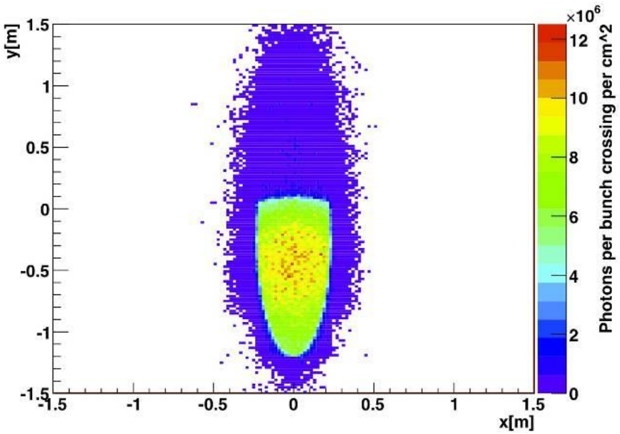
Background from Intermediate Dump to IP











From first absorber:

0.73 ± 0.05 photons/cm^2/bunchX

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

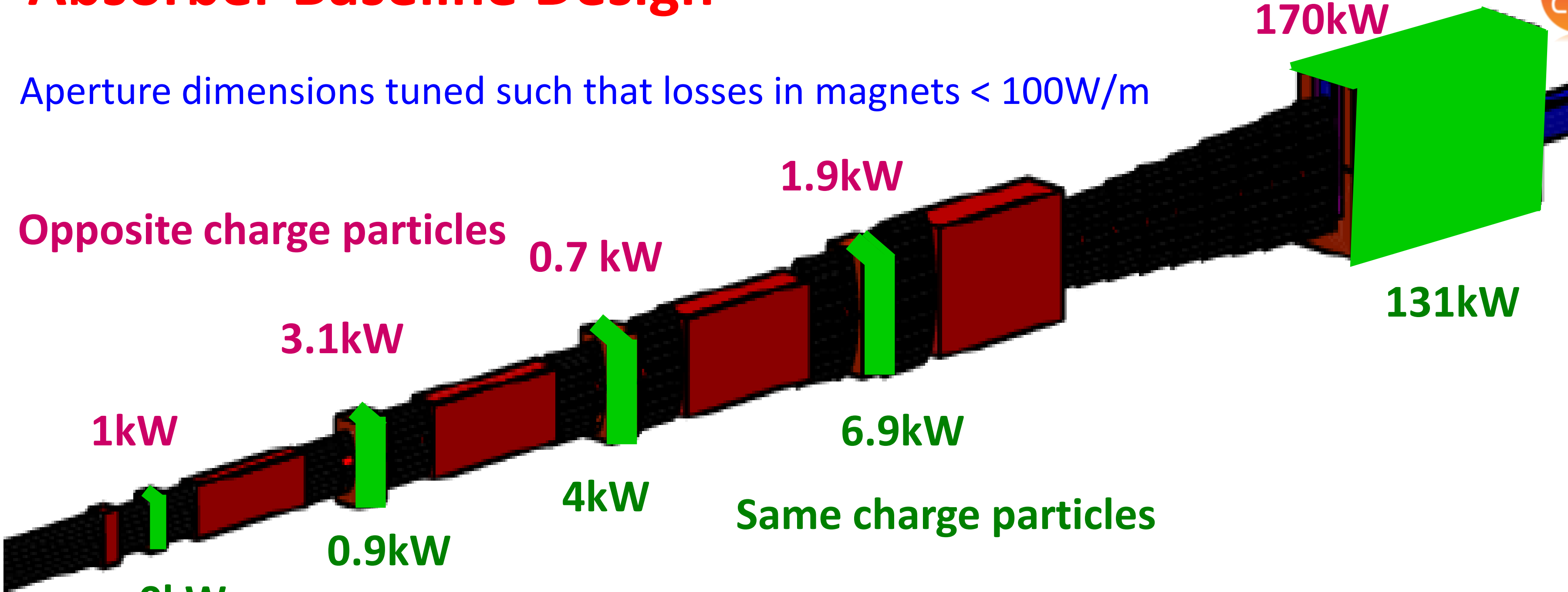
→**But** 98% attenuation thanks to magnetic chicane

M. Salt, Cockcroft Institute

Magnet Protection Absorbers and Intermediate Dump

Absorber Baseline Design

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



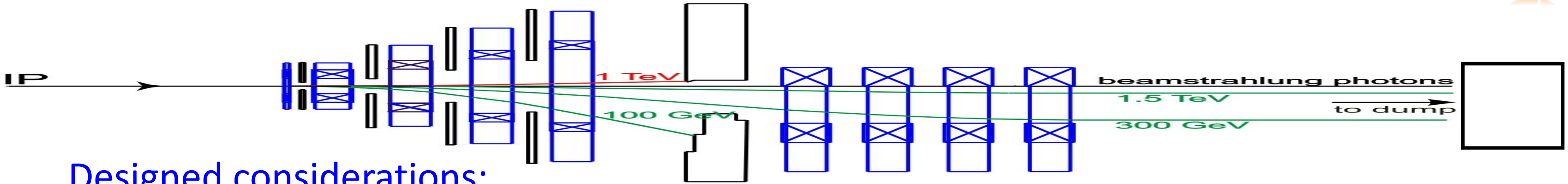
Intermediate dump (CNGS style):
carbon based absorber, water cooled aluminum plates, iron jacket
3.15m x 1.7m x 6m
→ aperture: X=18cm, Y=86cm

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

→ Non-trivial, but 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

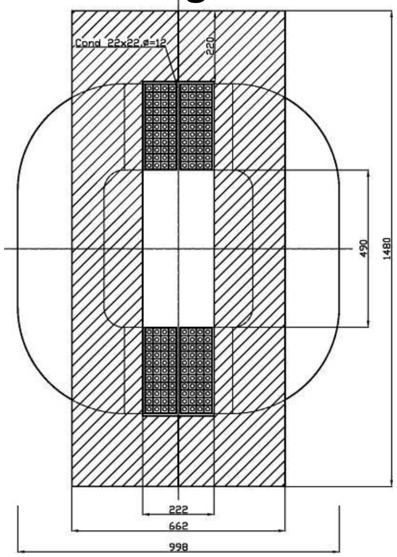
→ In total 18 magnets of 5 different types

→Total consumption is 3.3MW

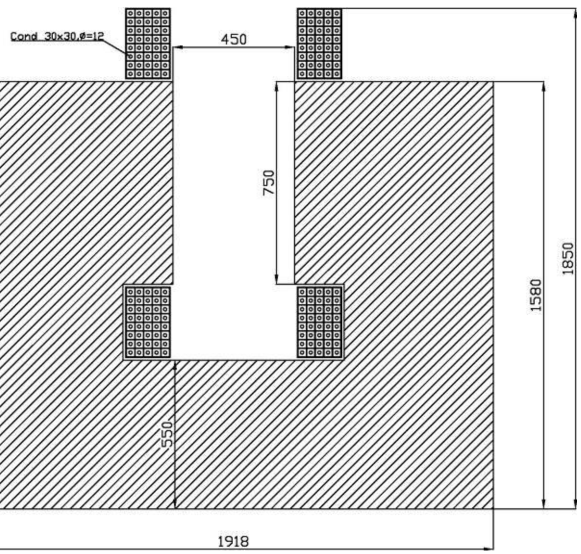
M. Modena, A. Vorozhtsov, TE-MSC

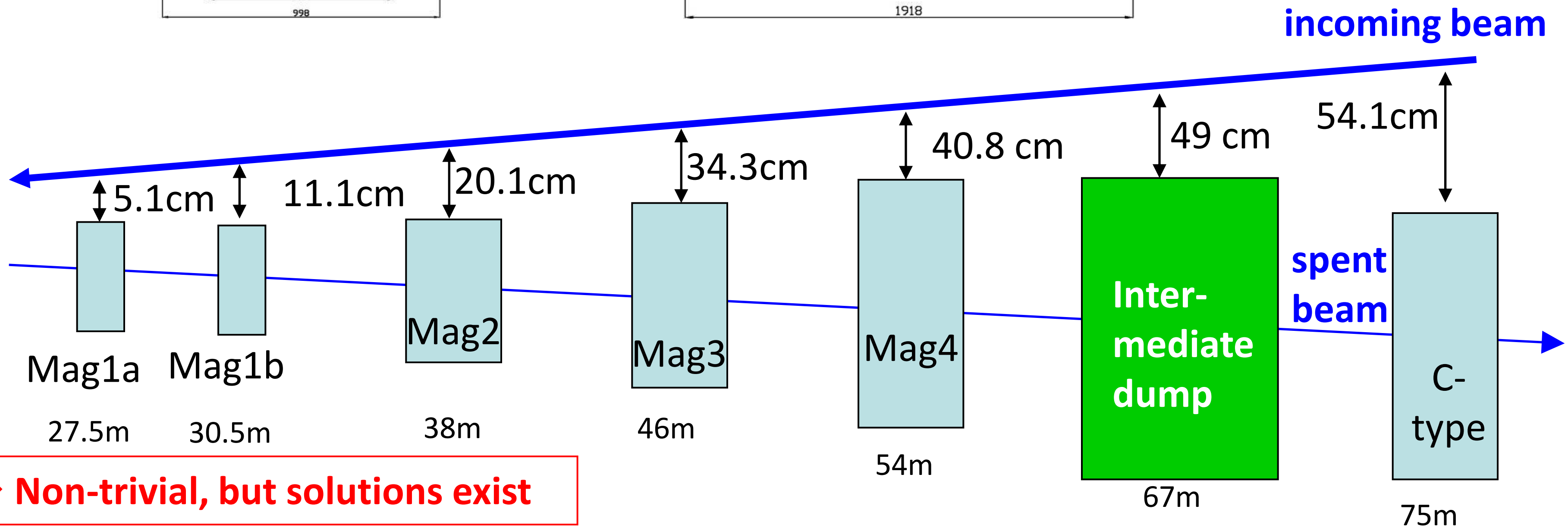
Magnets

Mag1a



C-type



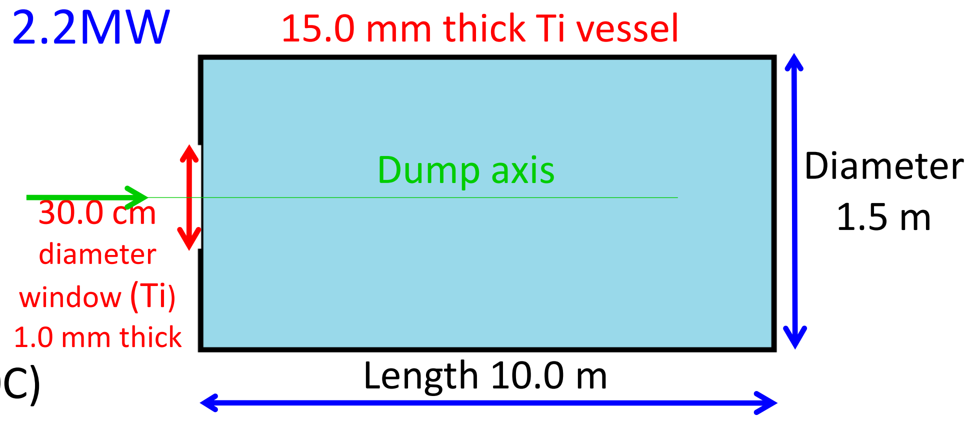


→ **Non-trivial, but solutions exist**

Main Beam Dump

Baseline Main Dump Design

- 1966: SLAC water based beam dump: 2.2MW
- 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



	CLIC	ILC
Beam energy	1500 GeV	250 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

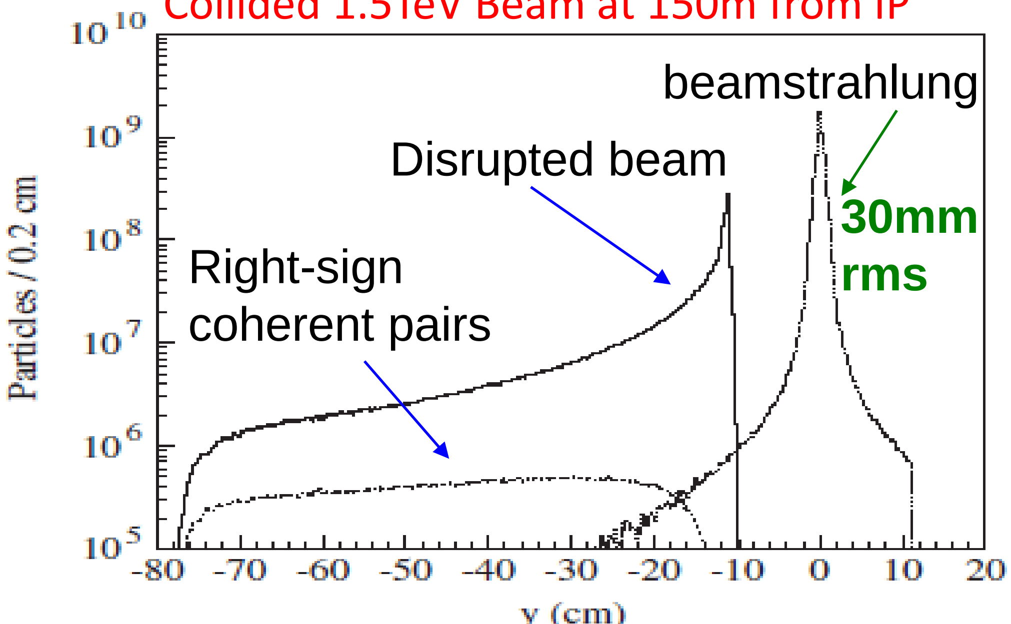
Main Beam Dump

- Uncollided beam:

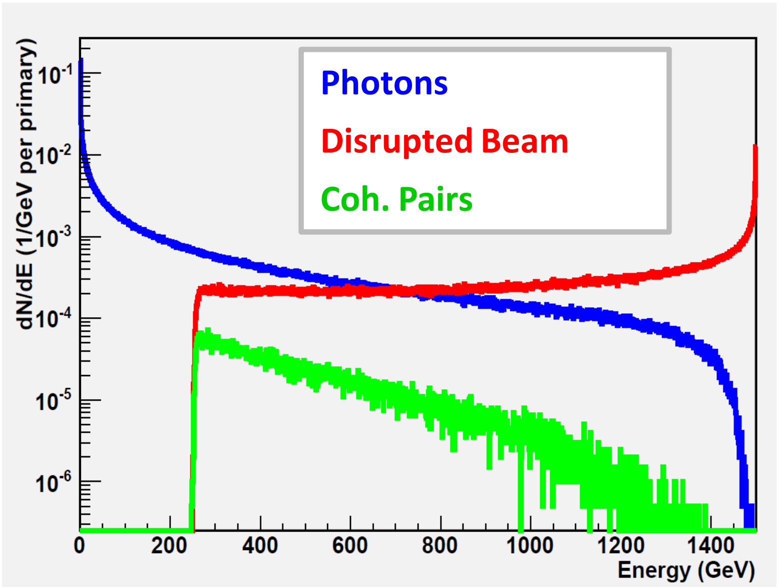
$$\sigma_x = 1.56mm, \sigma_y = 2.73mm \rightarrow \mathbf{5.6mm^2}$$

- Collided beam:

Collided 1.5TeV Beam at 150m from IP

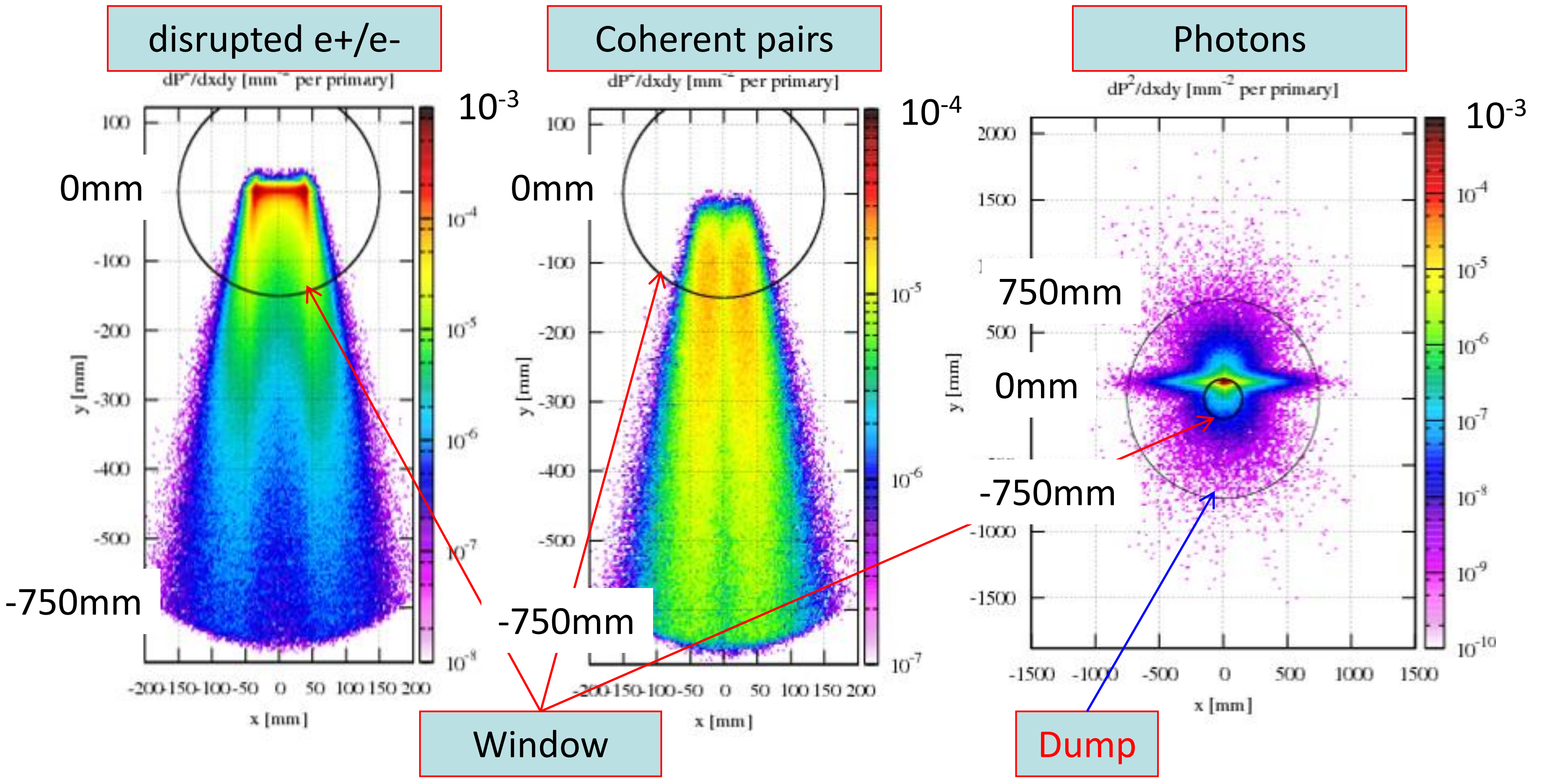


A. Ferrari et al



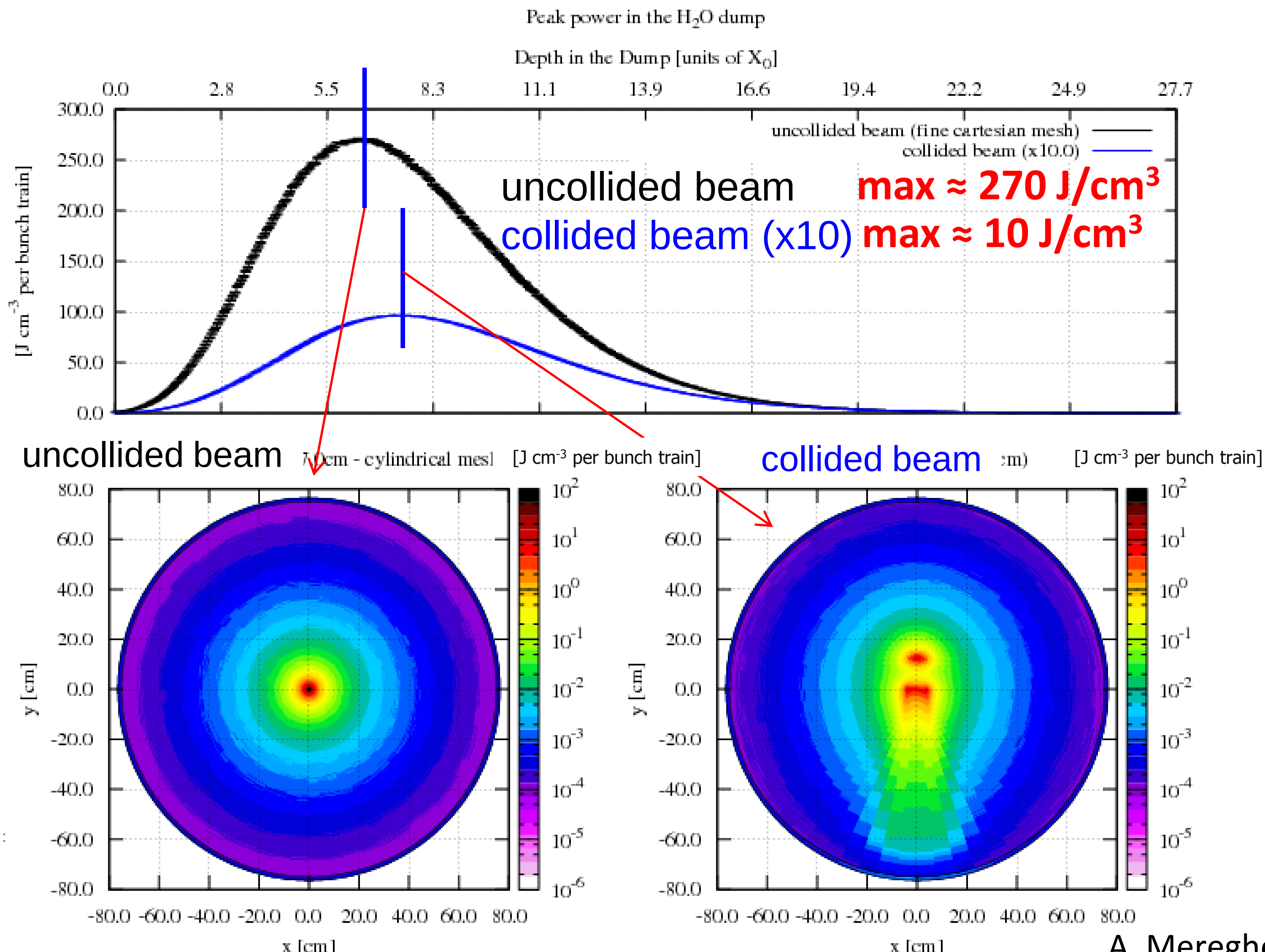
A. Apyan, EN-MEF

Particle Distribution at Entrance Window



A. Mereghetti, EN-STI

Energy Deposition in Main Dump



A. Mereghetti, EN-STI

Main Dump Issues

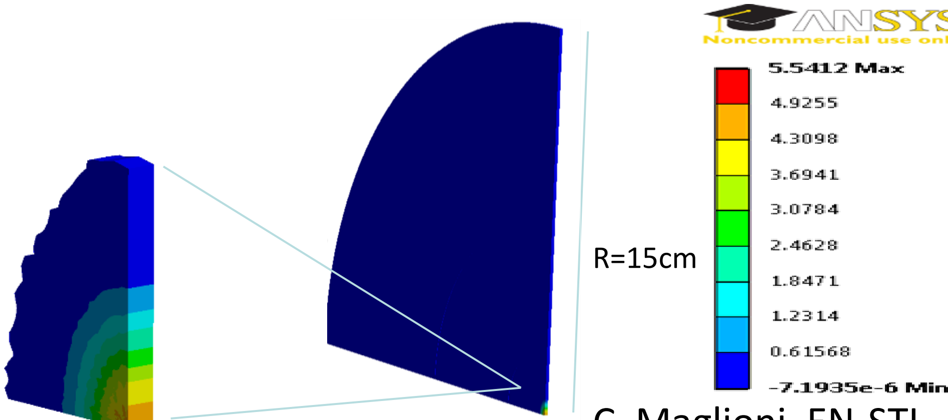
- Maximum energy deposition per bunch train: 270 J/cm^3
  → ILC: 240 J/cm^3 for a 6 cm beam sweep
- Remove heat deposited in the dump
  - Minimum water flow of 25-30 litre/s with v=1.5m/s
- Almost instantaneous heat deposition generate a dynamic pressure wave inside the bath!
  - Cause overstress on dump wall and window (to be added to 10bar hydrostatic pressure).

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

→ Calculations ongoing

Energy Deposition in Beam Window

→ Total deposited Power: **~6.2W**



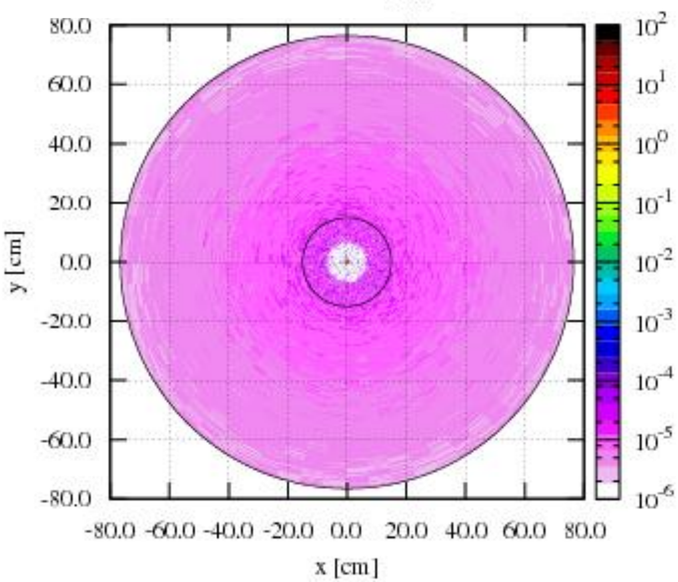
C. Maglioni, EN-STI

Ti-window, 1mm thick, 30cm diameter

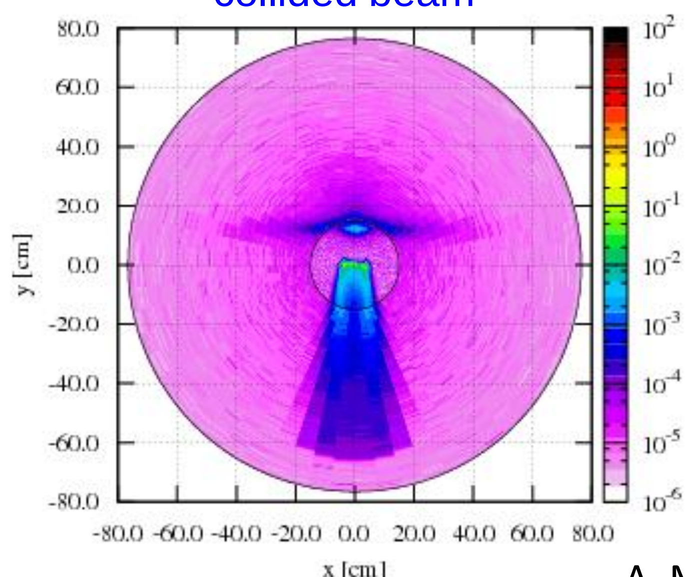
uncollided beam max ≈ 5.7 J/cm^3

collided beam max ≈ 0.13 J/cm^3

uncollided beam



collided beam



A. Mereghetti, EN-STI

Main Dump Window Considerations

- Maximum energy deposition per bunch train: 5.7 J/cm^3
  → **ILC: max total power of ~25 W with 21 J/cm^3**
- 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 for Temperature behavior, and vessel performance

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

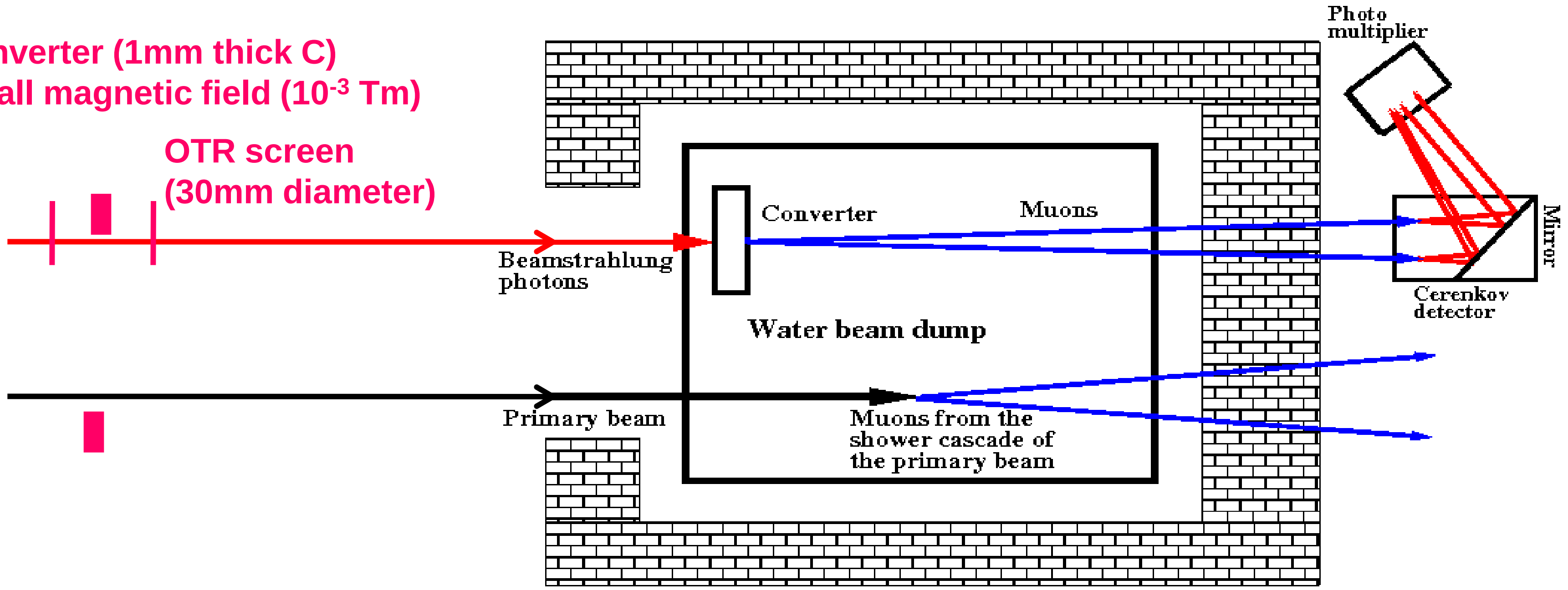
V.Ziemann – Eurotev-2008-016

μ+μ- pair production

Converter in main dump → muons → install detector behind dump

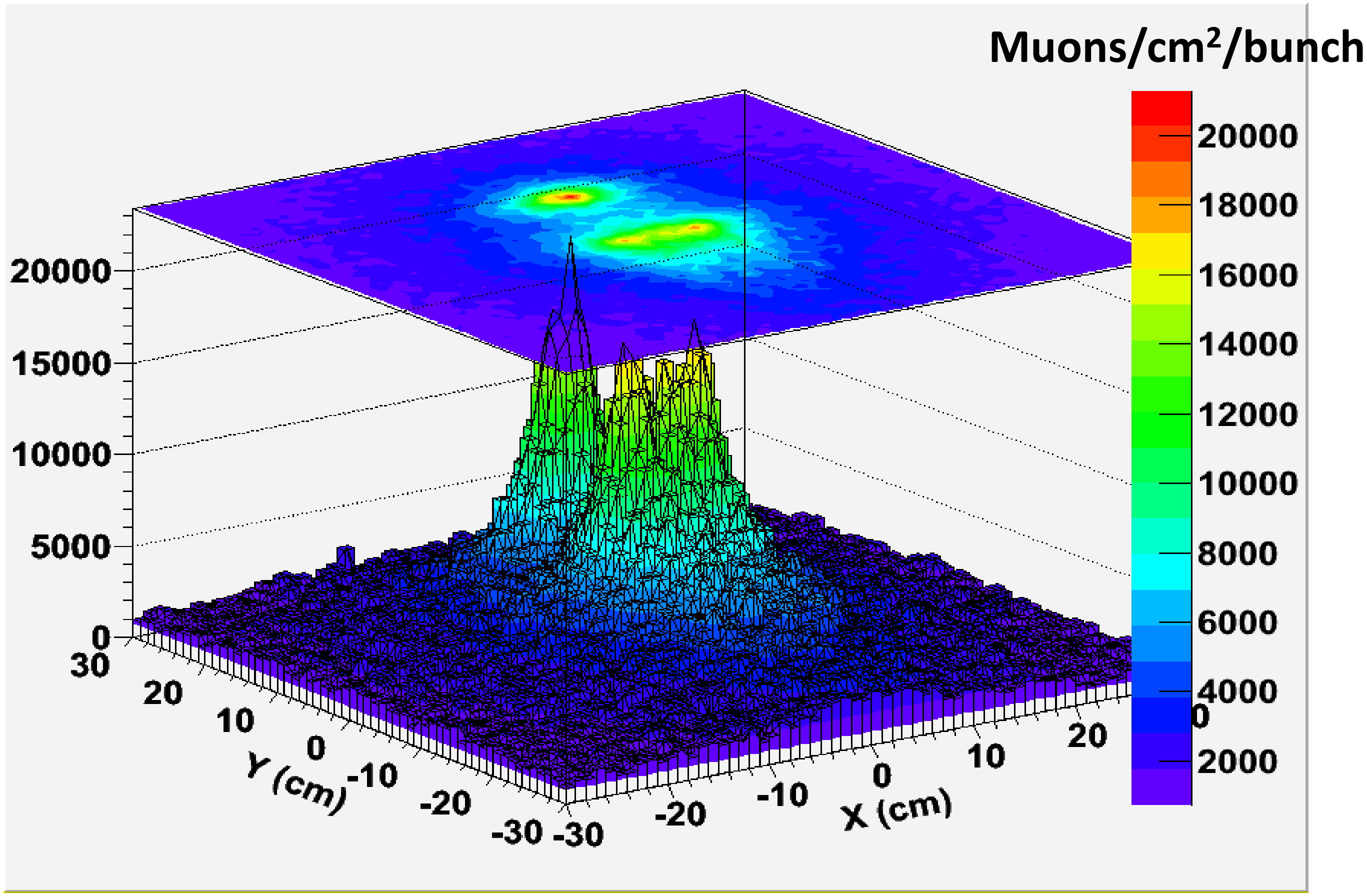
- With a Cherenkov detector: 2 E5 Cherenkov photons/bunch

Converter (1mm thick C)
Small magnetic field (10^{-3} Tm)



First Results

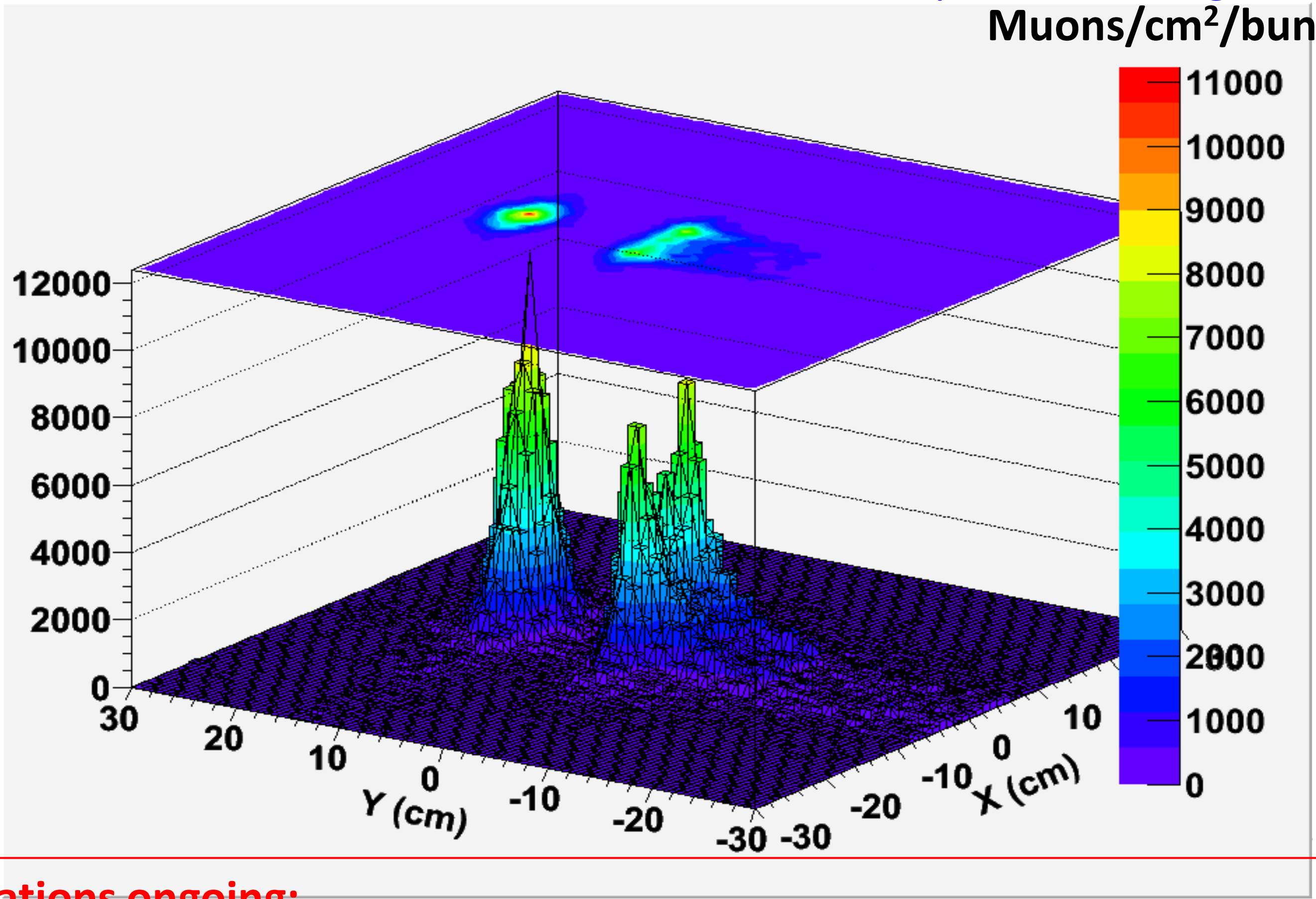
Muon distribution with **E> 212MeV** behind the beam dump and shielding



A. Apyan, EN-MEF

First Results

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



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

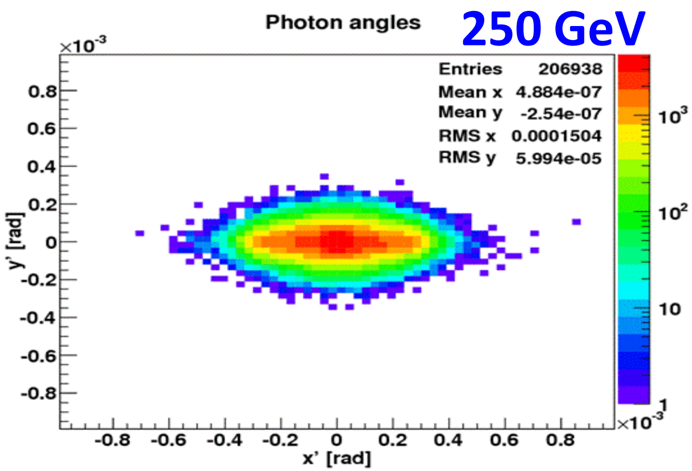
Summary

- 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

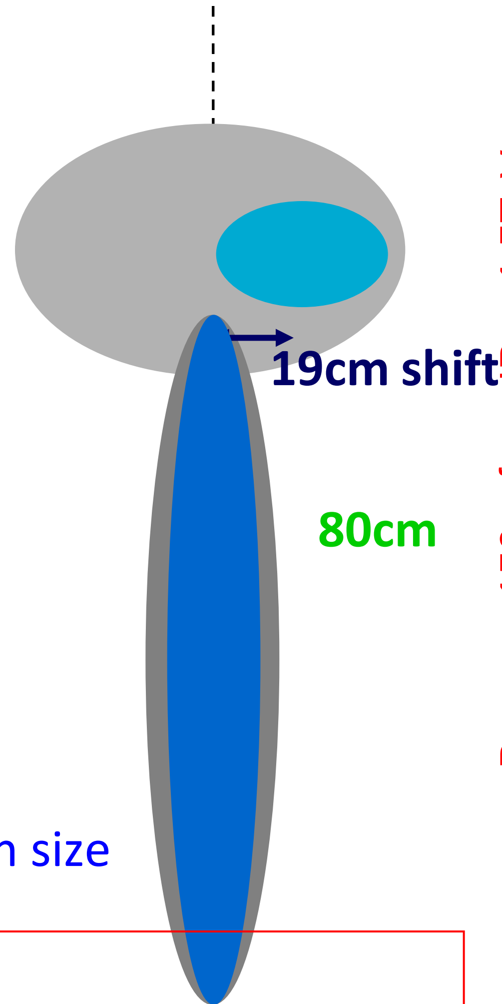
- Additional Slides

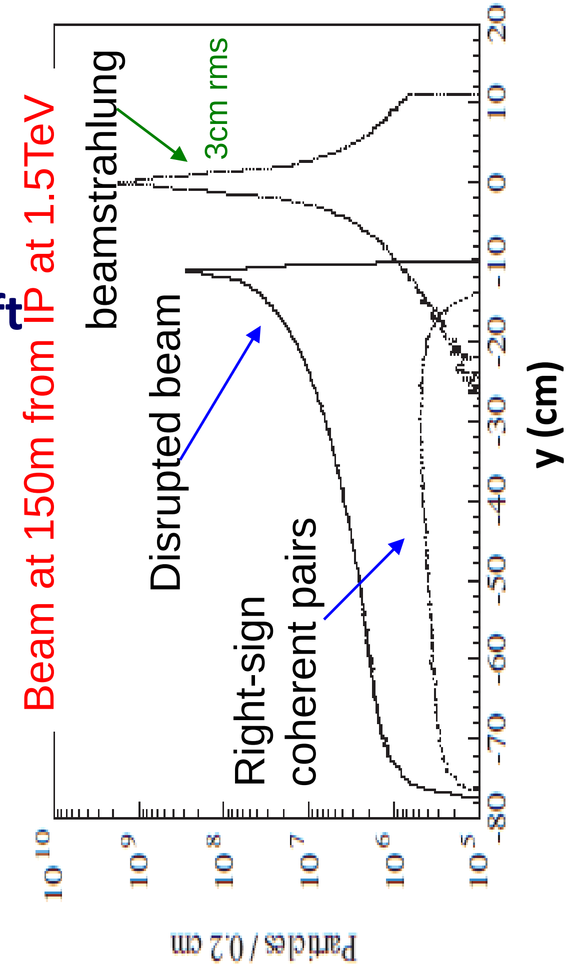
500 GeV c.m. /18.6mrad Option versus 3000 GeV c.m. / 20mrad Option



x'_{max} = ±0.6mrad

y'_{max} = ±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 of Energy Deposition in Main Dump

	max [J cm-3 per bunch train]		tot [W]	
	un-collided	**collided**	**un-collided**	**collided**
H2O	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