FCC-hh Beam Dump System (FBDS)

Group 4

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Outline

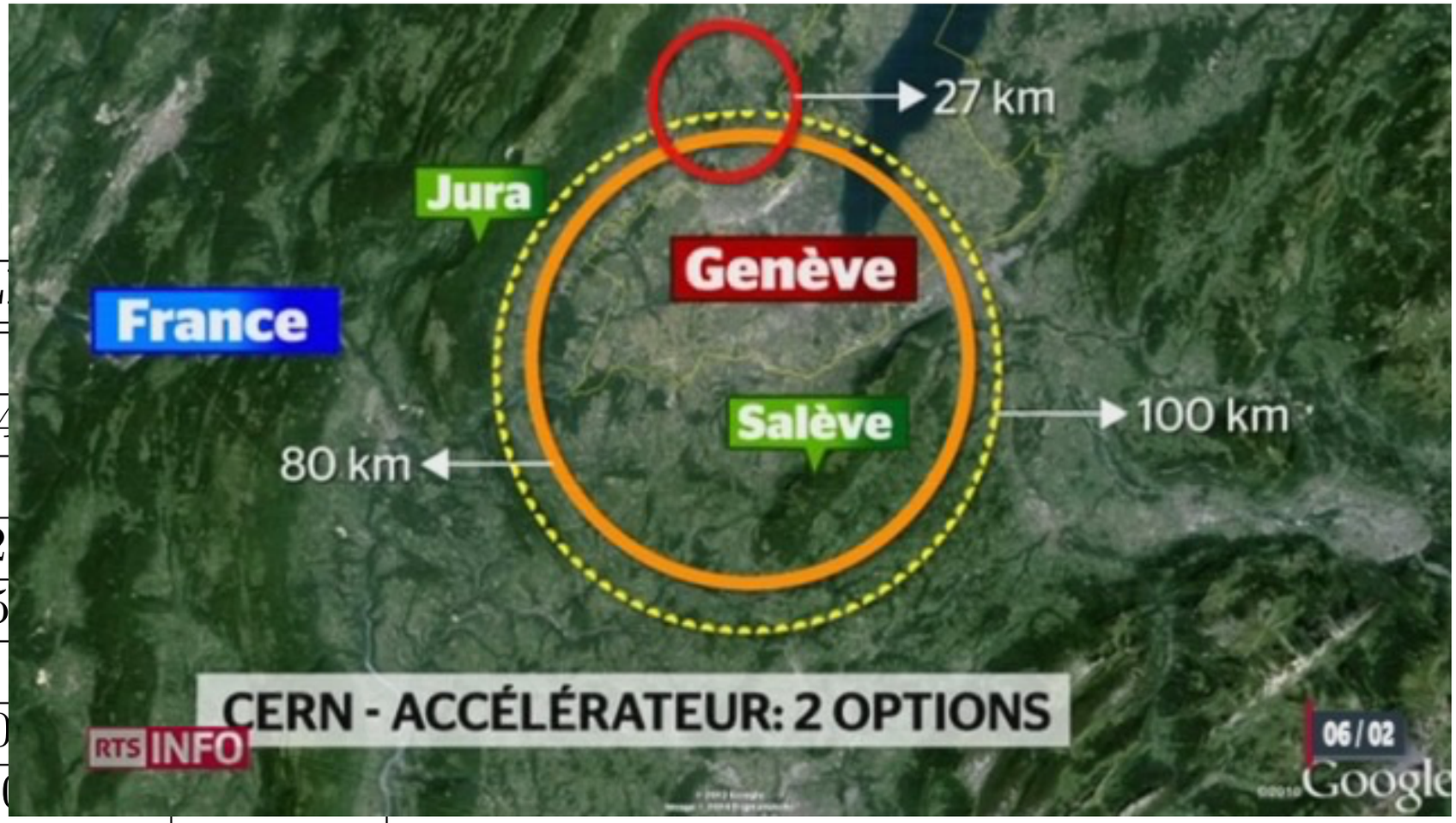
- Introduction
- LHC Beam Dump System
- Design of FCC Beam Dump System
- Machine protection considerations
- Summary and open questions

Introduction

- **Design of FCC-hh beam dump system**

- **Key parameters:**

Quantity	Unit	L	
Circumference	km		
p_{inj}	GeV/c	4	
p_{top}	TeV/c		
$N_{bunches}$	#	2	
I	p/bunch	1.15	
Bunch spacing	ns		
E	GJ	0	
P_{SR}	MW	0.0	
Beam length	μs	85	264

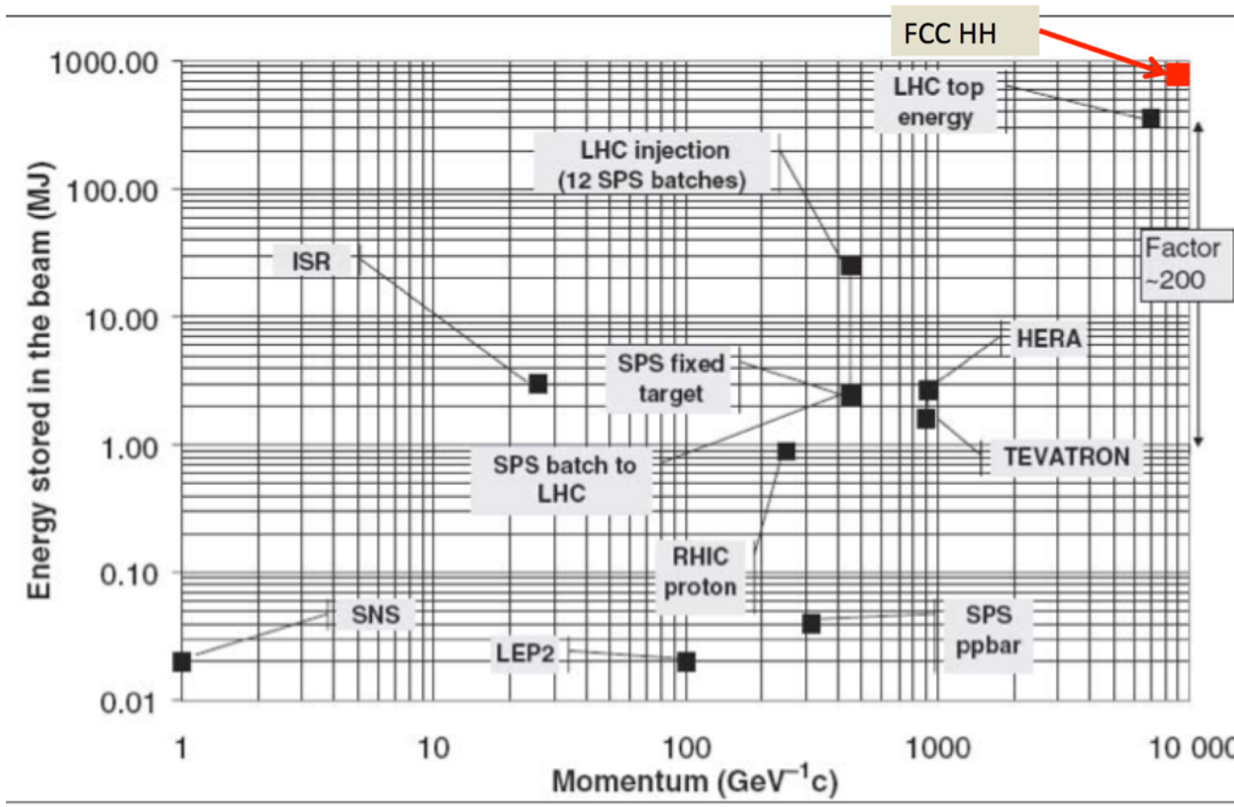


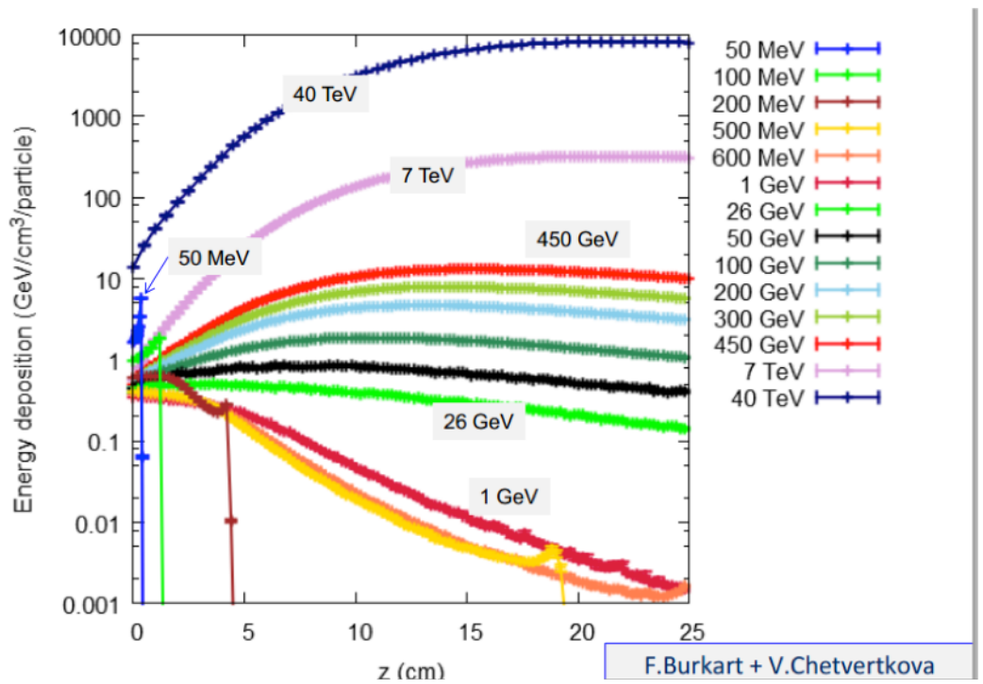
Introduction

- **Design of FCC-hh beam dump system**

- **Key parameters:**

Quantity	Unit	LHC	FCC
Circumference	km	27	100
p_{inj}	GeV/c	450	7000
p_{top}	TeV/c	7	50
$N_{bunches}$	#	2808	10600
I	p/bunch	1.15×10^{11}	1×10^{11}
Bunch spacing	ns	25	25
E	GJ	0.36	8.5
P_{SR}	MW	0.0036	2.4
Beam length	μs	85	264





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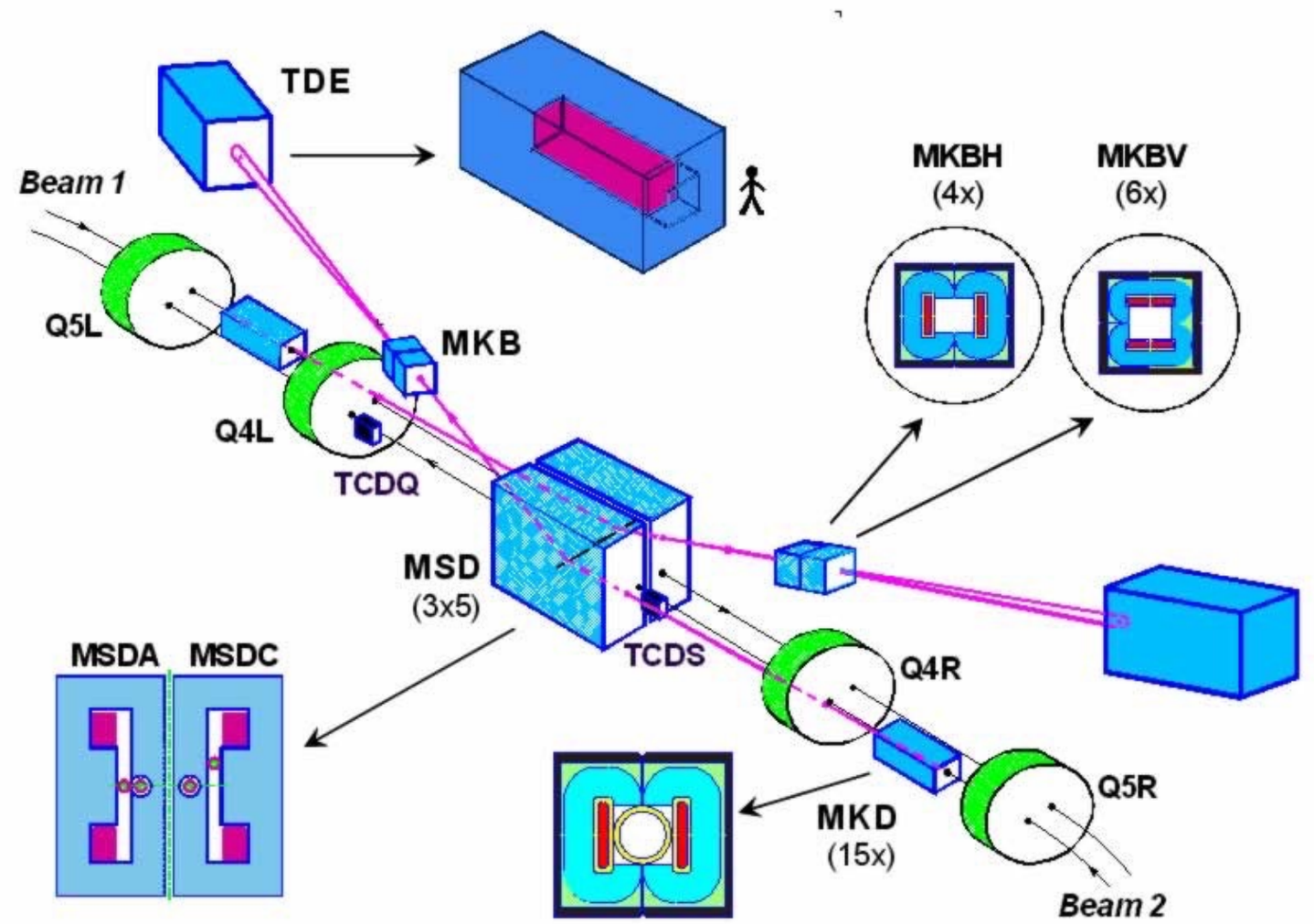
LHC Beam Dump System

- **Principle:** fast extraction from the rings (theoretically loss free) and dilution of the particle density before reaching the absorber block
- **Composed of:**
  - 15 horizontal kickers (MKDs)
  - 15 vertical septa (MSDs)
  - 10 sweepers
  - 1 Defocus quad (Q4)
  - Absorber block (~8 m)
  - 2 protection devices (before MSD and to protect the cold Q4)



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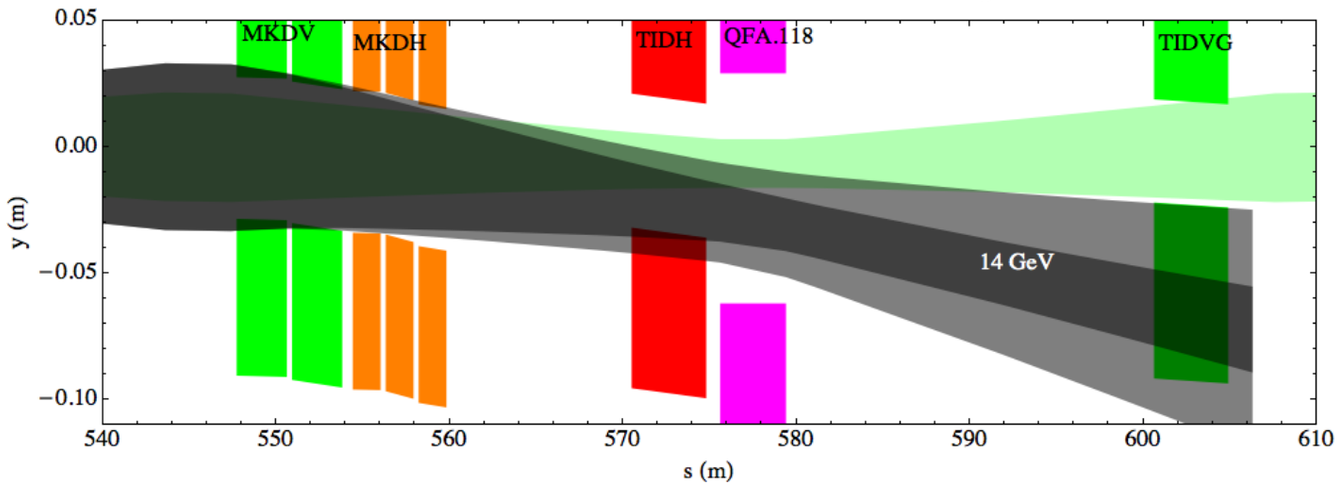
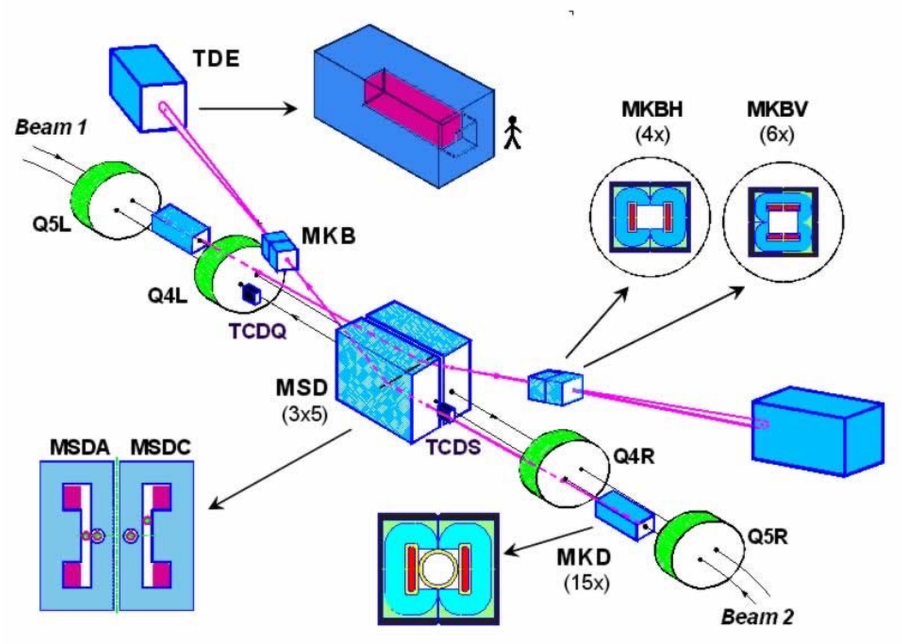
FBDS Design

- The idea is to use the same principle as the LHC Beam Dump System (LBDS):
  - An internal beam dump does not represent a solution for such high-energy machine (SPS, that has a much lower energy, suffers to have an internal beam dump)
  - The LBDS is a very reliable system

SPS Internal Dump System





Is one beam dumping system sufficient for each beam?

- **More than 1 Dump per Beam?**
- **Pros:**
  - Less intensity delivered at the absorber block
  - Shorter kicker flat top
- **Cons:**
  - Increases complexity – N times the number of elements
  - Two abort gaps (!!)
  - Fast kicker waveform fall time

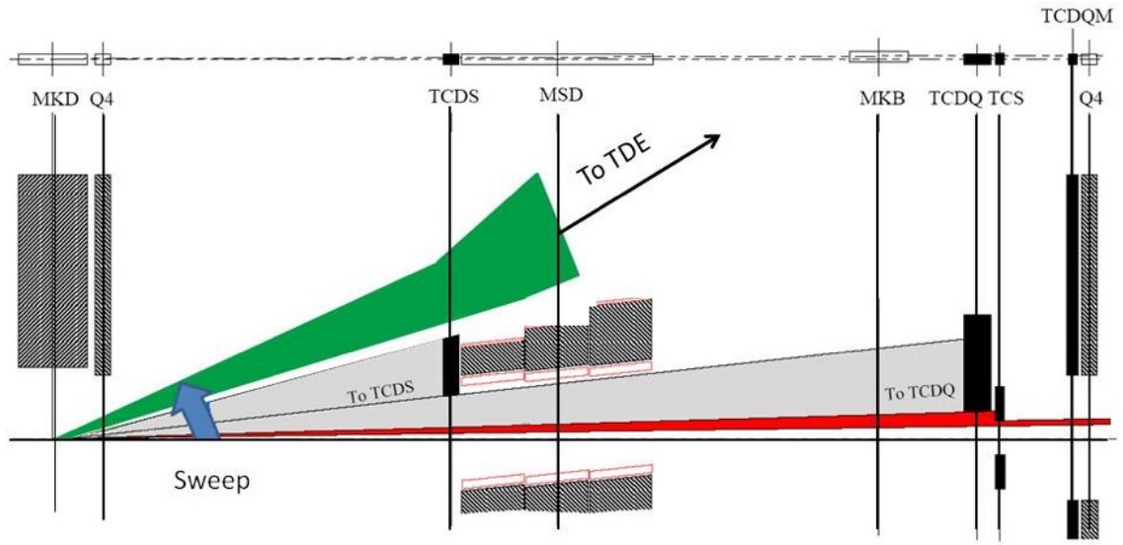
FBDS Design

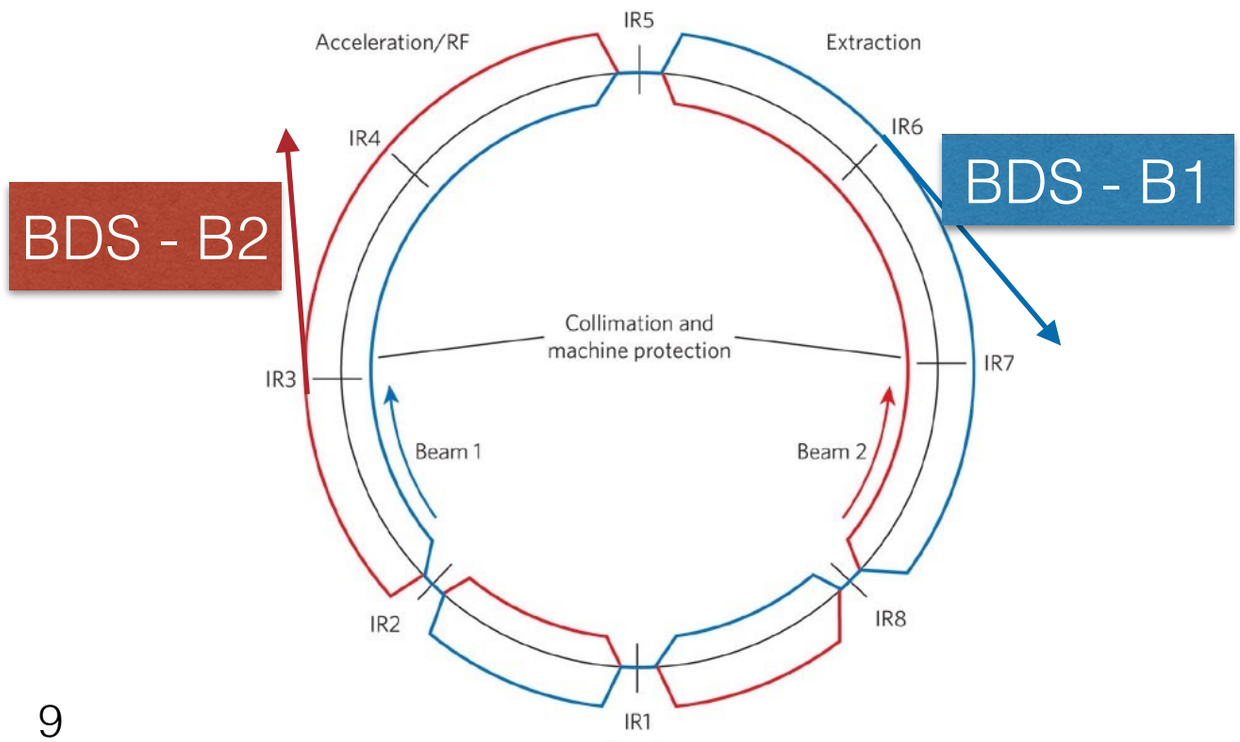
- **2 dump locations:** Beam 1 and Beam 2

- Extraction performed only on **one plane (x):**

  - Gain in kicker and septum strengths

  - Possible only if the two beams can be extracted from two different Long Straight Sections





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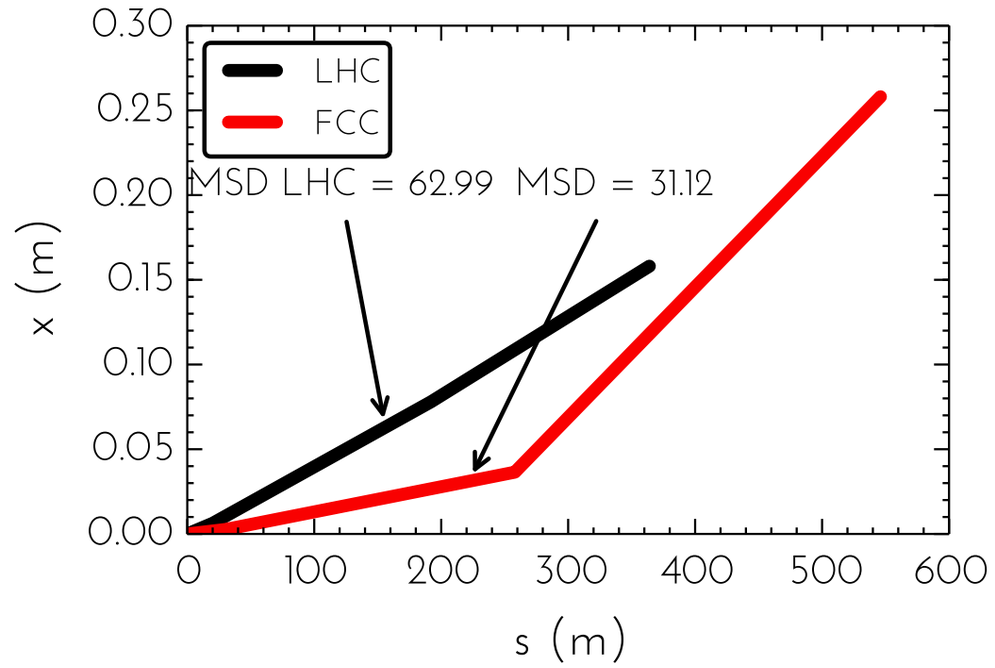
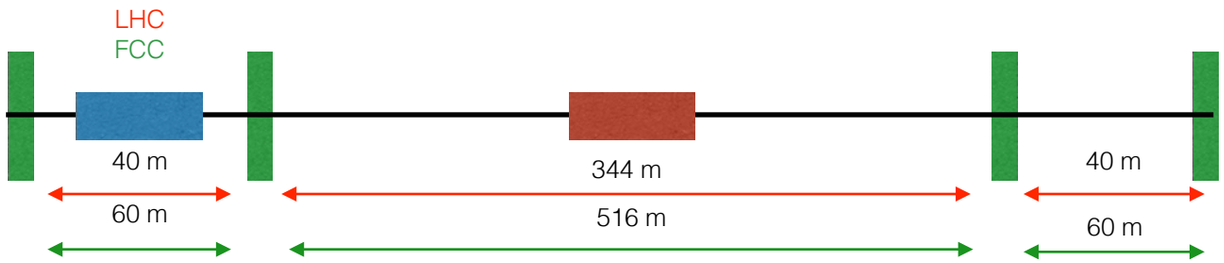
FBDS Design

- **17 MKD (LHC dump kickers) - like kickers:**
  - Same current and voltage required
  - Reduced gap (1/2 to have some margins)
  - Rise time: ~10 μs (as assumed abort gap)
  - Flat top: ~300 μs
- **15 MSD (LHC dump septa) - like septa:**
  - Horizontal deflection
  - B = 0.94 T (LHC = 0.84 T but vertical!!)
- **Reduced mechanical apertures in the extraction channel:**
  - Septum girder can be set closer to the circulating beam
  - Scales with $\propto \sqrt{\gamma_{LHC}/\gamma_{FCC}}$

$$B = \frac{\mu_0 I}{g} \qquad \theta = \frac{\int Bdl}{B\rho} \qquad \frac{(B\rho)_{7TeV}}{(B\rho)_{50TeV}} \sim 1/7$$

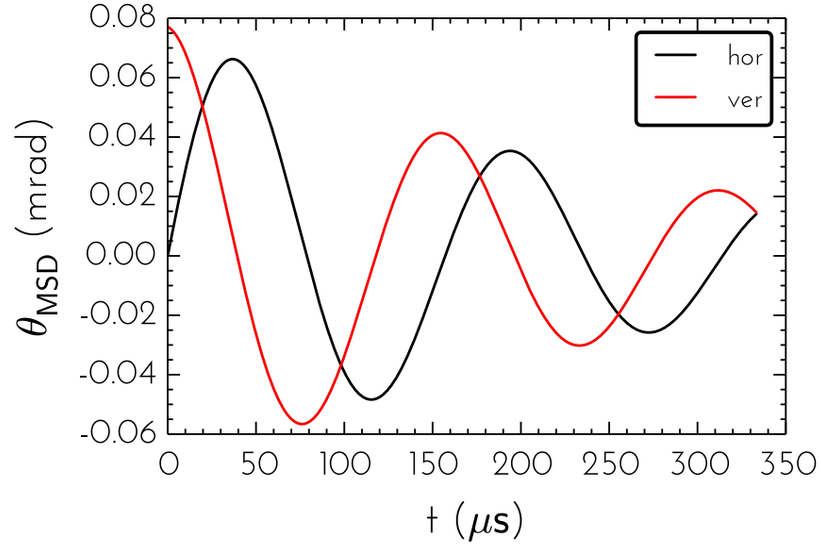


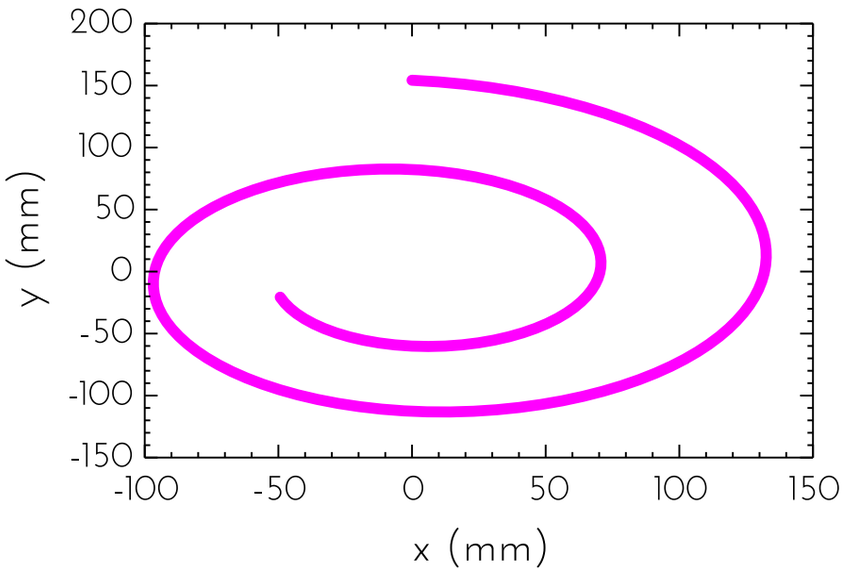


$$L_{FCC} = L_{LHC} * 1.5$$

FBDS Design

- **10 MKBs (LHC diluter kickers) - like:**
  - θ = 0.08 mrad (0.27 mrad for LHC)
  - f = 40 kHz
  - gap half of MKBs
  - Synchronised with the beam passage
- **Protection devices (passive):**
  - Septum blade protection
  - TCDQ-like to protect the cold Q4 (already 6 m, so it might be needed to have it sacrificial)
- **Absorber block:**
  - LHC dump is ~ 8 m long -> ~650 m long drift before
  - FCC should be ~16 m long (hadronic shower propagation length scales logarithmically with energy -> factor 2) -> ~2 km long drift
  - Low Z material at beginning of a sandwich structure
- **All active elements:**
  - Need to track the beam energy [7, 50] TeV





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What can fail?

- **Cannot fail: “It has to work!”**
- **Extraction Kicker Magnet**
  - 2 out of 17 kickers can have a failure
  - Energy tracking system
  - PFN elements (switch, misfire, etc.)
- **Septum Magnet**
  - Wrong field (PC error)
- **Dilution Magnets**
  - If all fail to pulse, the beam will damage (maybe destroy) the dump block
  - Failure of 1 of each type (H or V) should be considered as failure case in designing the absorber block
- **SC Quadrupole after kicker magnets**
  - Wrong field – 20% tolerance
- **Other**
  - Synchronisation error between kickers and abort gap
  - Too many particles in the abort gap
  - Unk Unks – of course!
- **If all else fails:**

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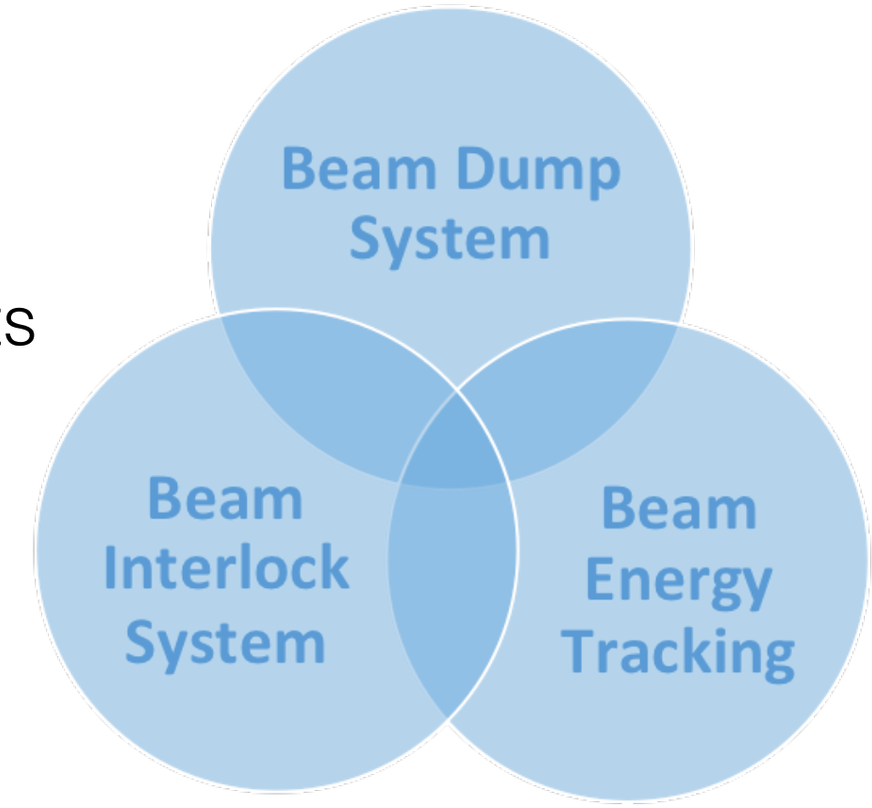
- **If all else fails:**

$$LHC \times \frac{\sqrt{\gamma_{50}}}{\sqrt{\gamma_7}}$$

Availability

- **High availability relies on:**
  - High quality components
  - Redundancy for the most critical elements
  - Redundant signal paths
  - Fault tolerant subsystems
  - Continuous surveillance
  - Validation tests before injecting beam in the LHC
  - Maintenance



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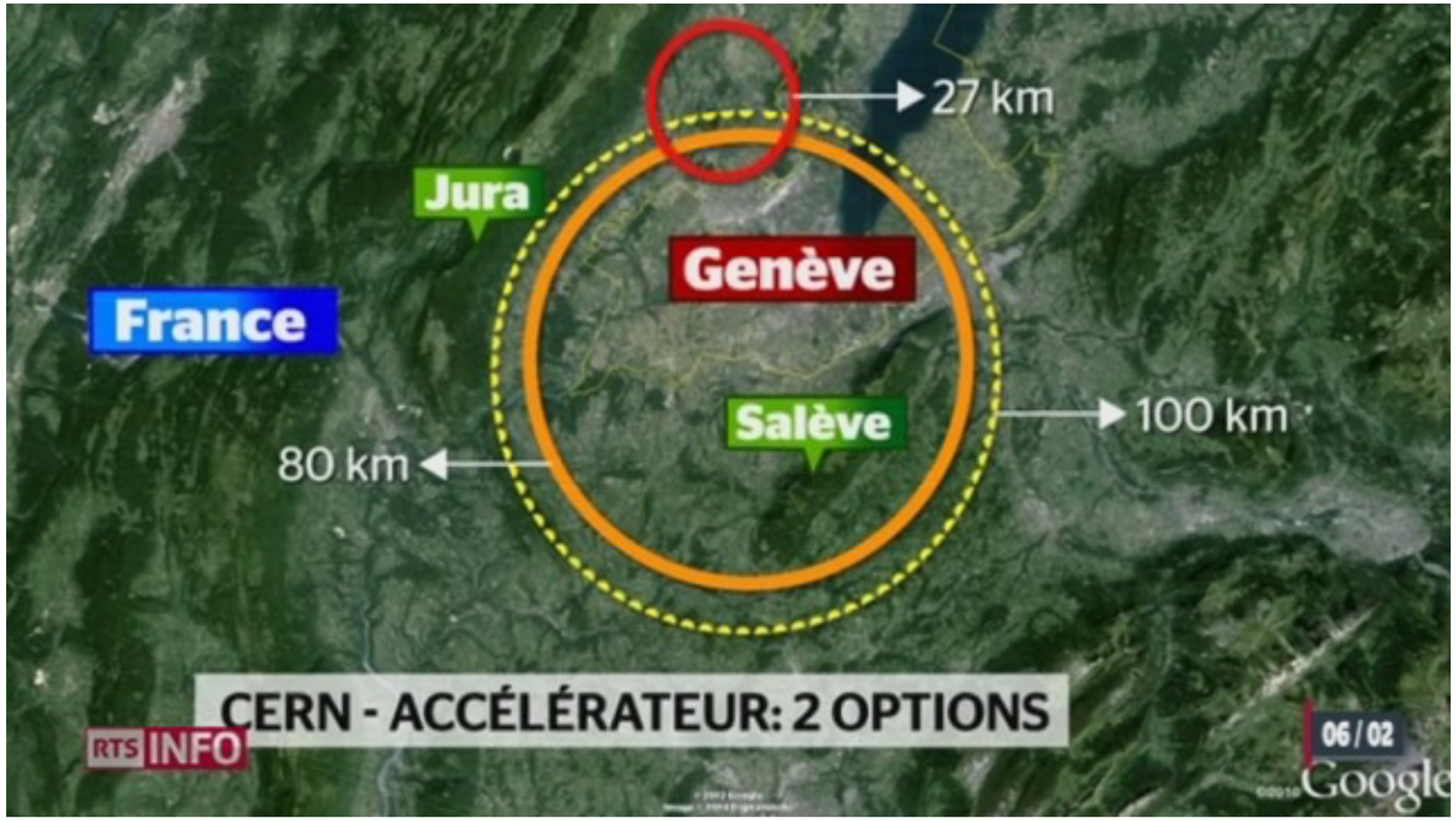
Summary

- A design for the FCC-hh beam dump system has been proposed
  - Only one beam dump per beam foreseen
- Lots of room for improvements:
  - Better dilution system
  - Careful design of the absorber block
  - …and many more

Questions

- **Does this design make sense?**
- How to test the kickers?
- Are there any hardware (circuitry) limitations?
- Will the propagation time of the beam interlock signal to the dump system be too long?
- Do we need a sacrificial passive protection devices? Modular design, easily replaceable?



THANKS A LOT FOR YOUR ATTENTION!!