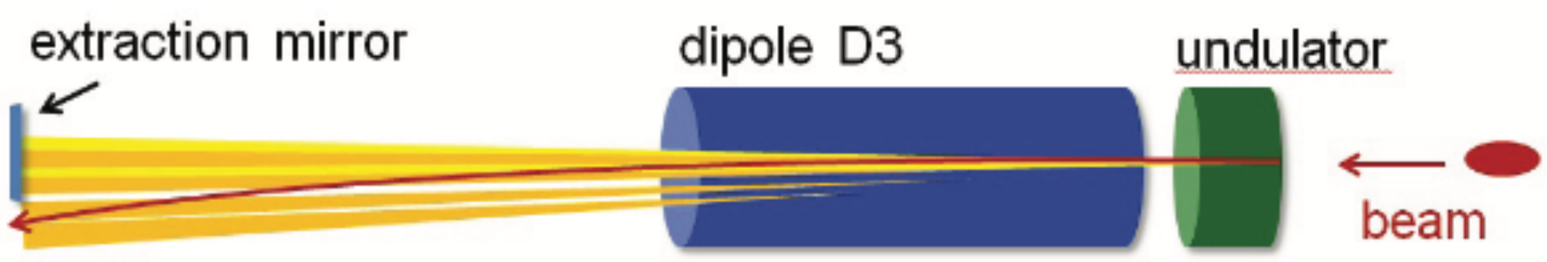
WP13: BSRT modifications for HL-LHC

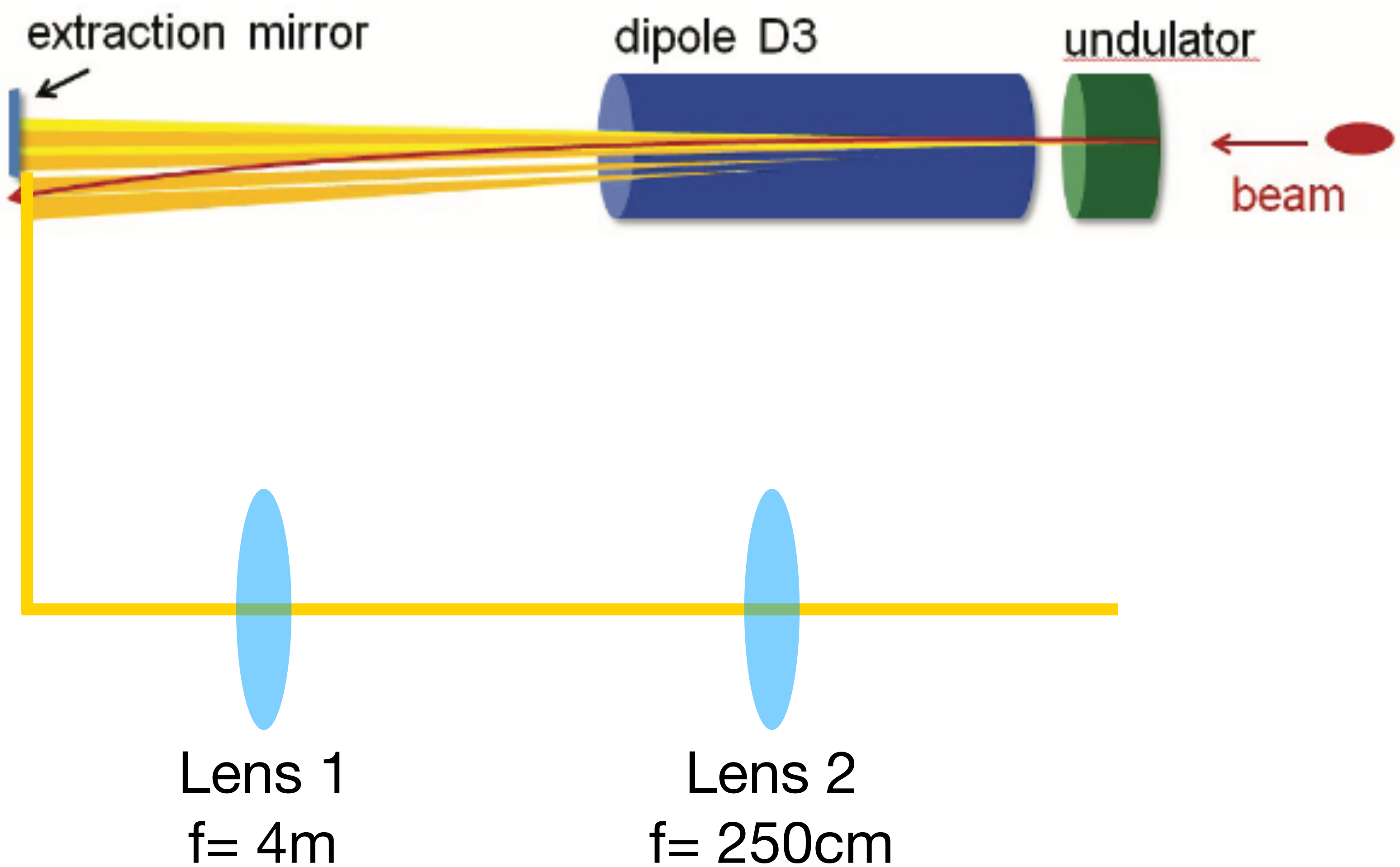
E. Bravin CERN BE-BI

Principle of the BSRT



- Synchrotron radiation is emitted by charged particles when the trajectory of the particles is deflected (ex. Inside bending magnets)
- Special magnets (undulators), which force an harmonic oscillation of the particles, can be used to stimulate the emission of synchrotron radiation
- In the LHC a short undulator is used at injection energy since the radiation from the bending dipole is not sufficient

Principle of the BSRT



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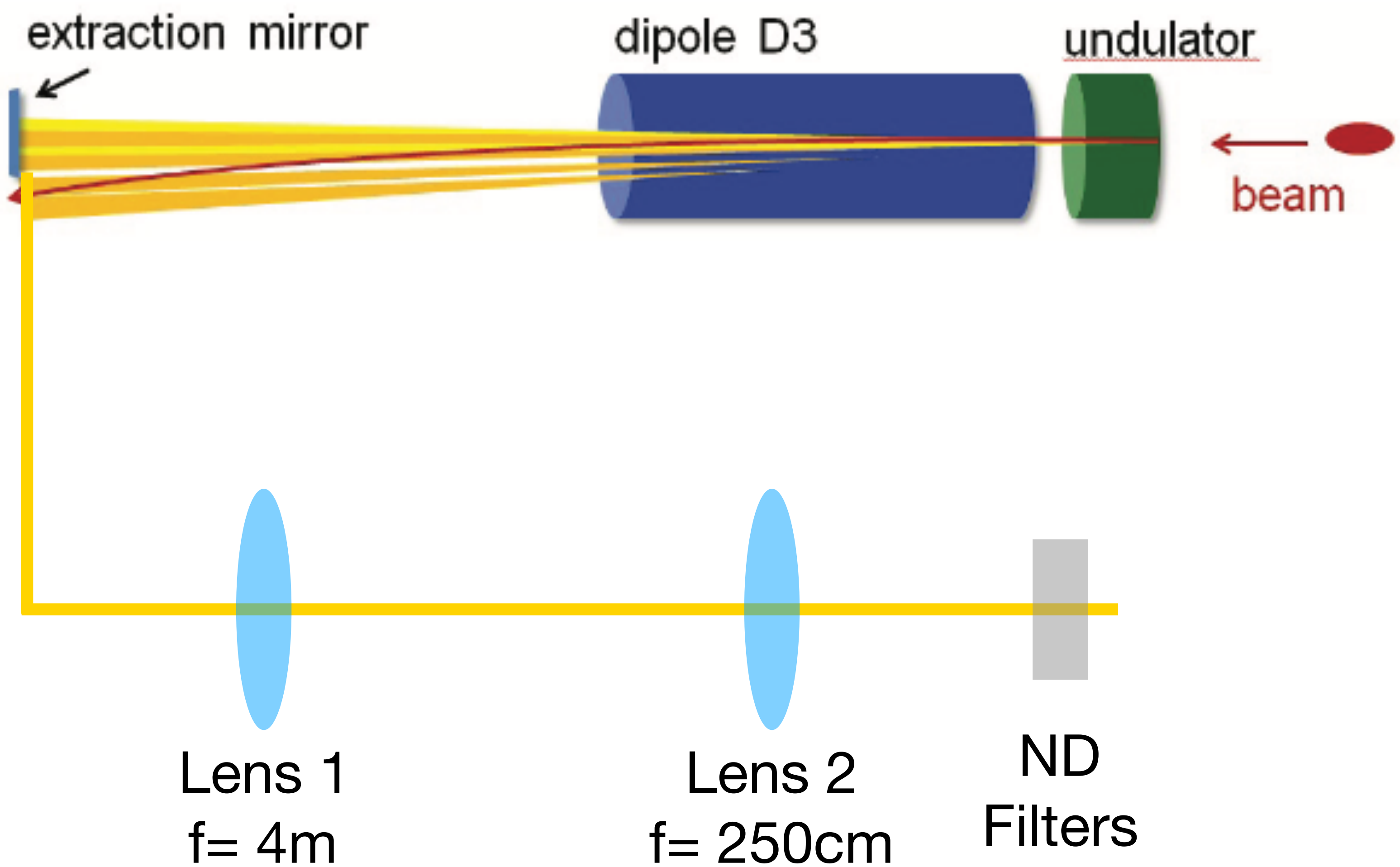

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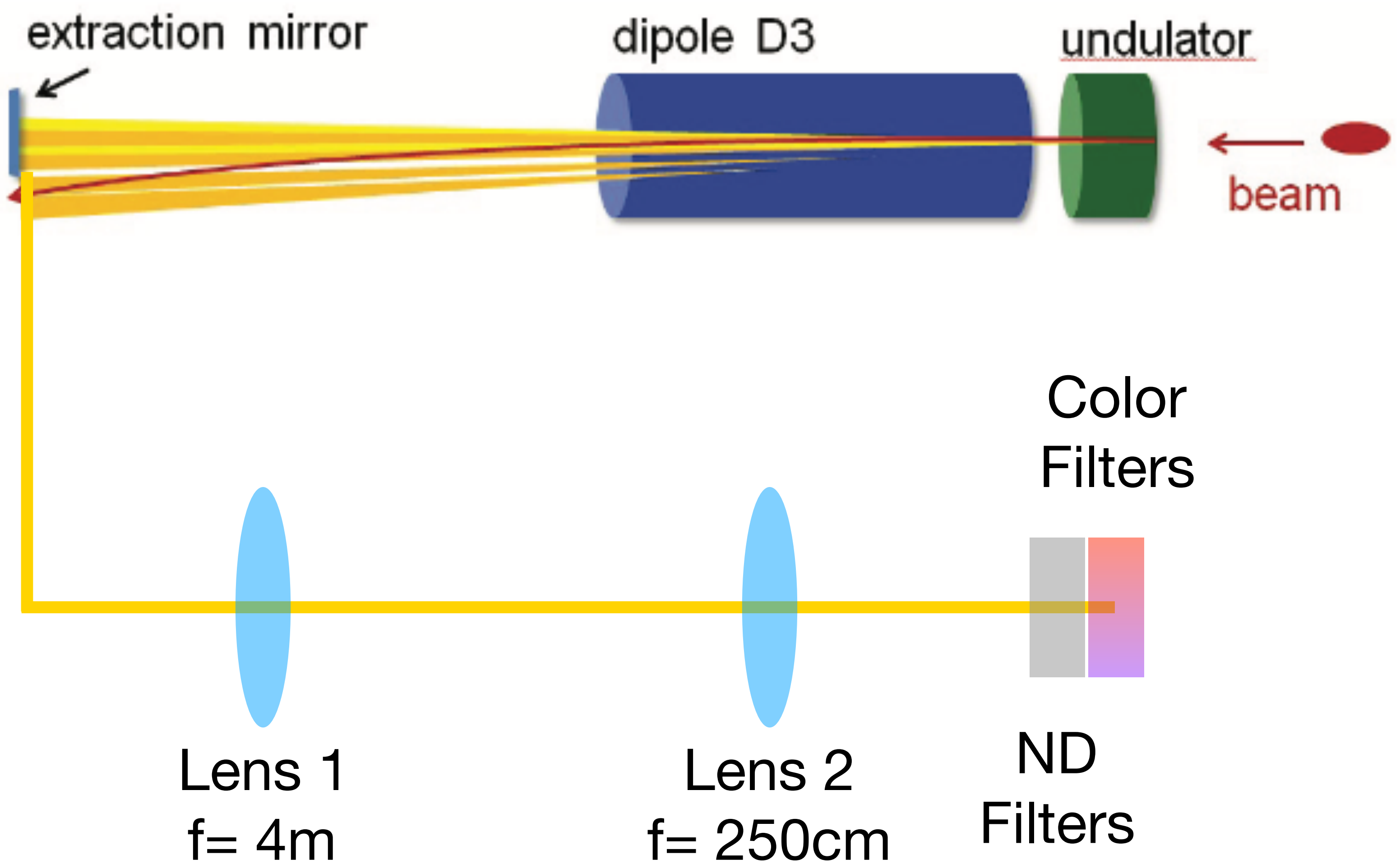

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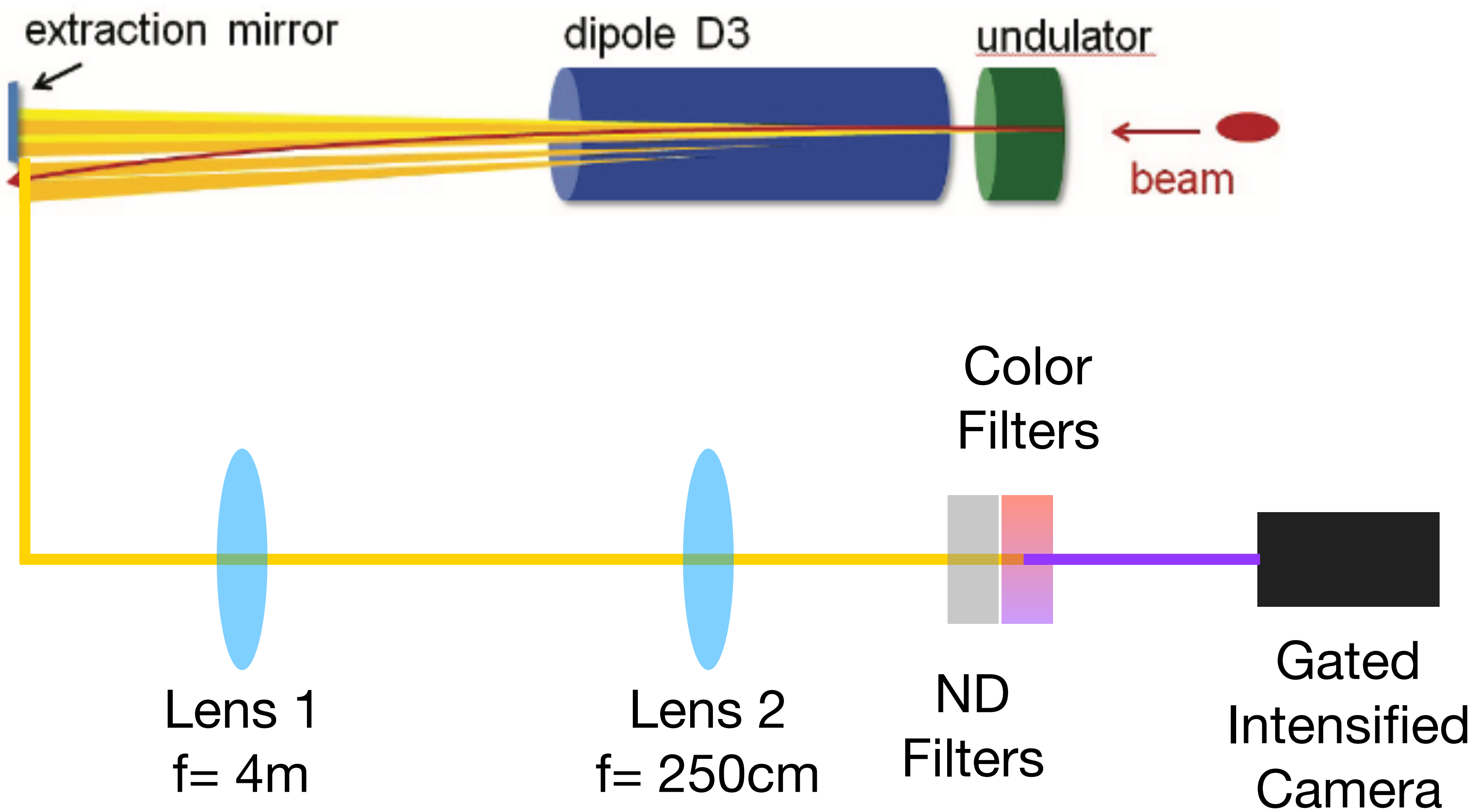

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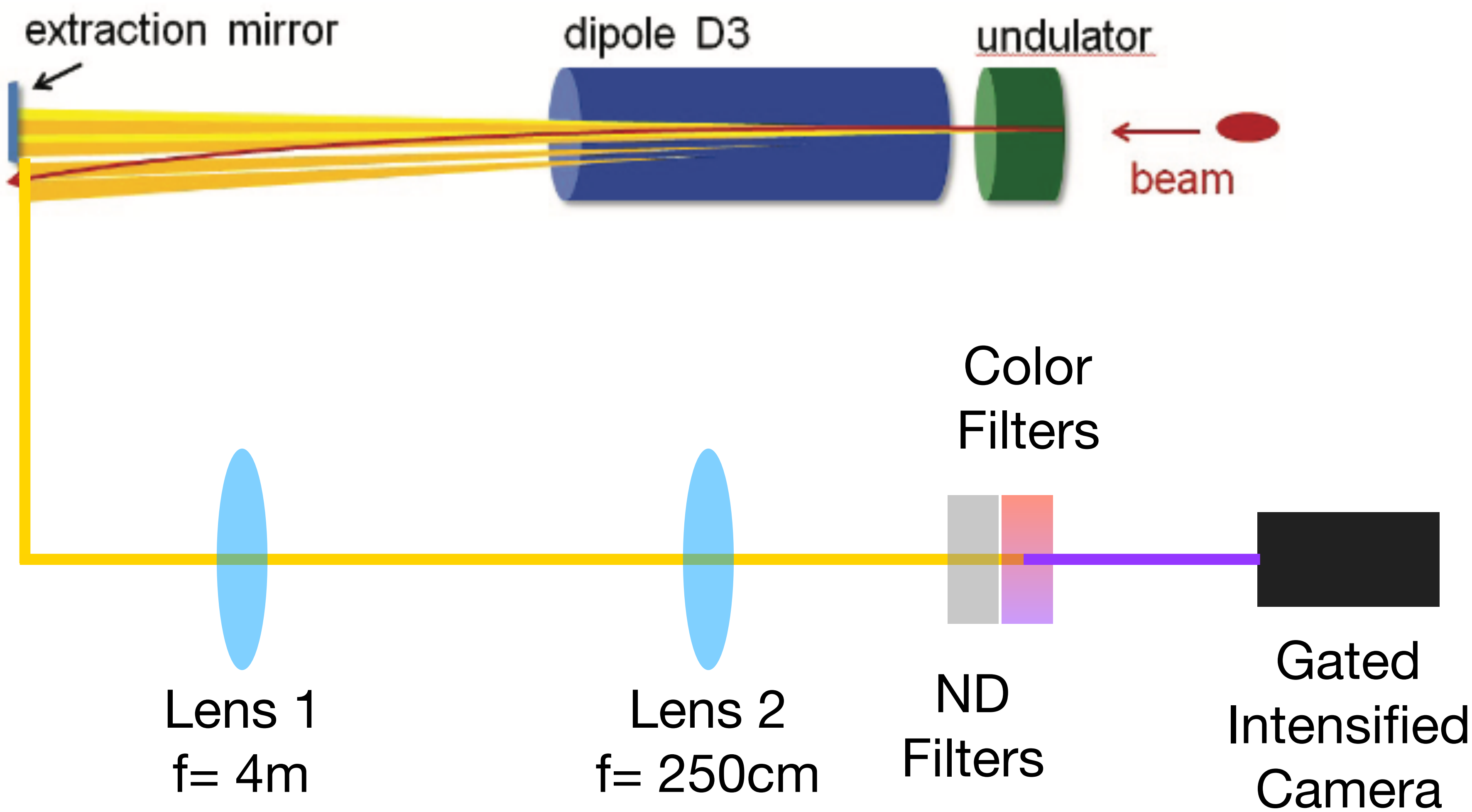

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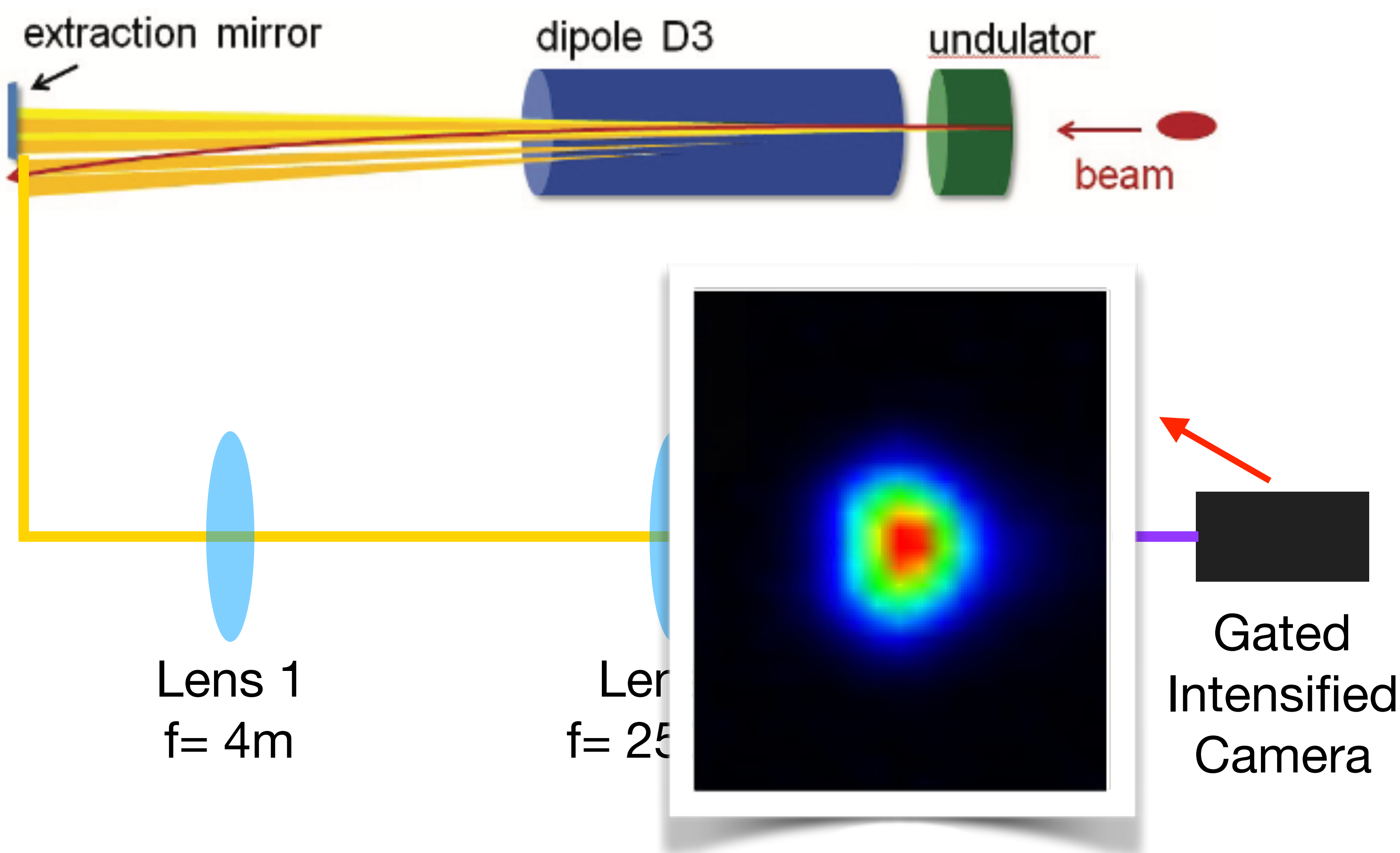

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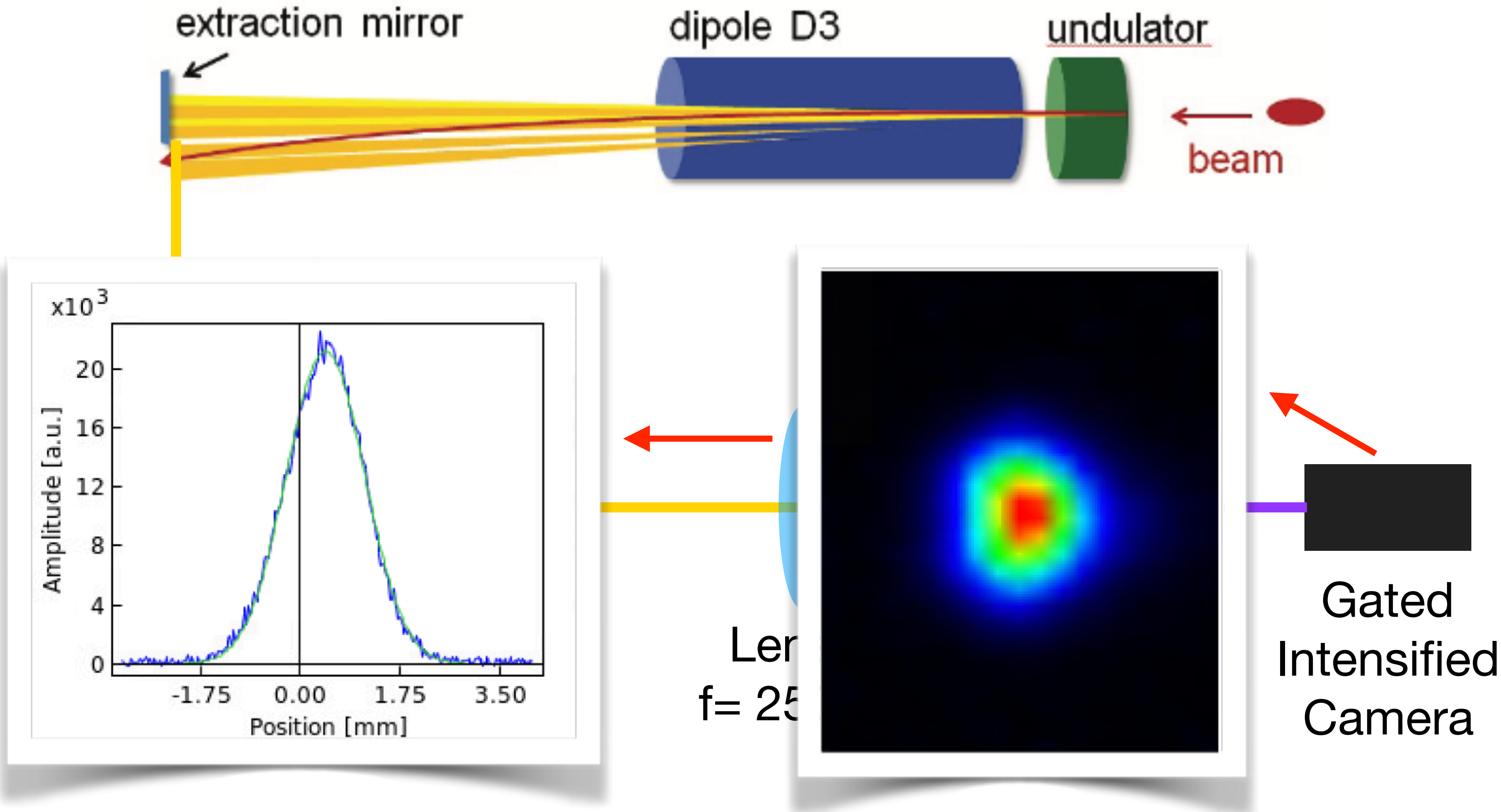

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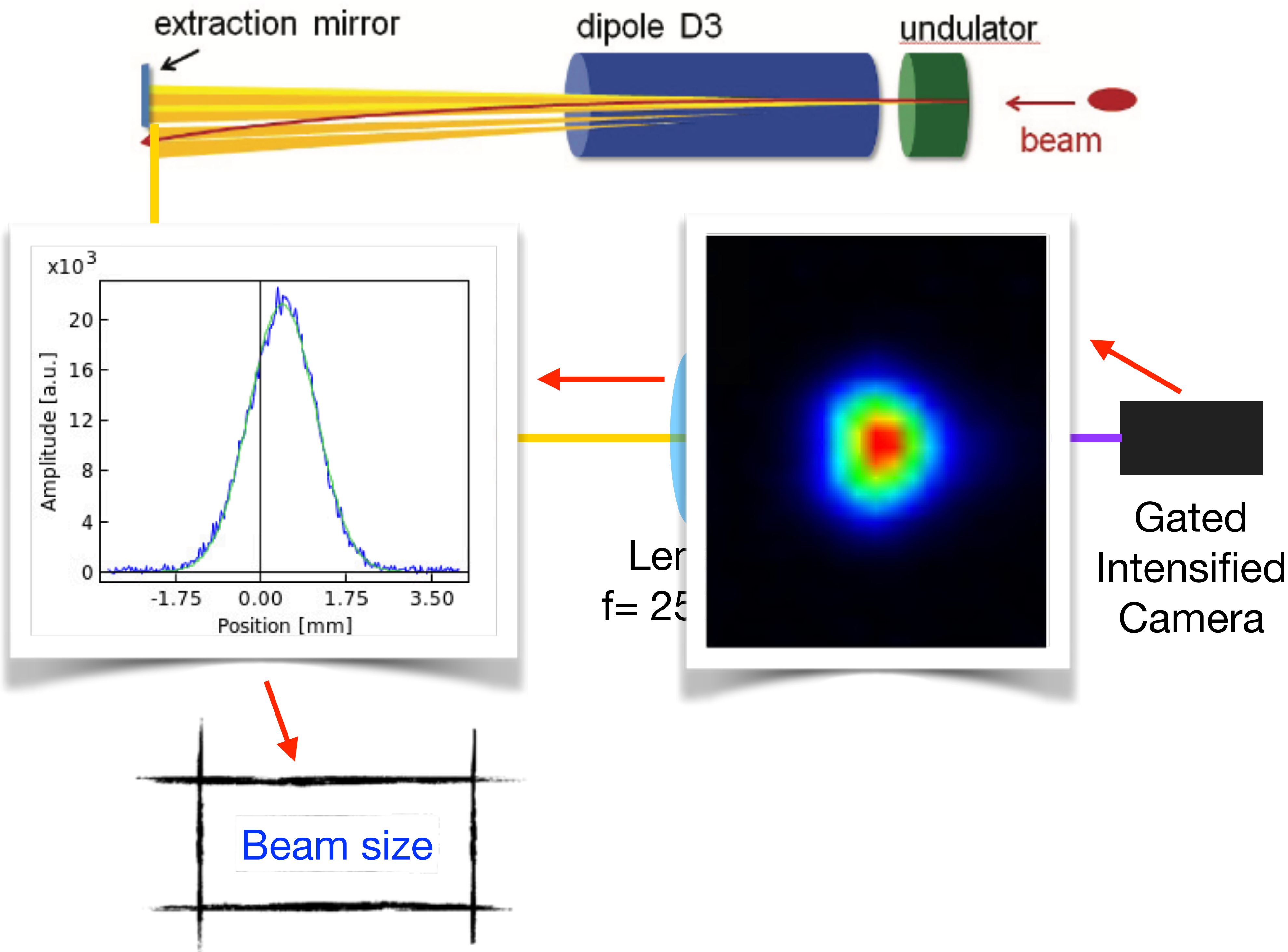

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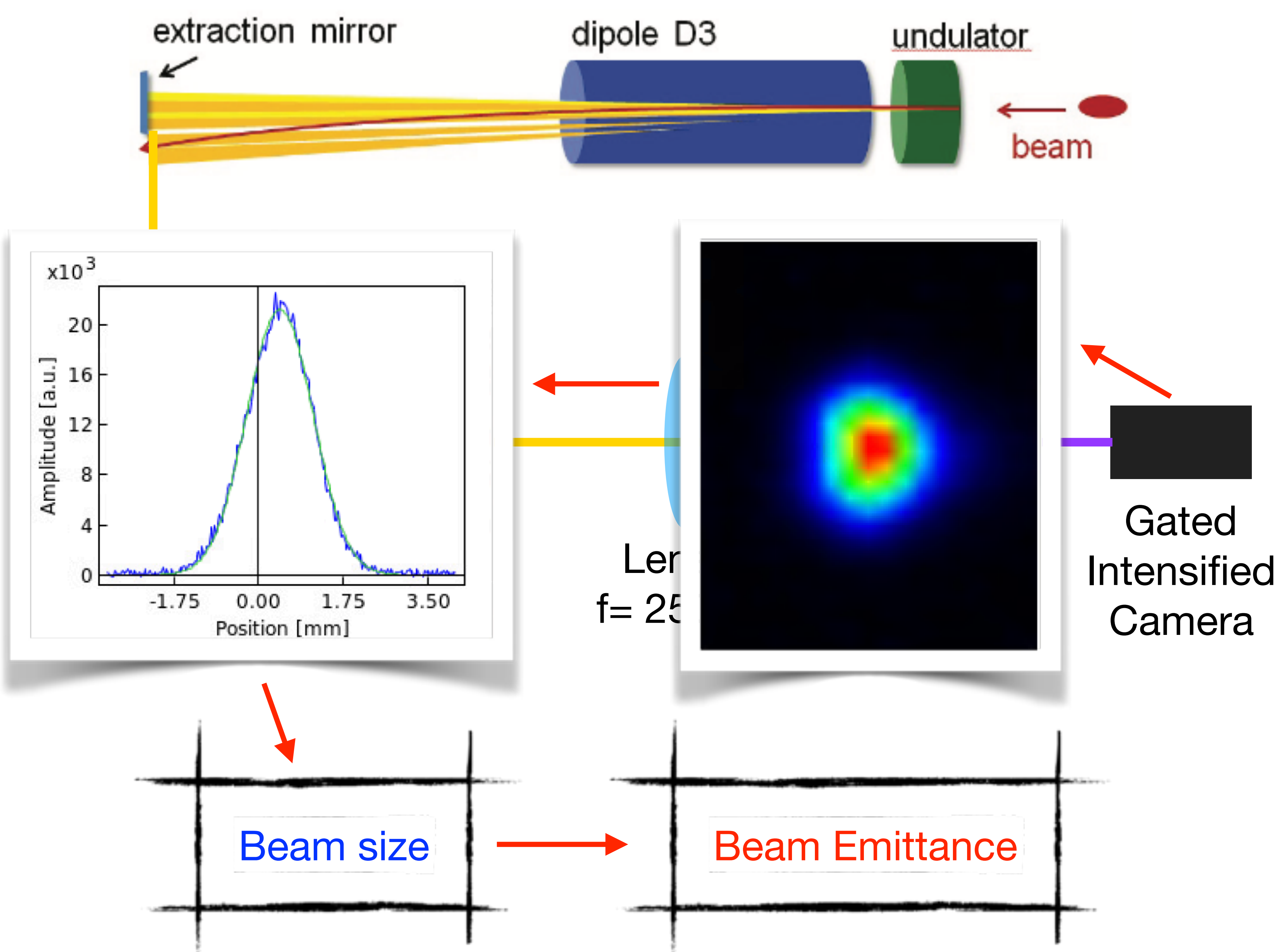
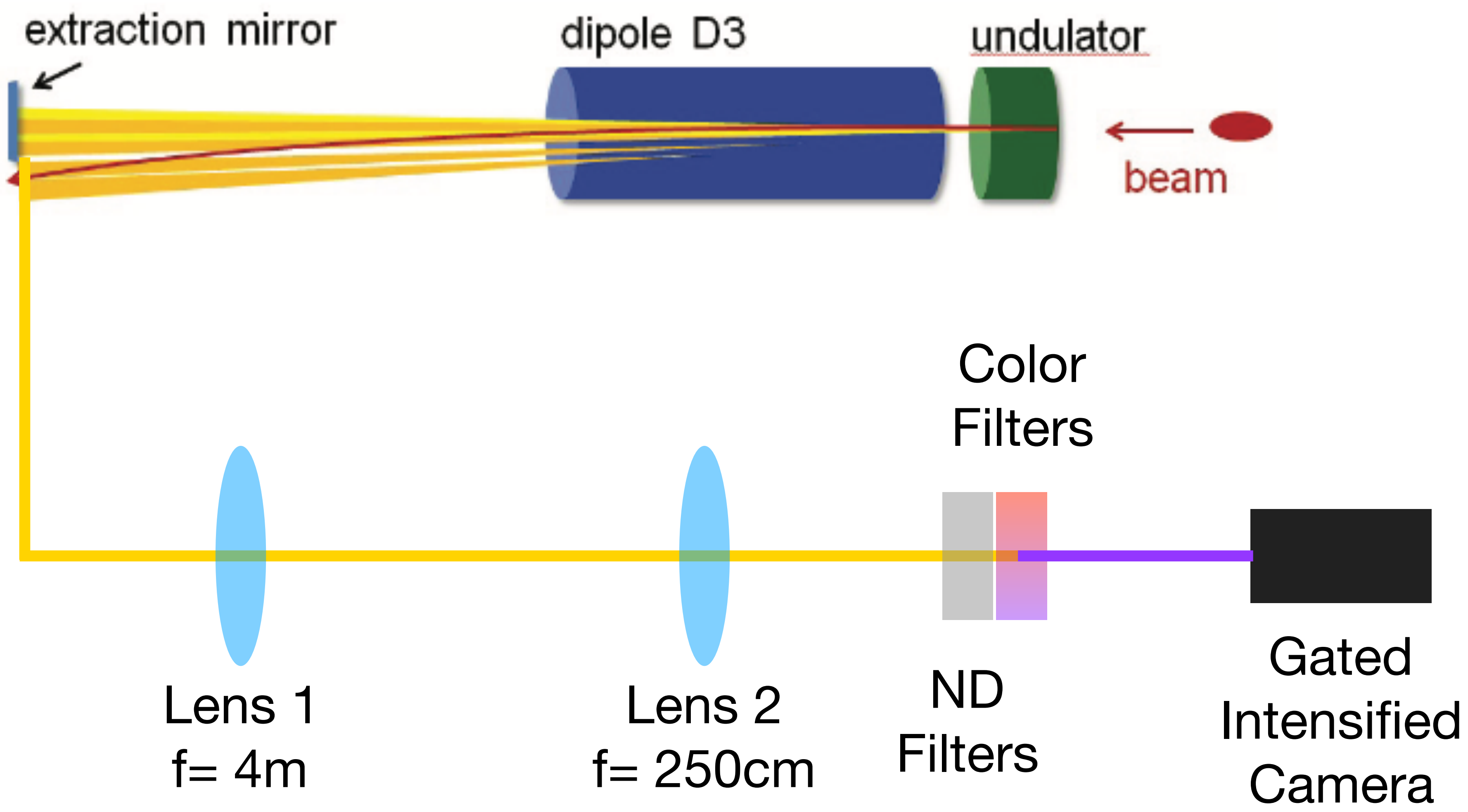


Present BSRT

- Beam 1 and Beam 2
  - BSRT: Refracting imaging telescope for online emittance measurement (limited by diffraction)
  - BSRA: Abort gap monitor
  - BSRL: Longitudinal density monitor (high dynamic range longitudinal profile with 50ps resolution)
- Beam 1
  - Double slit interferometer R&D (absolute beam size measurement not limited by diffraction)
  - Scanning slit with PMT (alternative to II+camera)
- Beam 2
  - Coronagraph for the measurement of the beam halo (HL-LHC R&D)

Principle of the BSRT



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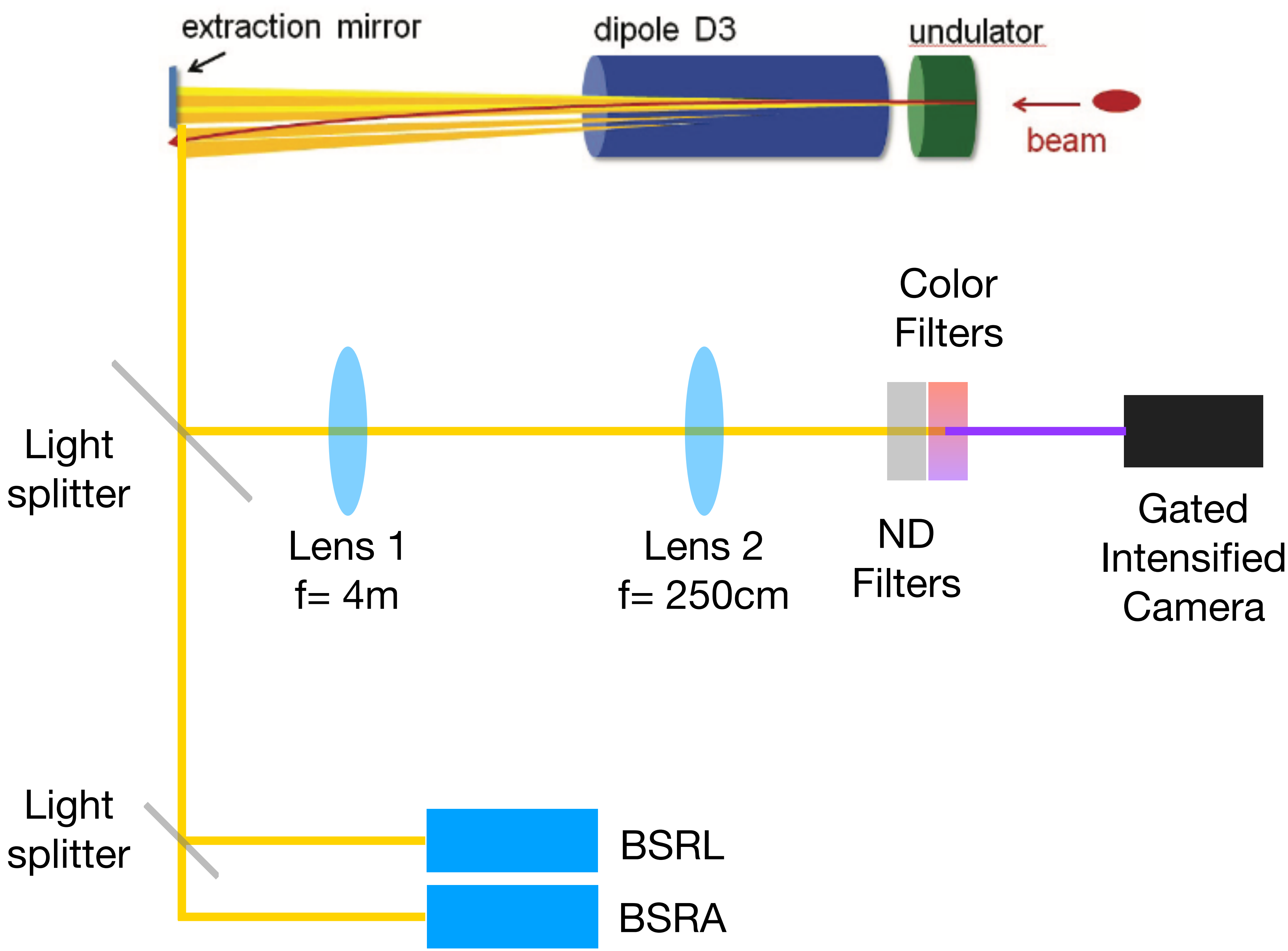

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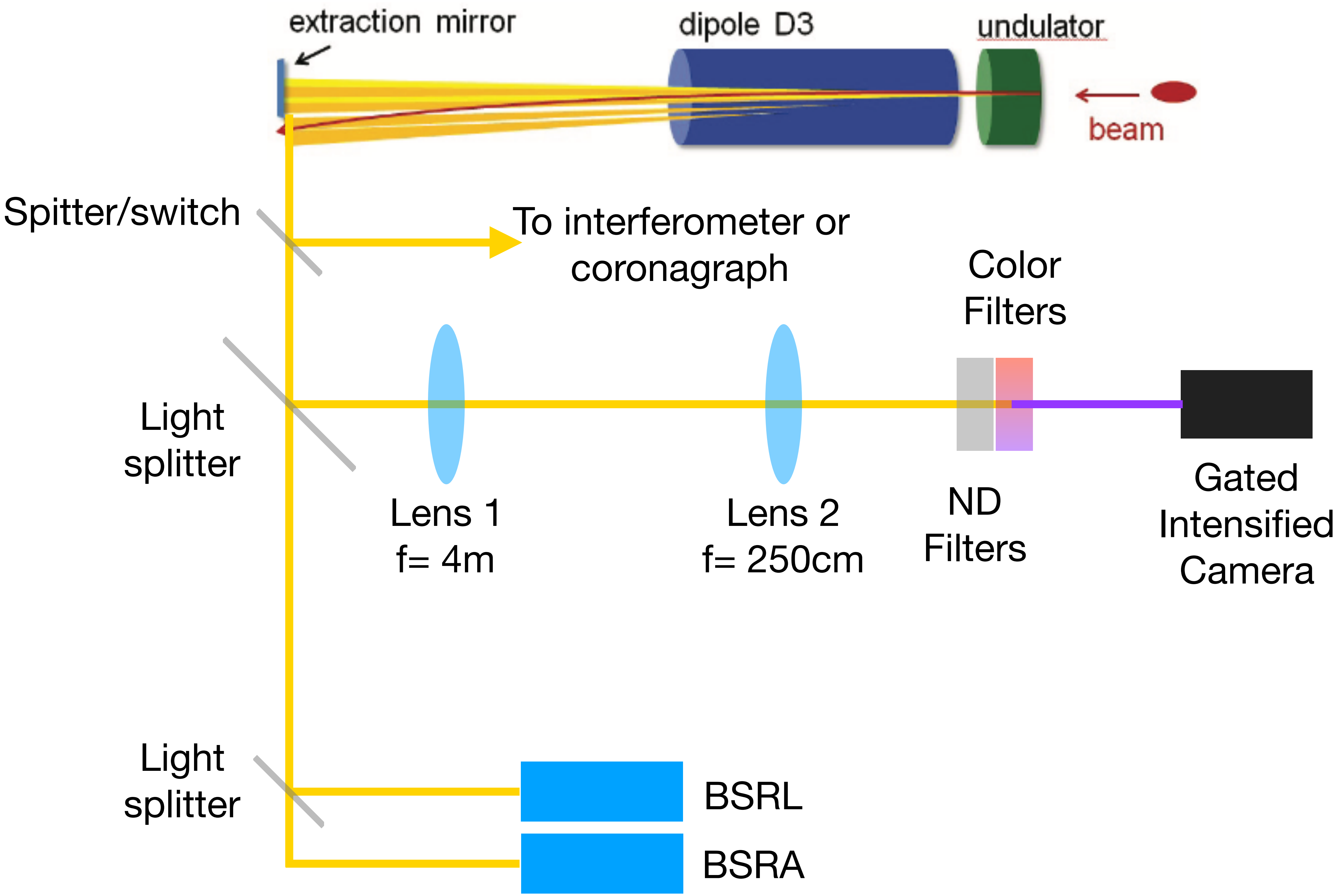
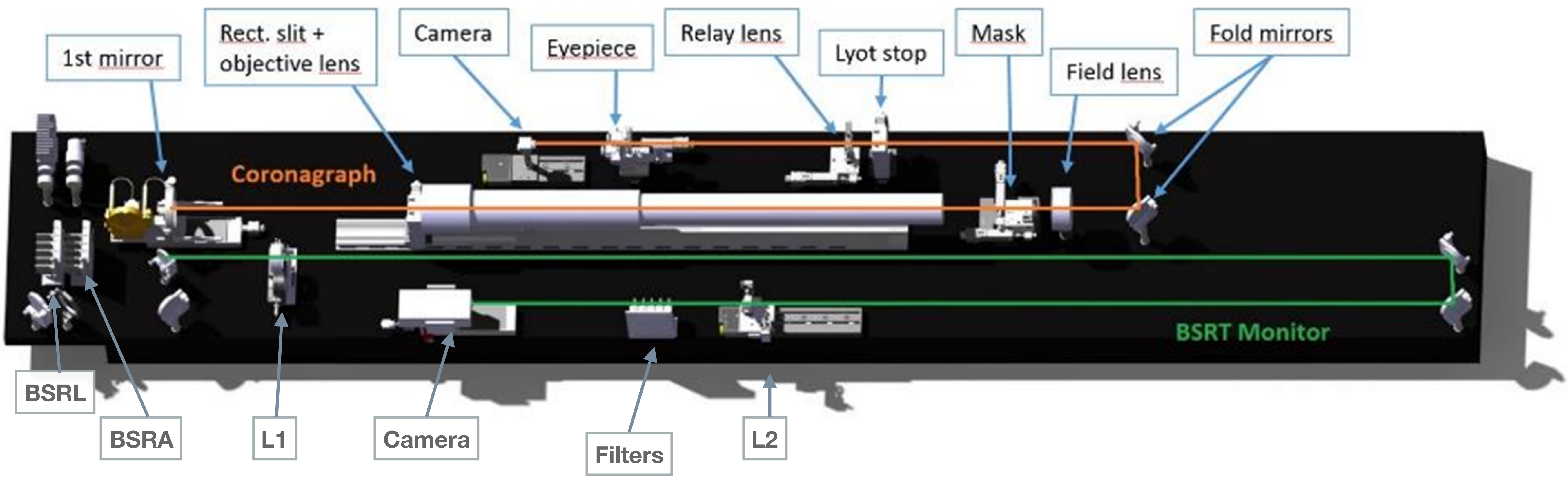
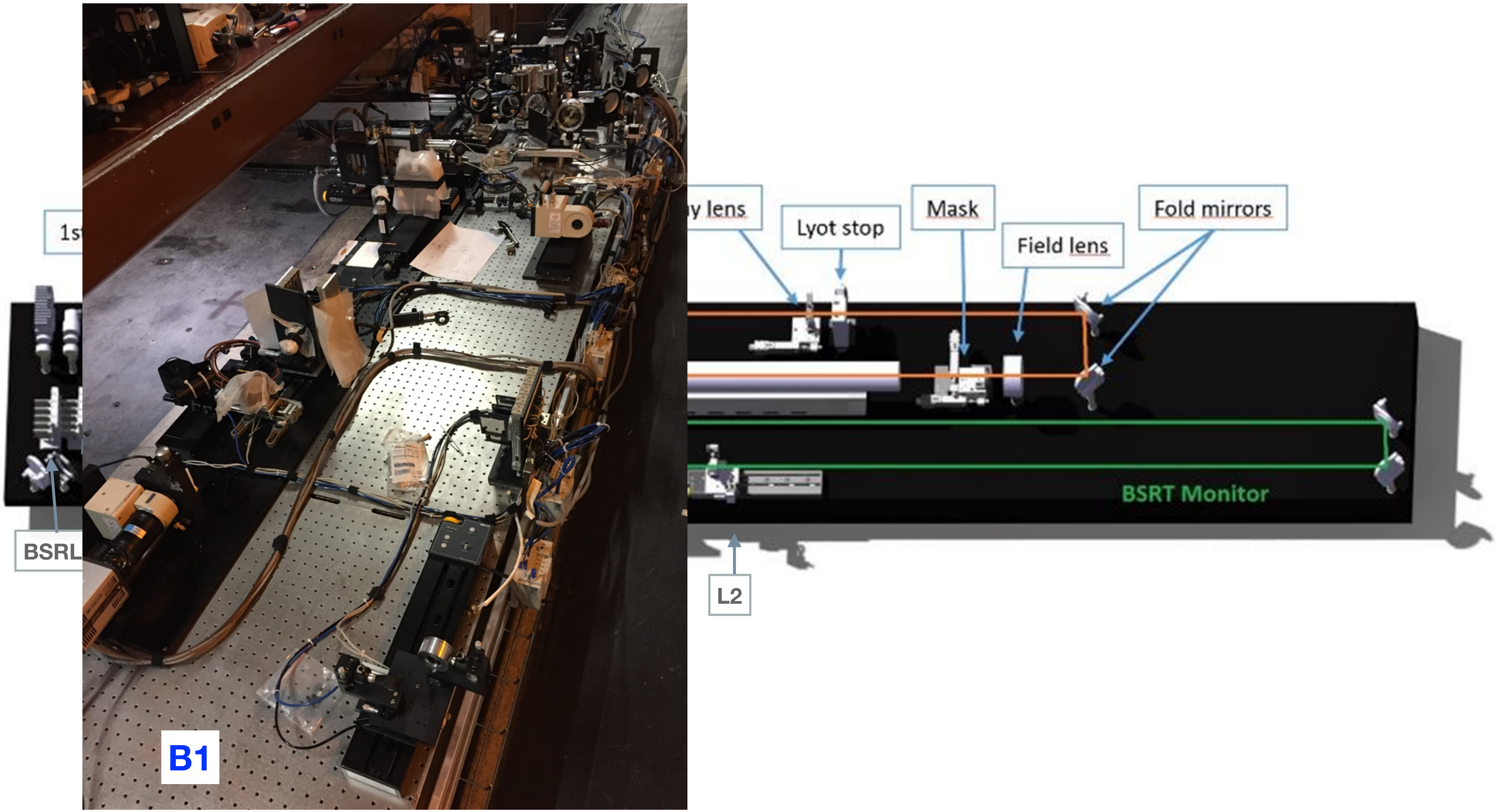


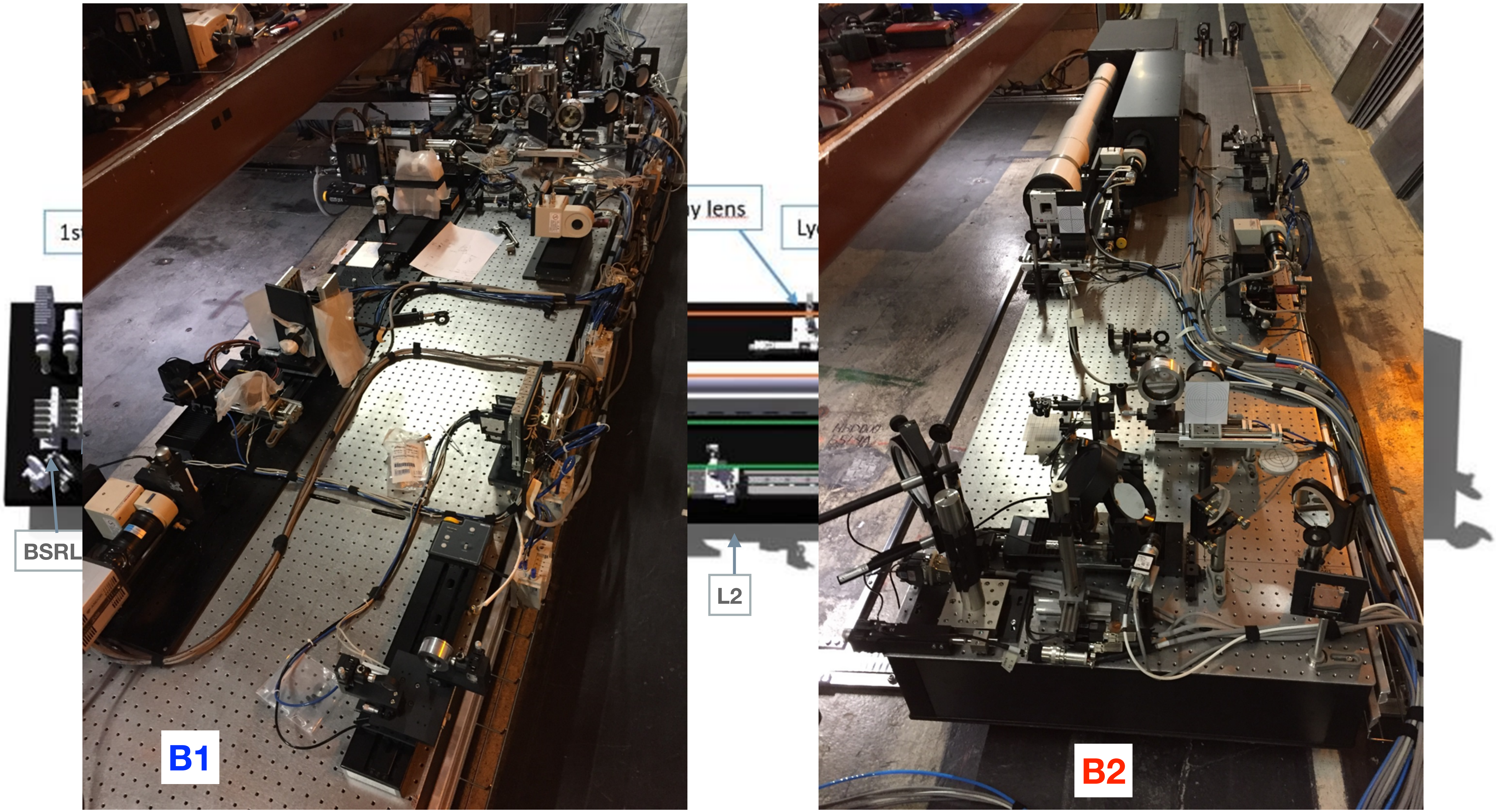
LHC BSRT layout



LHC BSRT layout



LHC BSRT layout



HL-LHC BSRT

- Beam 1 and Beam 2
  - BSRT: *Reflecting* imaging telescope for online emittance measurement (limited by diffraction) (compact version)
  - Double slit interferometer (simplified version)
  - Slit scanner for fast BbyB emittance measurement
    - Could help overcome limitation of image intensifier lifetime
  - Pin-hole camera using soft X-rays from undulator (High E) (option being investigated)
  - BSRA: Abort gap monitor
  - BSRL: Longitudinal density monitor (high dynamic range longitudinal profile with 50ps resolution)
  - Coronagraph for the measurement of the beam halo
  - ~~Streak camera for the measurement of the crabbing~~
    - ~~Clear specifications pending!~~

HL-LHC BSRT

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  - Corona… …t of the beam halo
  - ~~Streak camer… …surement of the crabbing~~
    - ~~Clear specifica… …s pending!~~

To many things to fit on one light source

Changes in BSRT for HL-LHC

Changes in BSRT for HL-LHC

High Luminosity LHC

EDMS NO.	REV.	VALIDITY
1371099	0.2	DRAFT

REFERENCE : LHC-BSR-ES-0002

CONCEPTUAL SPECIFICATION

CONTRUCTION OF A NEW OPTICAL LIGHT EXTRACTION SYSTEM FOR SYNCHROTRON LIGHT DIAGNOSTICS IN LSS4 WITH AN ASSOCIATED OPTICAL LIGHT PATH AND OPTICAL HUTCH

[LHC-BSR]

WP13

Equipment/system description

This specification concerns the contruction of a new light extraction system for synchrotron light diagnostics in HL-LHC. Synchrotron light from the D4 magnet will be extracted with an in-vacuum mirror located between D4 and D3 on each incoming beam to the left and right of Point 4. The extracted light will be sent via an optical light path from the tunnel to the respective UA in LSS4, where it will be used in a purpose built optical hutch

Layout Versions	**LHC sectors concerned**	**CDD Drawings root names (drawing storage):**
Baseline	LSS4	LHC BSR

TRACEABILITY

Project Engineer in charge of the equipment E. Bravin	**WP Leader in charge of the equipment** R. Jones	
Committee/Verification Role	**Decision**	**Date**
PLC-HLTC/ Performance and technical parameters	Rejected/Accepted	2014-07-08
Configuration-Integration / Configuraration, installation and interface parameters	Rejected/Accepted	20YY-MM-DD
TC / Cost and schedule	Rejected/Accepted	20YY-MM-DD
Final decision by PL	Rejected/Accepted/Accepted pending (integration studies, …)	20YY-MM-DD

Distribution: HL-TC

Rev. No.	***Date***	***Description of Changes*** *(major changes only, minor changes in EDMS)*
1.0	2014-06-06	Creation Date

Changes in BSRT for HL-LHC

High Luminosity LHC

EDMS NO.	REV.	VALIDITY
1371099	0.2	DRAFT

REFERENCE : LHC-BSR-ES-0002

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1.0	2014-06-06	Creation Date

This document is uncontrolled when printed. Check the EDMS to verify that this is the correct version before use

High Luminosity LHC

EDMS NO.	REV.	VALIDITY
1371100	0.2	DRAFT

REFERENCE : LHC-BSR-ES-0001

CONCEPTUAL SPECIFICATION

CONTRUCTION OF AN OPTICAL LIGHT PATH AND OPTICAL HUTCH FOR THE EXISTING SYNCHROTRON LIGHT MONITORS IN LSS4

[LHC-BSR]

WP13

Equipment/system description

This specification concerns the creation of an optical light path from the tunnel to the UA in LSS4 and the construction of an associated optical hutch in UA43 and UA47.

Version	LHC sectors concerned	CDD Drawings root names (drawing storage):
Baseline	LSS4	LHCBSR

TRACEABILITY

Project Engineer in charge of the equipment	WP Leader in charge of the equipment
E. Bravin	R. Jones

Committee/Verification Role	Decision	Date
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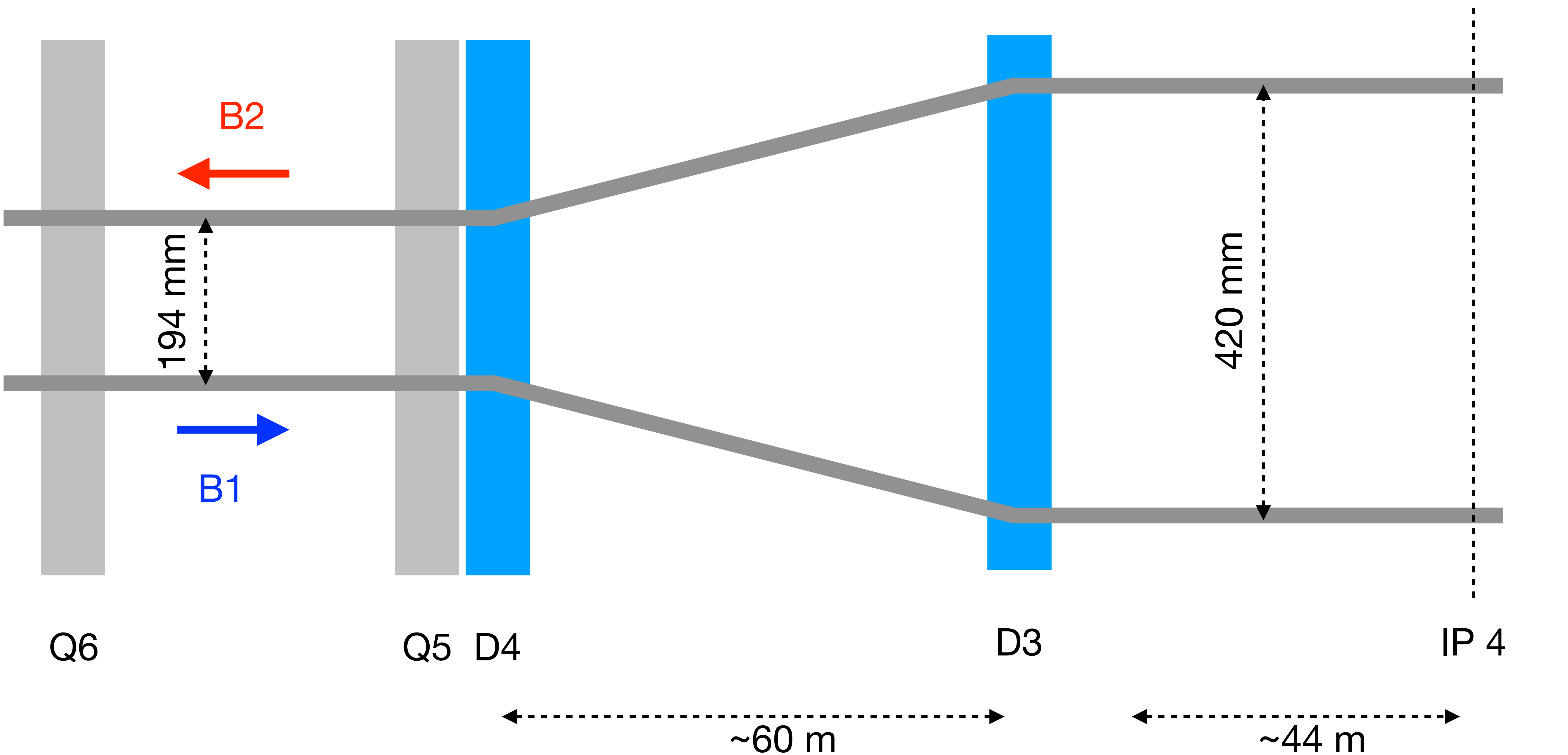
Synchrotron light in IP4 (L)



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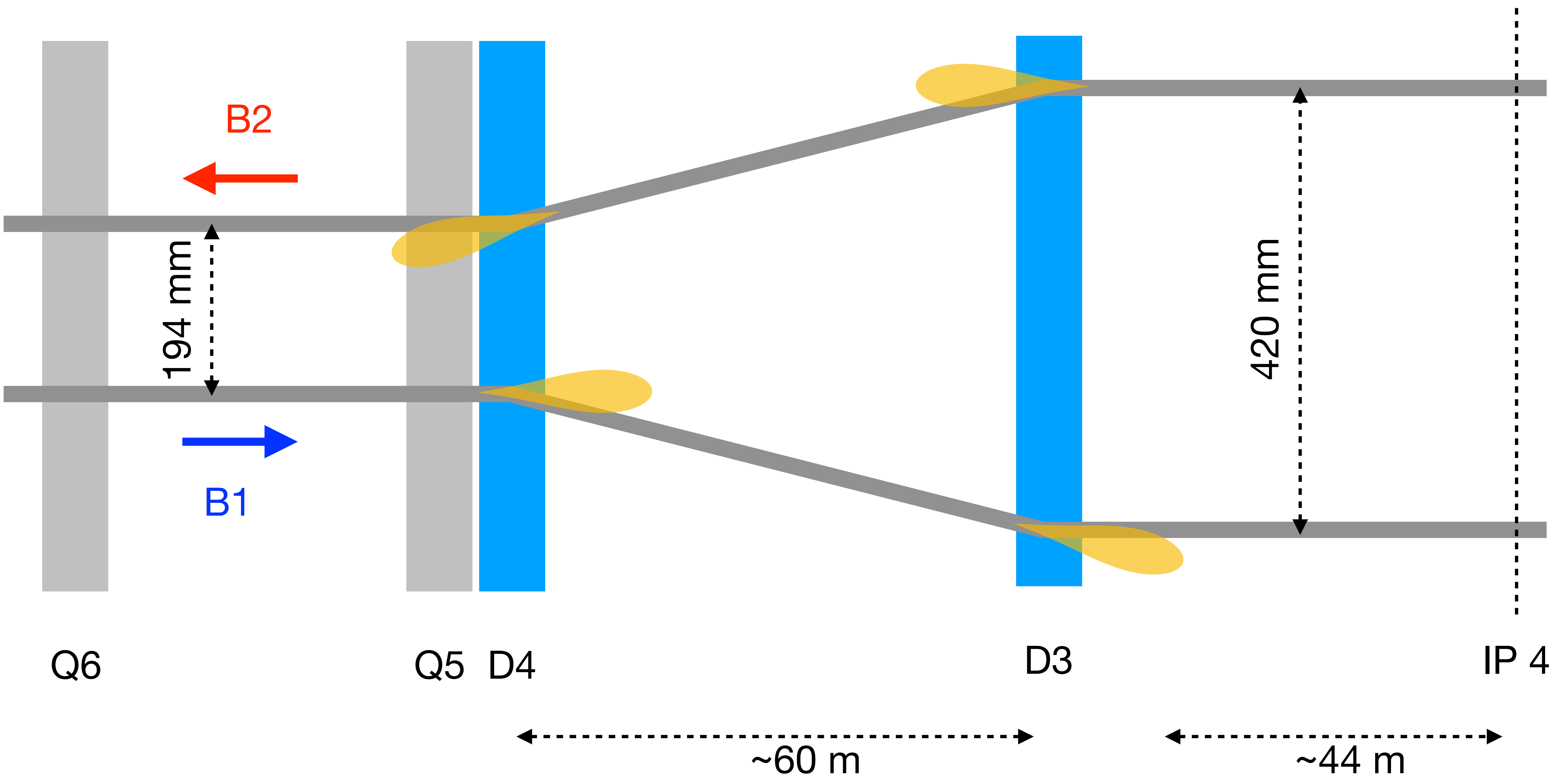

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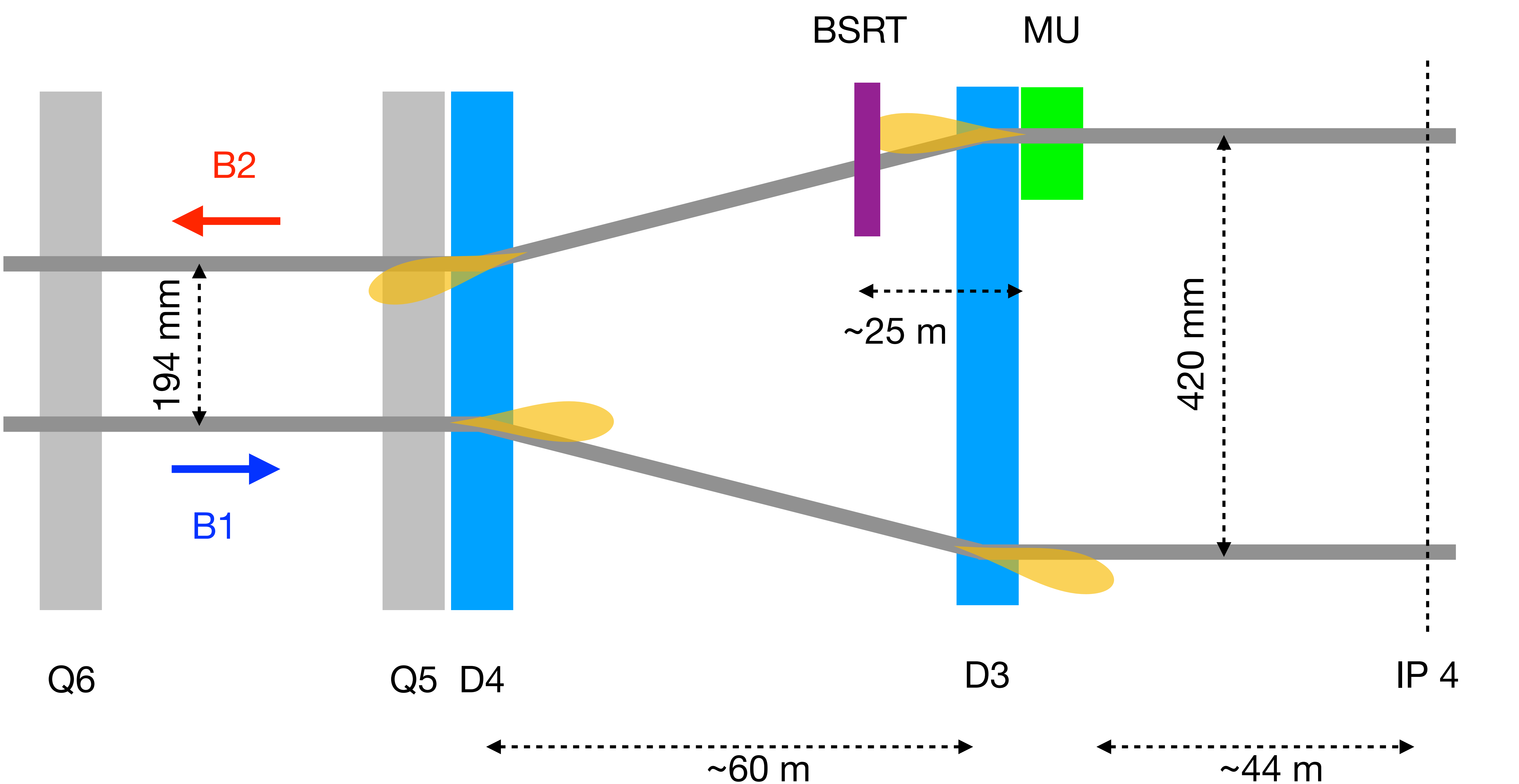

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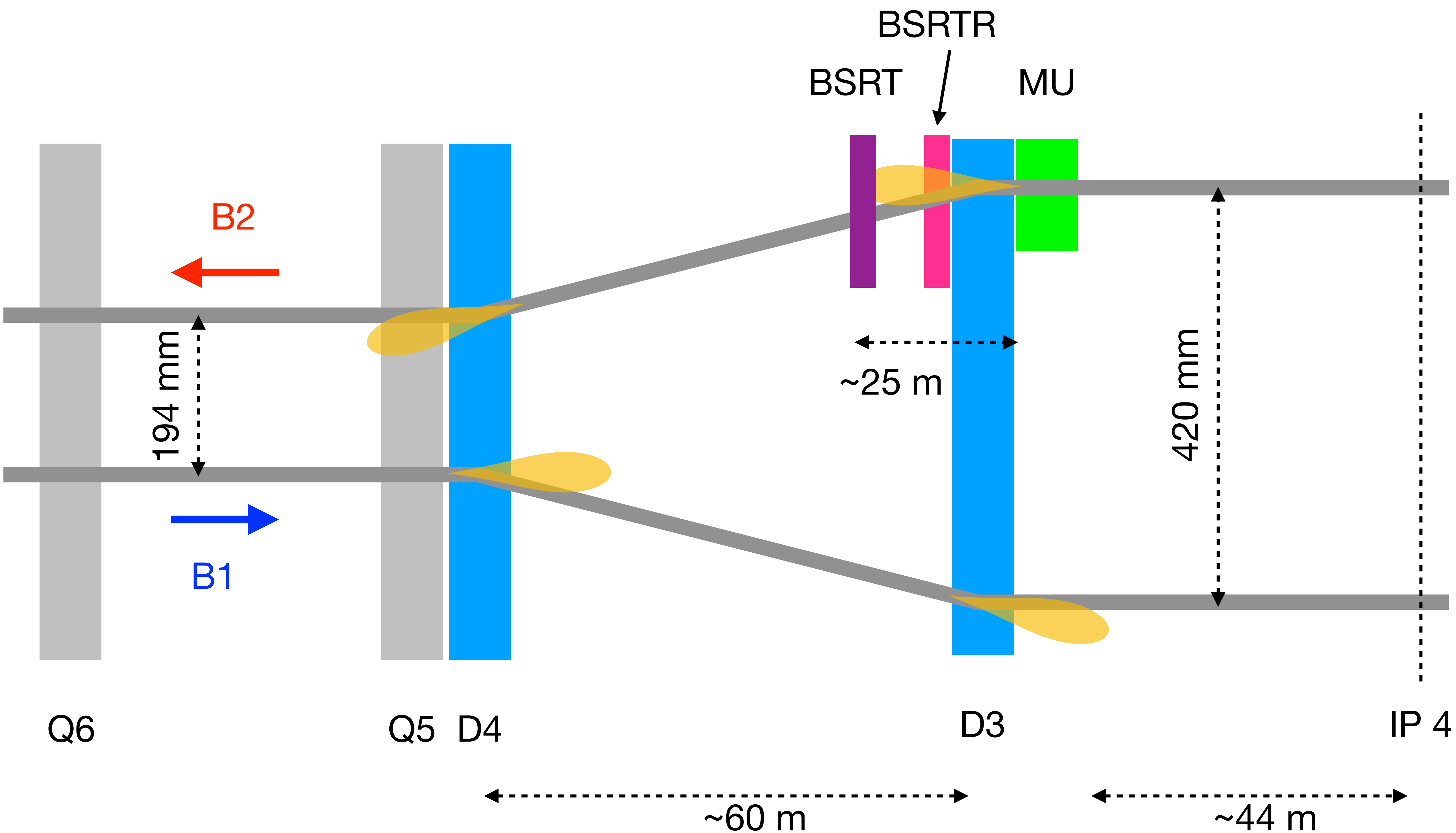

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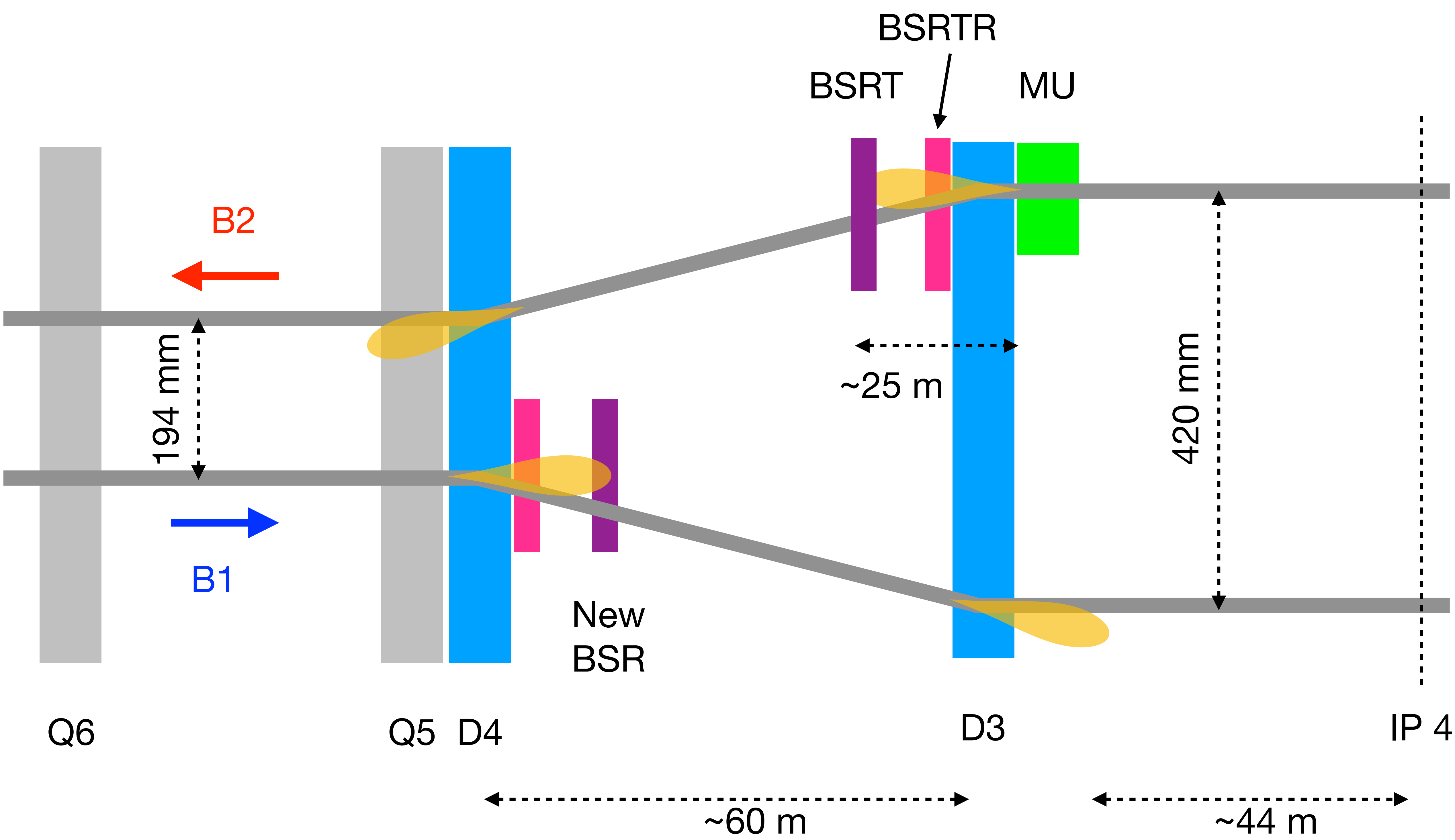

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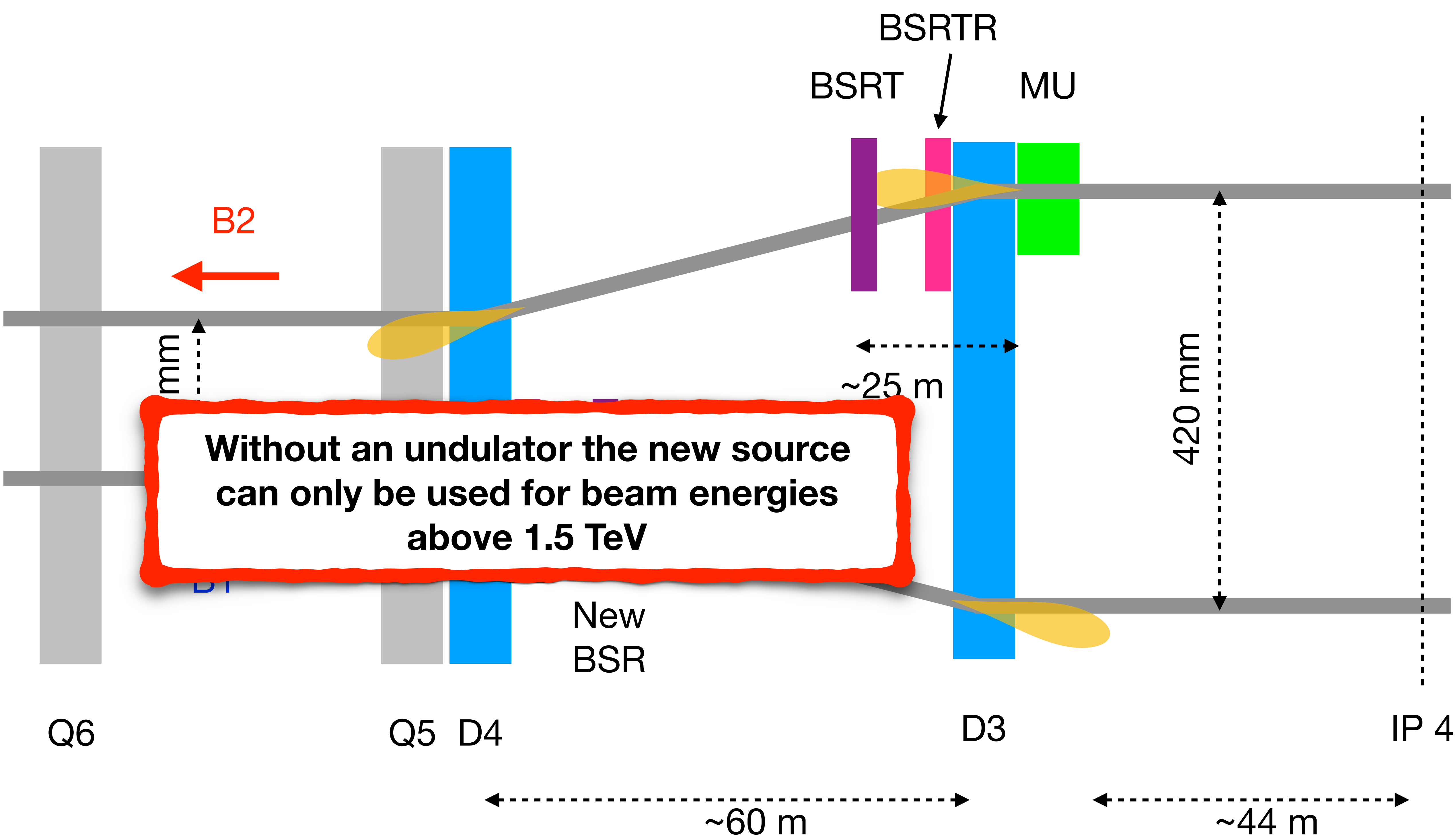
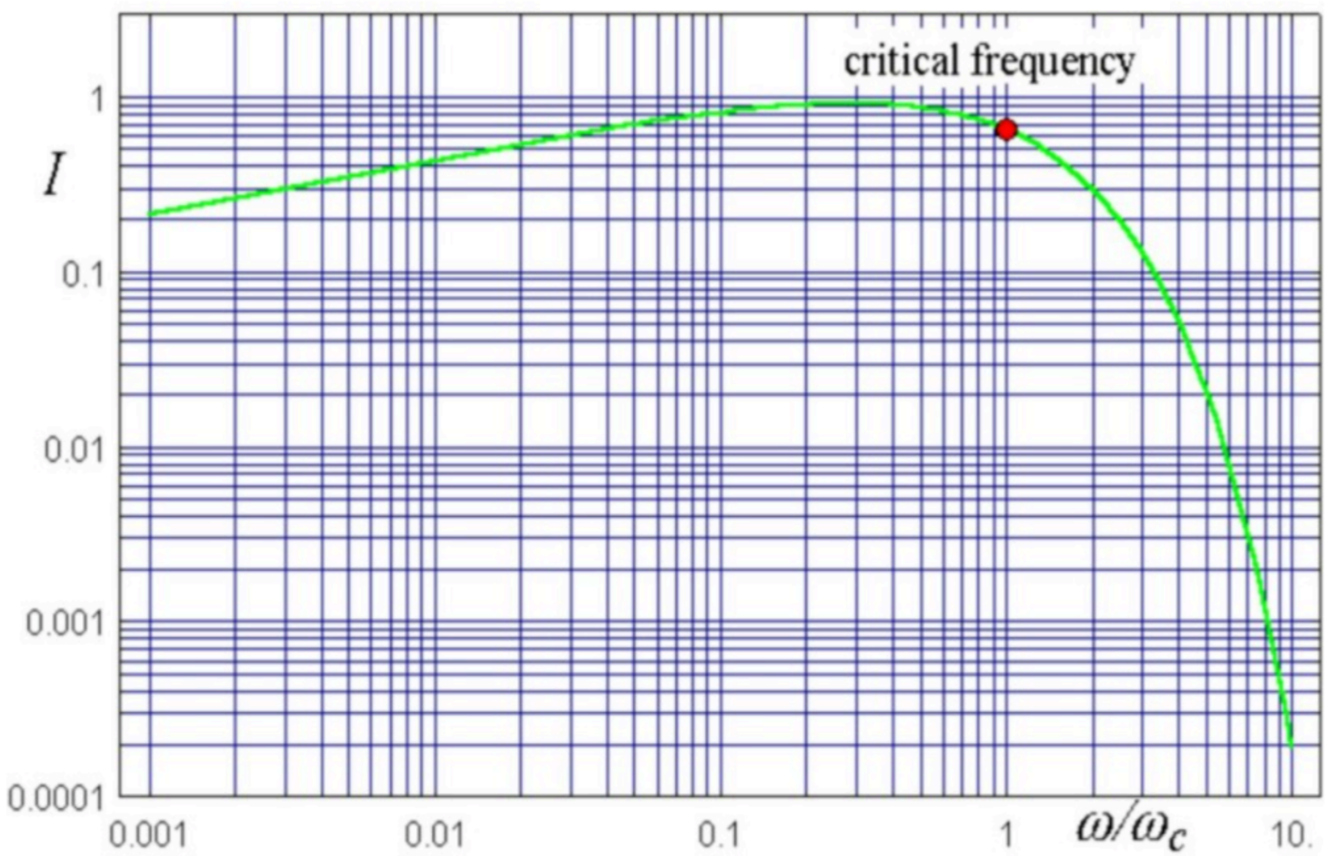


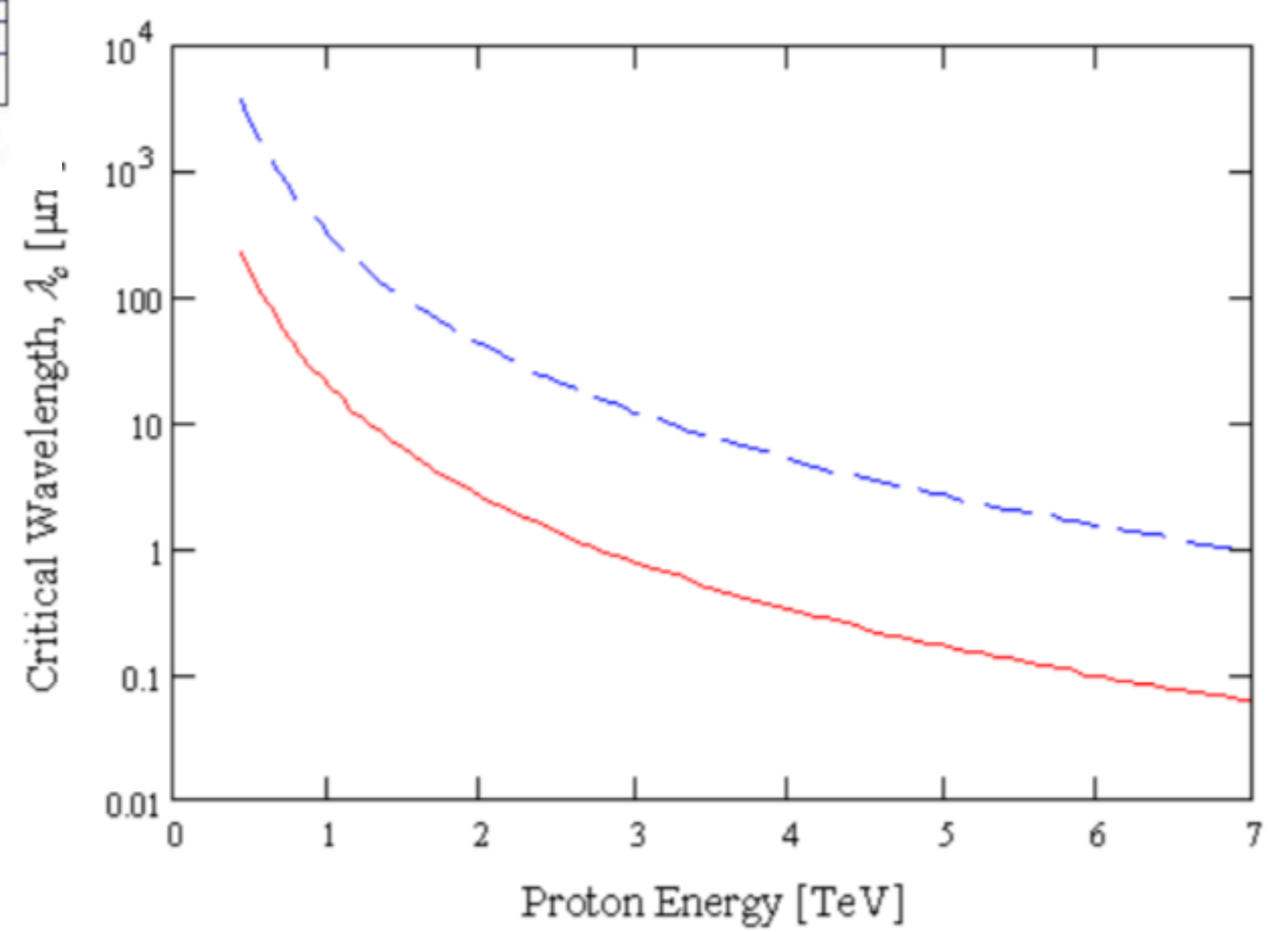
Without an undulator the new source can only be used for beam energies above 1.5 TeV

SR spectrum in dipole magnet

$$\omega_{max} = 0.29\omega_c$$

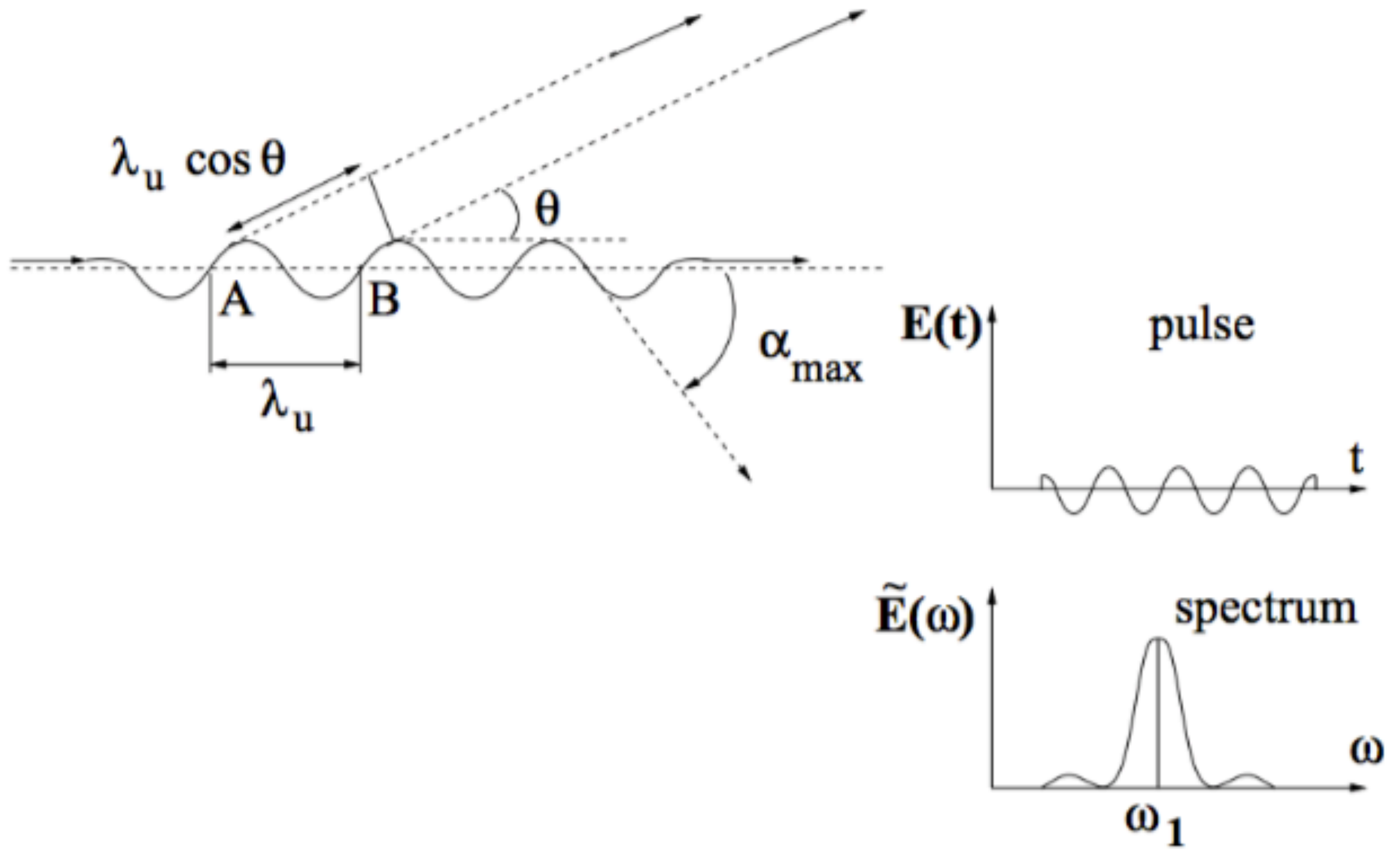


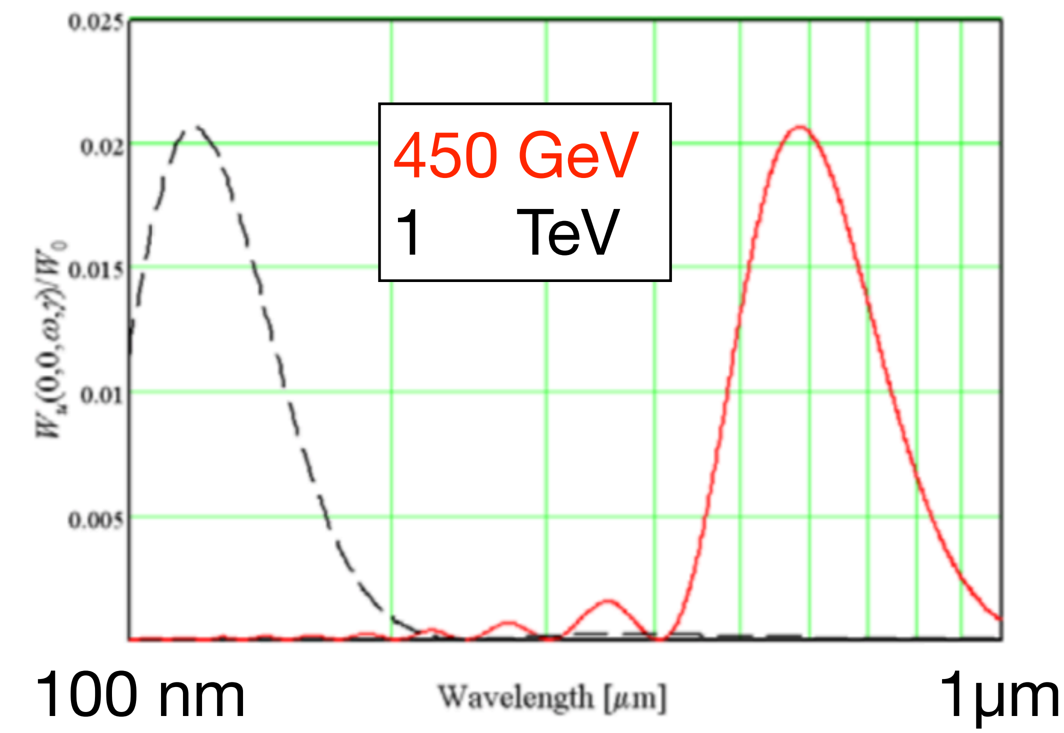
$$\omega_c = \frac{3}{2}\frac{c}{\rho}\gamma^3$$



- At 6.5Tev we use 250nm (near ω_{max})
- At 450GeV we use the full visible spectrum
    - Dipole radiation basically absent (~1000 x ω_{cr})

Undulator





- $\Theta_{obs} = 0$
- $\lambda \propto \lambda_u/\gamma^2$
- $P \propto \gamma^2$

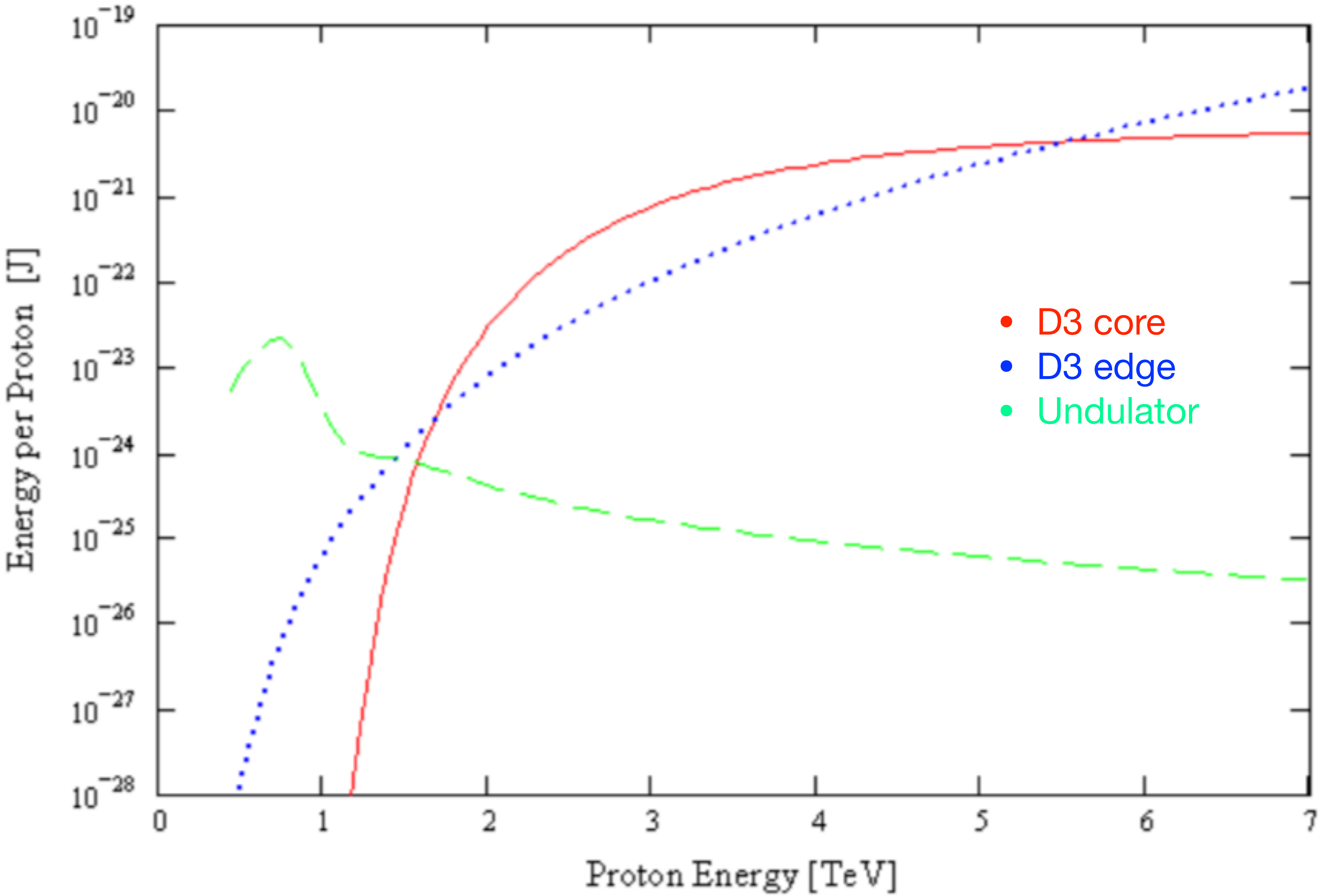
- 609nm at 450GeV
- 3nm at 6.5TeV

$$\lambda_{coh} = \frac{\lambda_u}{2\gamma^2}\left(1 + \frac{K^2}{2} + \gamma^2\Theta_{obs}^2\right)$$

$$K = \frac{e\,B_0\,\lambda_u}{2\pi\,m_0\,c}$$

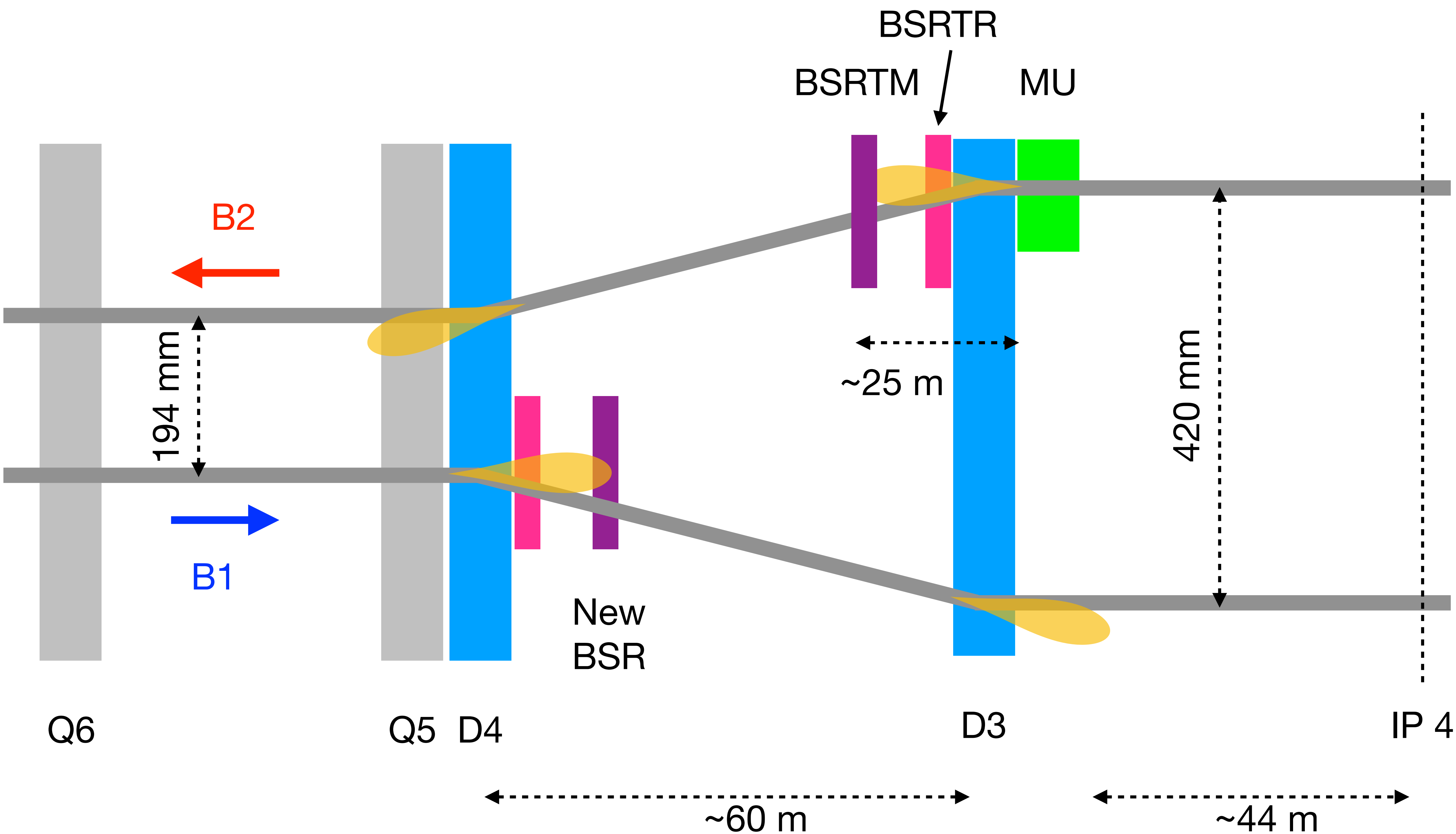
$$P = \frac{\pi e^2 c \gamma^2}{\epsilon_0 \lambda_u^2 N_u}\frac{K^2}{(1 + K^2/2)^2}$$

SR power



10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10^{-28}
Energy per Proton [J]
0
1
2
3
4
5
6
7
Proton Energy [TeV]
D3 core
D3 edge
Undulator

Pin-hole camera



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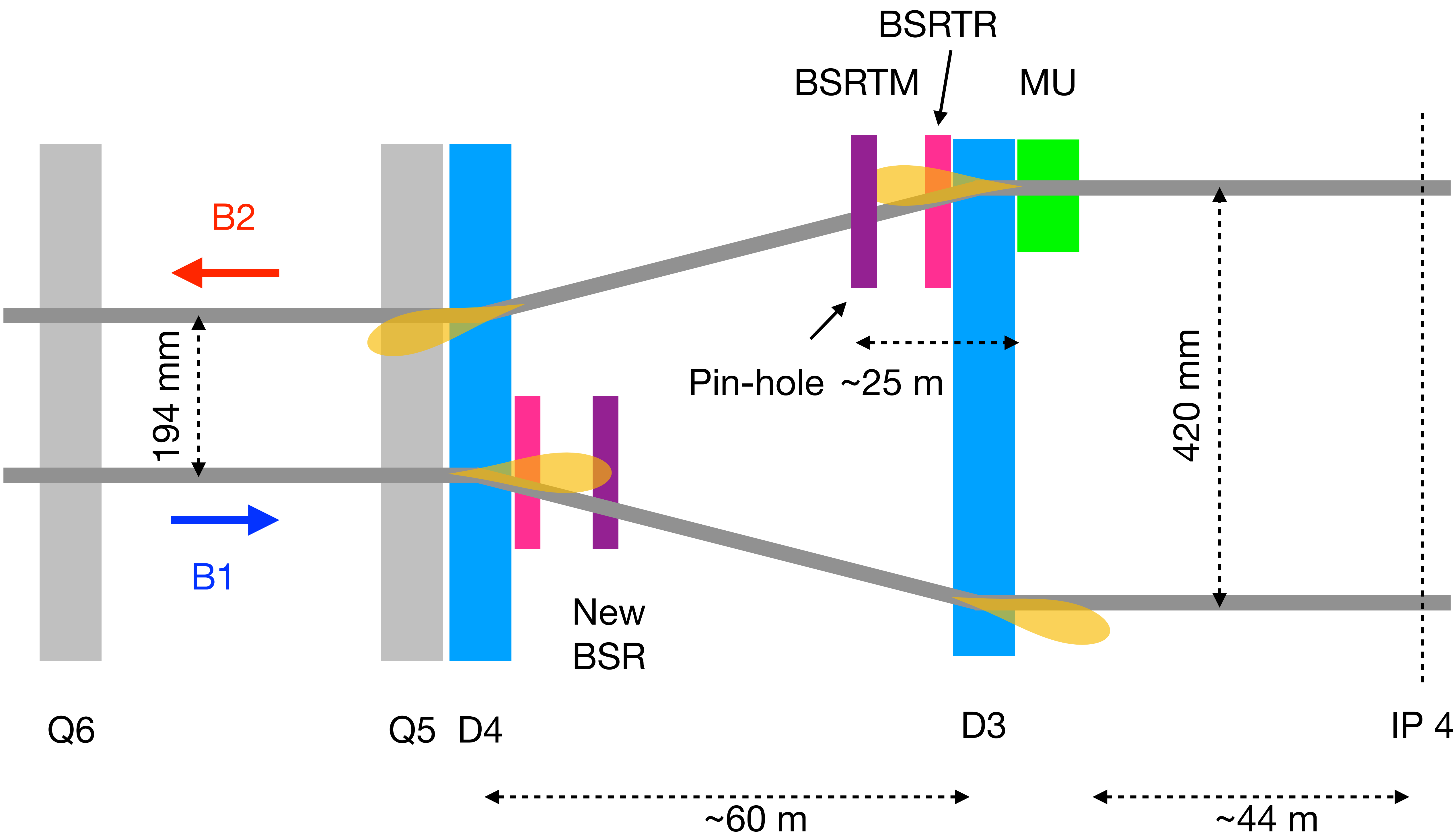

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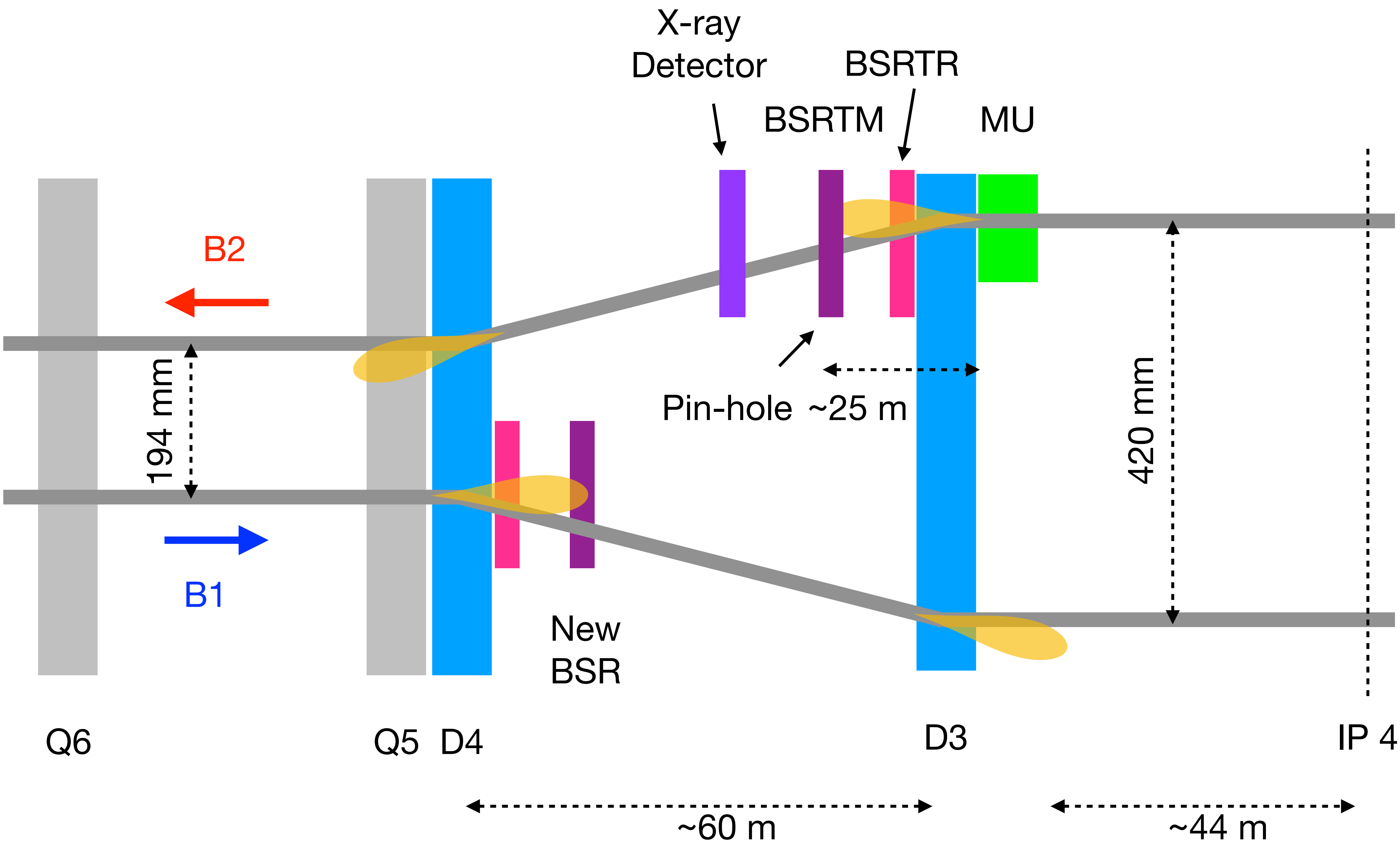

Do we need a new undulator?

- Do we need to ramp down the undulators? (the present one can not)
  - The SR from the undulator is certainly not helping
  - No quantification of the negative effect (heating and damage on the extraction mirror, complex source during the ramp (harmonics)
- Can we clearly define the final configuration of the BSRT for HL-LHC now?
  - Seen the experience with the present one … (continuous R&D)
- Advantage of second undulator
  - Freedom to move instruments from one source to the other
  - Instrument of second source (BSRH for now) useable at injection energy
- We could ask for new undulators that can be ramped down during the energy ramp for the main instruments and reuse the present ones on the other line
- The pin-hole looks interesting, but requires a dedicated source (with undulator)!

Summary

- HL-LHC requirements require a new synchrotron light pick-out
- Outgoing radiation from D4 identified as best option
- New SR extraction tank needed (design 2018)
- Undulator on new synchrotron light source would give more freedom in distributing instruments between sources
- Second source without undulator can be used only for the BSRH (and R&D at high energy)