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DAΦNE Test-Facility for Future Colliders

Antonio De Santis
INFN-Laboratori Nazionali di Frascati

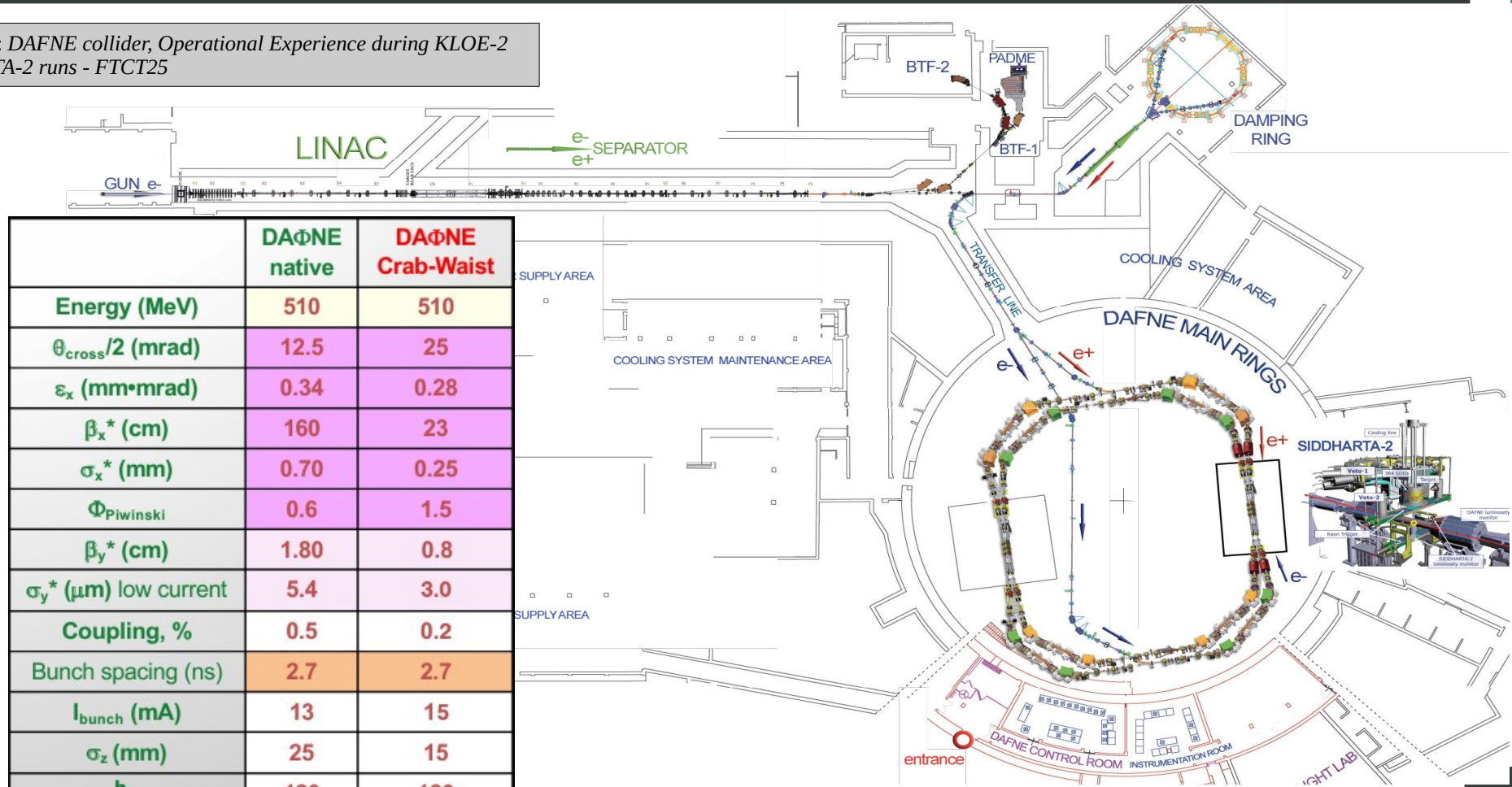
On behalf of
DA StorageRing team

The DAΦNE *Collider*

DAΦNE Complex

See **C. Milardi**: *DAFNE collider, Operational Experience during KLOE-2 and SIDDHARTA-2 runs - FTCT25*

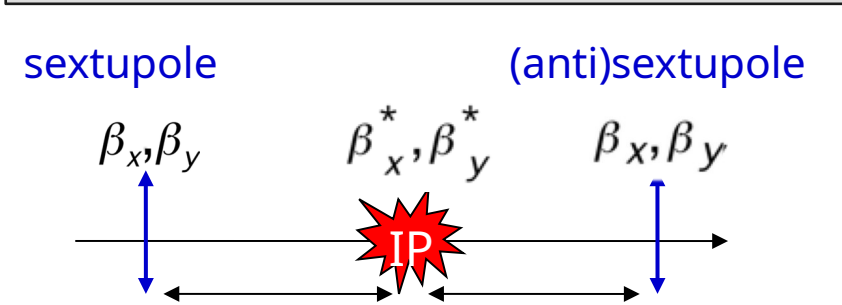
	DAΦNE native	DAΦNE Crab-Waist
Energy (MeV)	510	510
$\theta_{cross}/2$ (mrad)	12.5	25
ε_x (mm•mrad)	0.34	0.28
β_x^* (cm)	160	23
σ_x^* (mm)	0.70	0.25
$\Phi_{Piwinski}$	0.6	1.5
β_y^* (cm)	1.80	0.8
σ_y^* (μm) low current	5.4	3.0
Coupling, %	0.5	0.2
Bunch spacing (ns)	2.7	2.7
I_{bunch} (mA)	13	15
σ_z (mm)	25	15
h	120	120



DAΦNE Crab-Waist

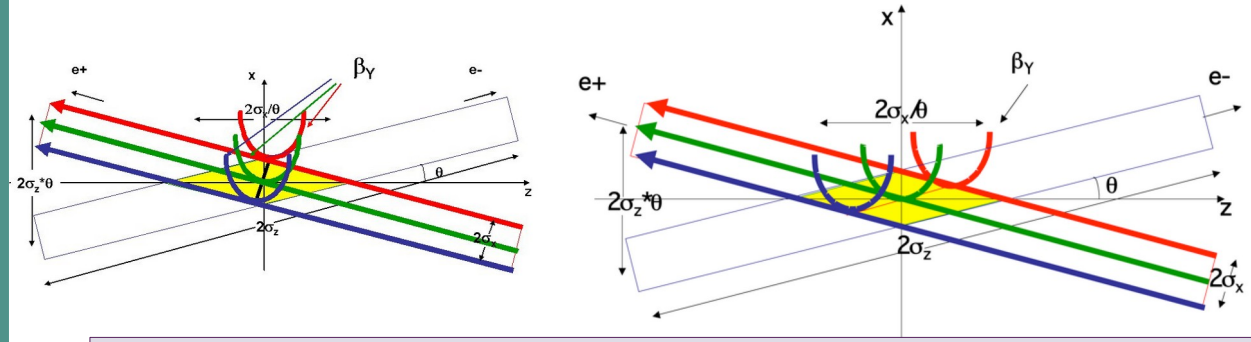
Large horizontal crossing angle - Large Piwinsky angle.
Reduced Overlap area -> *lower* β^*_y *at IP.*
Beam-beam non-linear resonances suppressed by a *pair of Crab-Waist Sextupole*

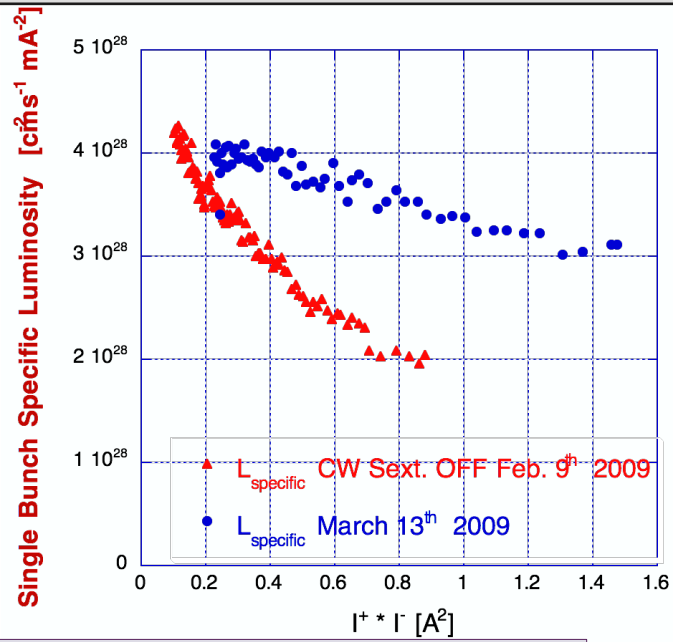
P. Raimondi , *2° SuperB Workshop, March 2006,*
M.Zobov et al., Phys.Rev.Lett. 104 (2010) 174801,
C. Milardi et al., Int.J.Mod.Phys.A24, 2009.



$$\Delta\nu_x = \pi$$

$$\Delta\nu_y = \frac{\pi}{2}$$





SIDDHARTA-2 Best

$I(e^-)^{Max}$: 1.3 A

$I(e^+)^{Max}$: 0.9 A

L_{Max} : 2.4x10^{32} cm^{-2}s^{-1}

L_{Max}(Day) : 9.4 pb^{-1}

The “Test Facility” proposal

LNF Scientific Committee Recommendations

68th SciCom Meeting (Nov 2024)

The committee encourages the DAΦNE team, in collaboration with the CERN FCC-ee project team, to **identify and prioritize a set of activities and tests, to be conducted at the collider (or its complex)**, that could be validate models, concepts, hardware choices considered for FCC-ee. Feasibility, possible timelines and resources requirements should be evaluated. Compatibility with physics operation should be assessed.

We suggest **involving the younger members of the DAΦNE team in this process** as they are expected to implement it. An analysis of the necessary maintenance and consolidation of the DAΦNE complex should be conducted and possible descoping options identified with the associated risks.

April 2025

Circular Collider expert from Accelerator Division organized a dedicated Working-Group in order to drive the DAΦNE Test-Facility proposal and DAΦNE Storage rings future activities.

A. De Santis (Coordinator)

S. Bilanishvili, M. Boscolo, A. Ciarma, G. Franzini, A. Gallo, C. Milardi, D. Quartullo, M. Zobov.

Chapters

- **DAΦNE Present Status**
- **Collider-Mode Activity**
  - Monocromatization
  - Beam-Beam & Feedback study
  - eCloud and Background models validation
- **Single Ring-Mode Activity**
  - Pulse stretcher
  - Synchrotron light source
  - Longitudinal Injection
  - Crystal collimations with leptons

Monochromatization

Outline

- DAFNE Present Status
- Collider-Mode Activity
  - **Monocromatization**
  - & Feedback study
  - lidation
- S
  - Longitudinal Injection
  - Crystal collimations with leptons

EXCALIBUR:
C. Curceanu, et al., Front. Phys. 11 (2023) 1240250.

Compatible with Physics operations (e.g. EXCALIBUR)
Short runs (few months)
Activity-driven consolidation needed
Under study for FCCee (Special run)
Never tested – Large impact

Monochromatization: general theory

$$\sigma_E(beam) = E_b\delta$$

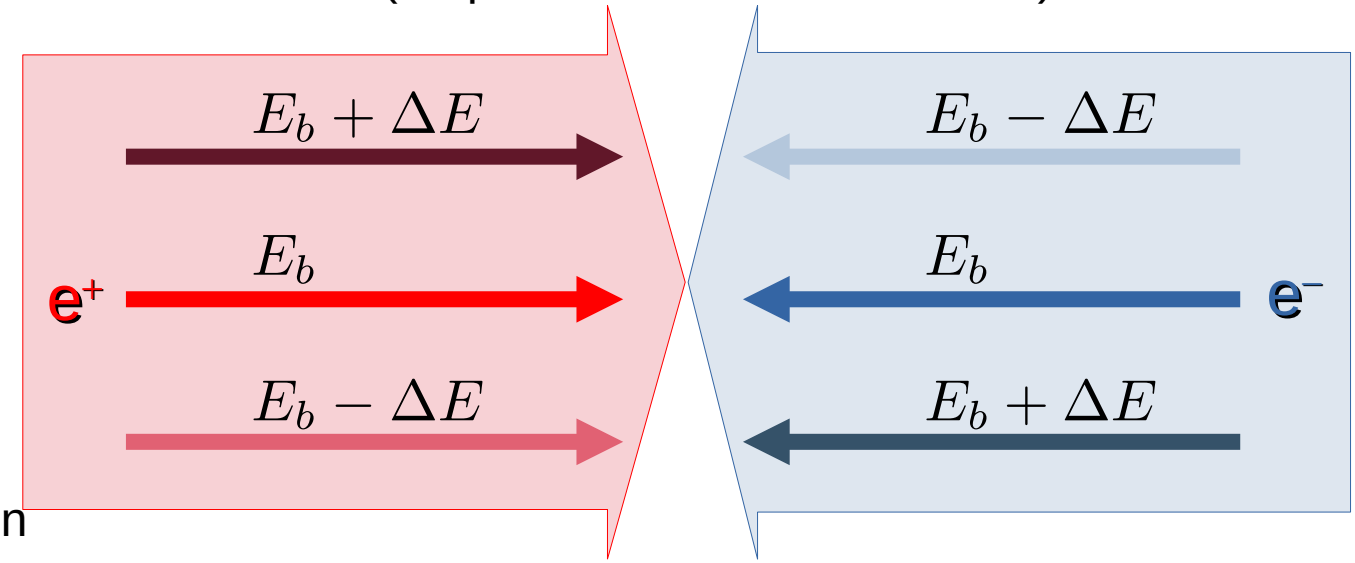
Usually:

$$w = 2E_b$$

$$\sigma_w = \sqrt{2}\delta E_b$$

Proposed by
A. Renieri 1975 (ADONE)

Monochromatization scheme
(Dispersion at Interaction Point)



Effect on energy resolution

$$w = 2E_b$$

$$\sigma_w = \frac{\sqrt{2}\delta E_b}{\lambda}$$

$$\lambda = \sqrt{1 + \delta^2\left(\frac{D_x^{*2}}{\sigma_{x\beta}^{*2}} + \frac{D_y^{*2}}{\sigma_{y\beta}^{*2}}\right)}$$

See also A. Faus-Golfe talk

Monochromatization: Crab-Waist edition

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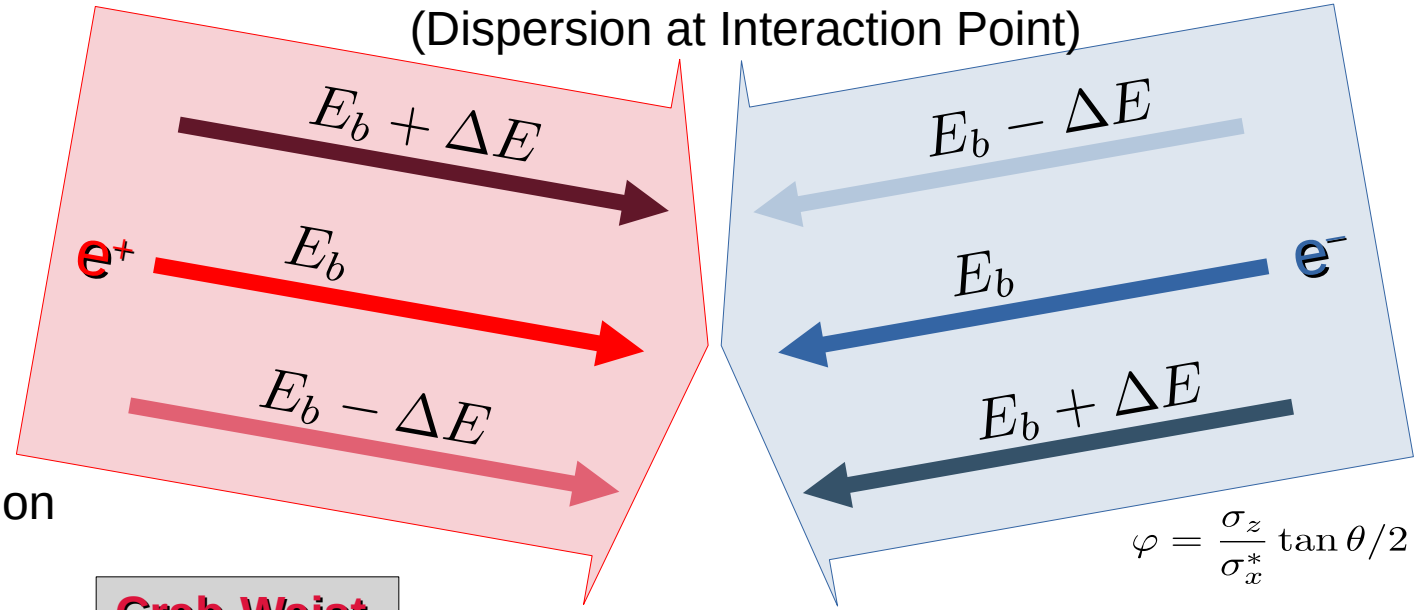


$$\varphi = \frac{\sigma_z}{\sigma_x^*}\tan\theta/2$$

Effect on energy resolution

$$w = 2E_b$$

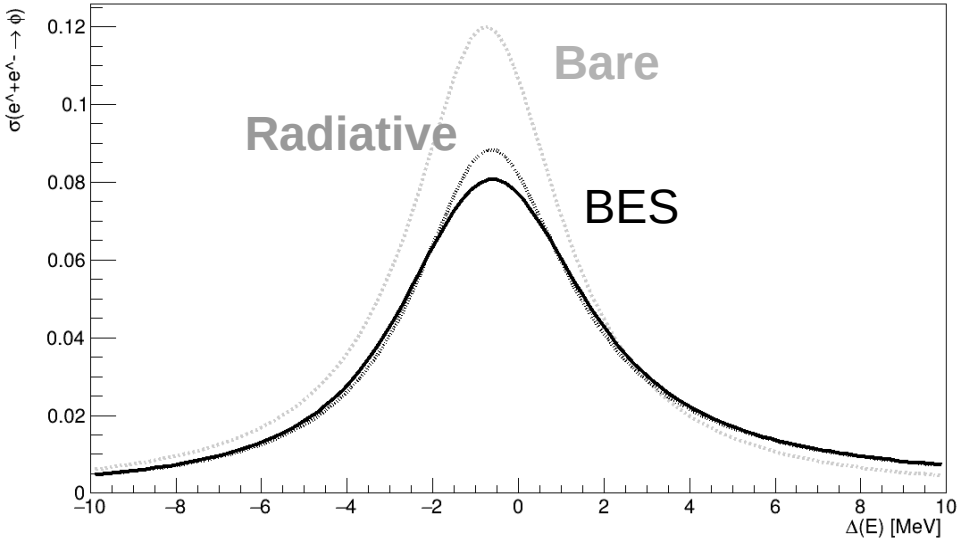
Crab-Waist

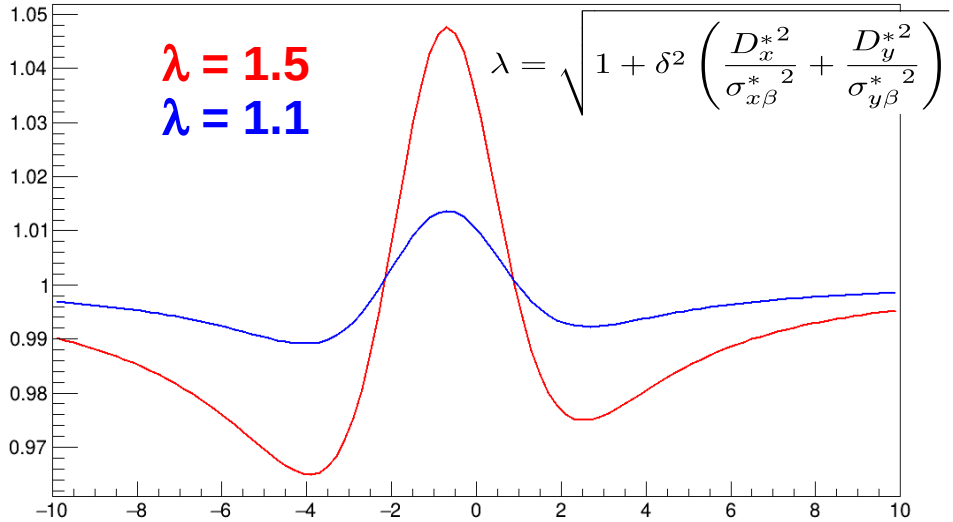
$$\sigma_w = \sqrt{2}\delta E_b\sqrt{\left(\frac{\sigma_\delta\cos(\theta_c/2)}{\lambda^2}\right)^2 + \sigma_{x'}^*\sin(\theta_c/2)}$$

$$\lambda = \sqrt{1+\delta^2\left(\frac{D_x^{*2}}{\sigma_{x\beta}^{*2}(1+\varphi^2)} + \frac{D_y^{*2}}{\sigma_{y\beta}^{*2}}\right)}$$

Zhang, Z., et al., NIMA 1073 (2025) 17268

Observable definition





The impact of Beam Energy Spread (BES) on the line-shape is moderate
Different λ implies different run length (sensitivity)

$$\left.\frac{N(K^{\pm})}{N_{Bha}}(\sqrt{s})\right|_{\lambda=\lambda_0} \Big/ \left.\frac{N(K^{\pm})}{N_{Bha}}\right|_{\lambda=1}(\sqrt{s})$$

Using the "double-ratio" method allows to cancel out most of the systematics

Resonance lineshape measurement

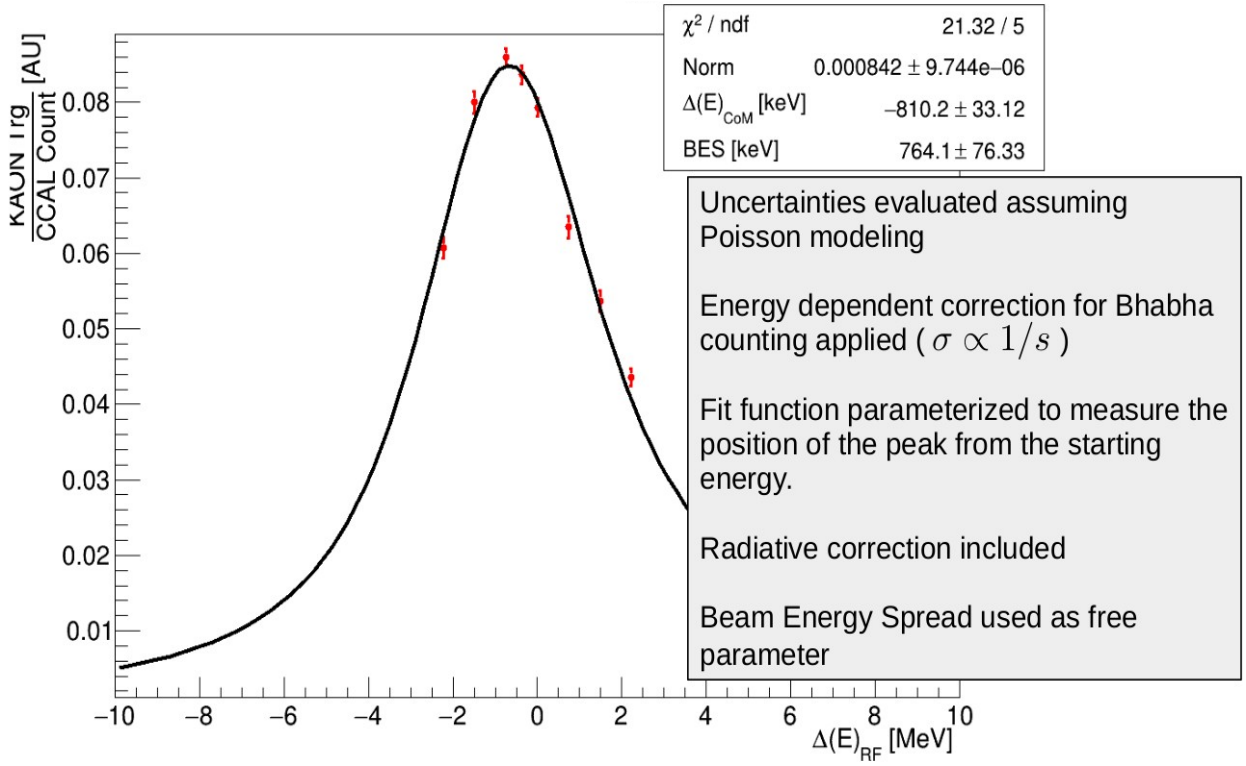
Simultaneous measurement of *Charged Kaon* pair production Rate and *Bhabha* scattering events rate at different energy.

Observable:

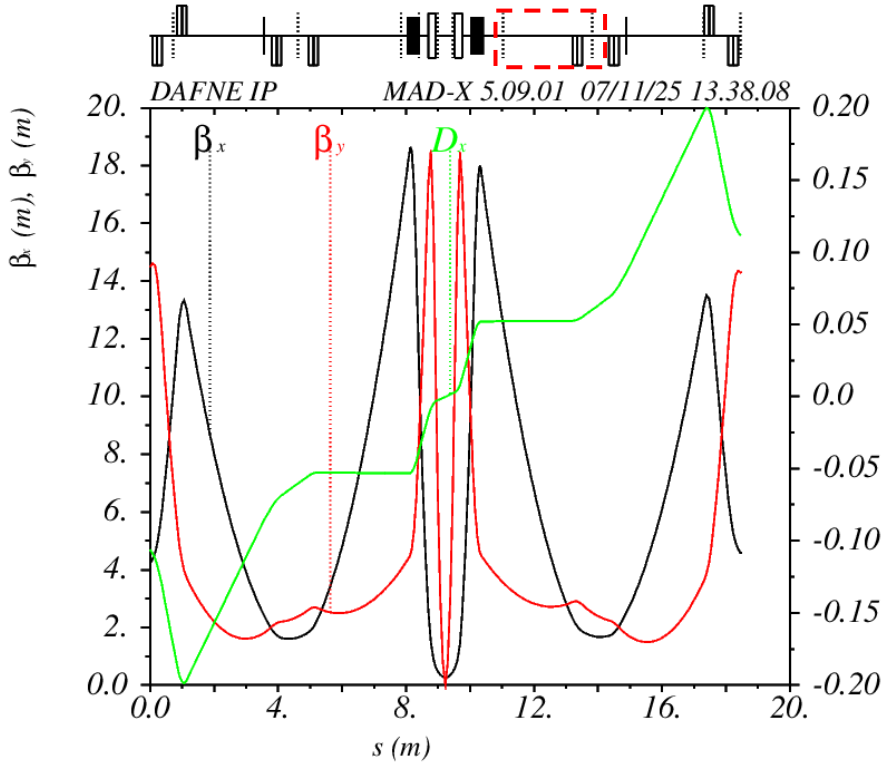
Beam Energy Spread

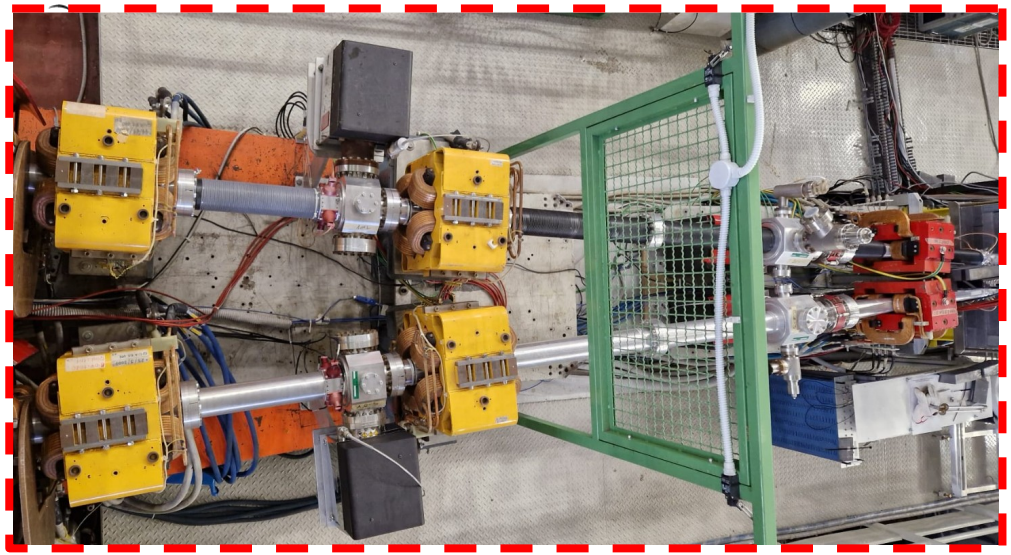
Measurement performed to verify the working point of the collider.

Setup already available



Interaction Region lattice



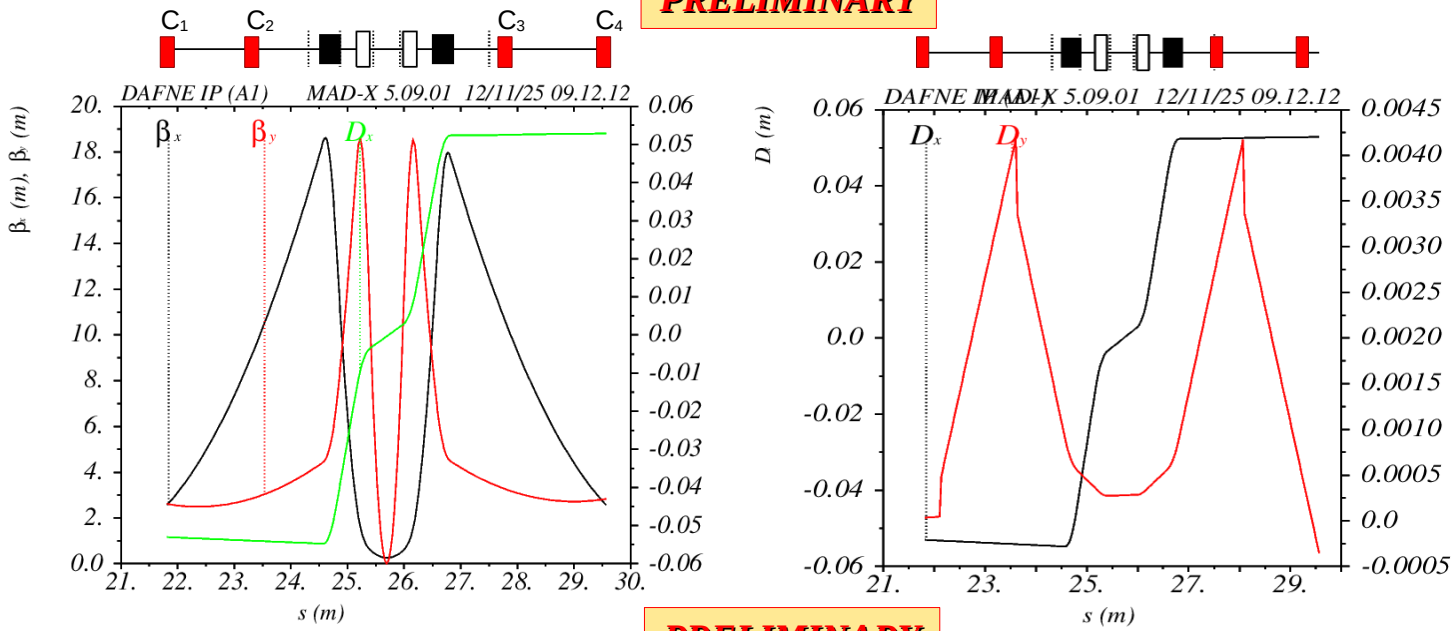


Interaction Region (IR) of DAΦNE has limited space for new magnets.
In the central region (Between QFs and QDs) the two beams have common beam pipe.

Vertical Dispersion at IP

New Correctors: D_y bump at IP

PRELIMINARY



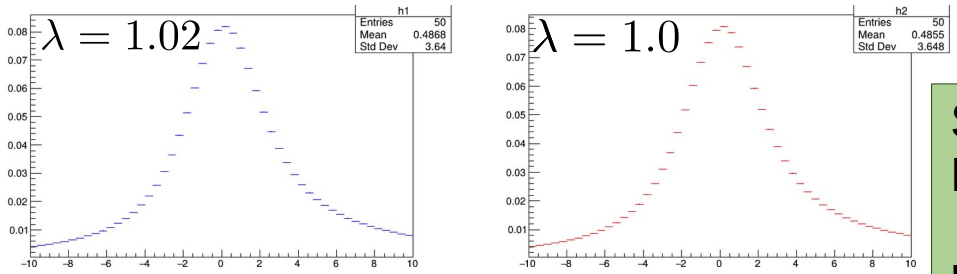
PRELIMINARY

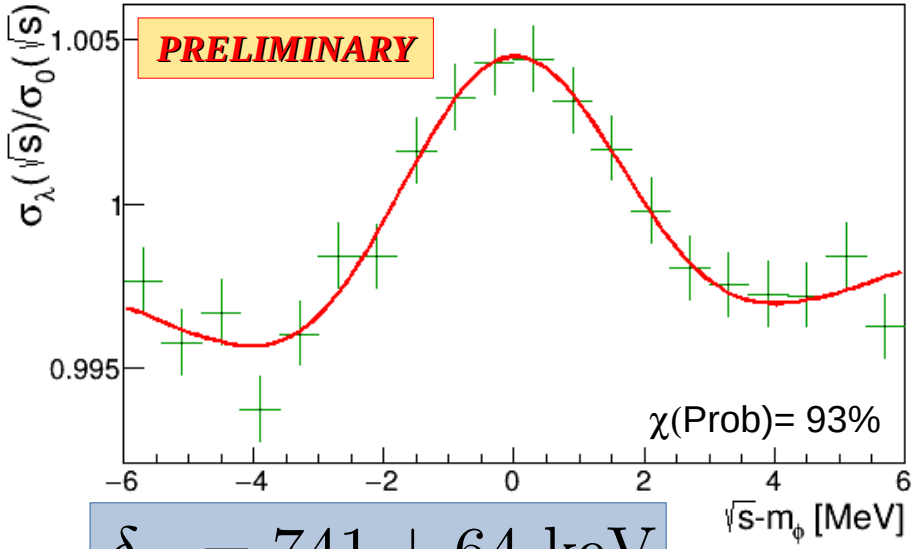
Magnet Strengths: (mrad)
θ_1: -2.3
θ_2: 5.0
θ_3: 5.0
θ_4: -2.3

$$D_y@\mathrm{IP} = 0.4\ \mathrm{mm} \Rightarrow \lambda \sim 1.02$$

Deeper study on the optics and beam dynamics are mandatory

Measurement simulation





$$\delta_E = 741 \pm 64 \text{ keV}$$
$$\lambda = 1.021 \pm 0.003$$

Statistical uncertainty is related only to the KAON counting.

DAFNE Luminometer and KAON Trigger (SIDDHARTA-2) counting rate assumed

Several energy range and collected statistics have been simulated with **λ = 1.02**

Accuracy of ~10-15% requires 60-80 days of collisions operations @ 10^{32} $cm^{-2}s^{-1}$

Luminosity drop with dispersion included (beam size increase)

eCloud study

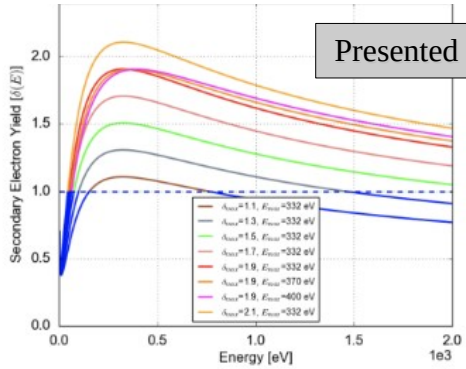
Ring characterization: eCloud simulation

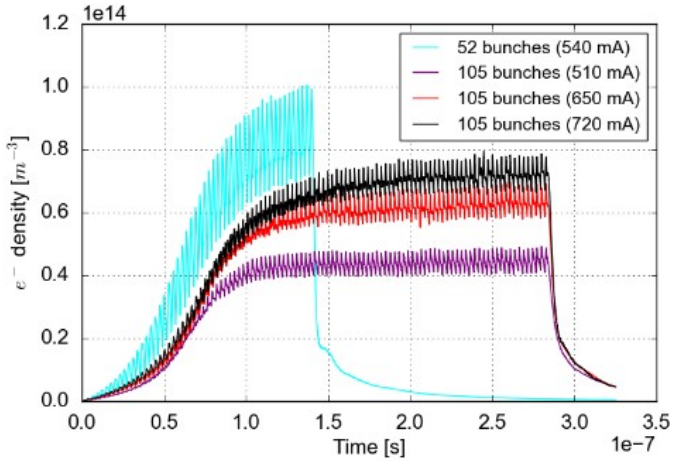
E-cloud build-up simulation by using PyECLOUD code.

E-cloud formation depends on many parameters: external magnetic fields, geometry, chamber surface, bunch spacing, bunch intensity, bunch length, bunch number, beam sizes, and Secondary Electron Yield (SEY).

SEY for Al surface: δ_{max} =1.9 and E_{max} = 332 eV

Presented at IPAC2024-WEPR08



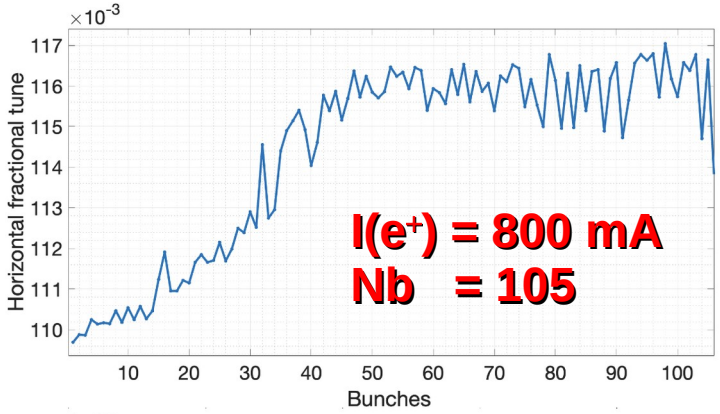


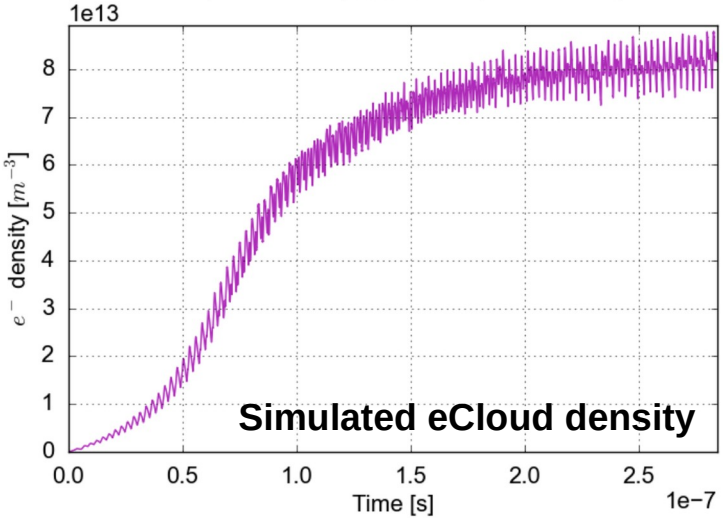
Etisken, O., et al., NIMA 1018 (2026) 171019

	Meas	Simulated
Bunch no	**Growth rate**	**e^- density**
105 bunches [720 mA]	44 ms^{-1}	0.8×10^{14} m^{-3}
105 bunches [650 mA]	22 ms^{-1}	0.7×10^{14} m^{-3}
105 bunches [510 mA]	6 ms^{-1}	0.5×10^{14} m^{-3}
52 bunches [540 mA]	18 ms^{-1}	1.0×10^{14} m^{-3}

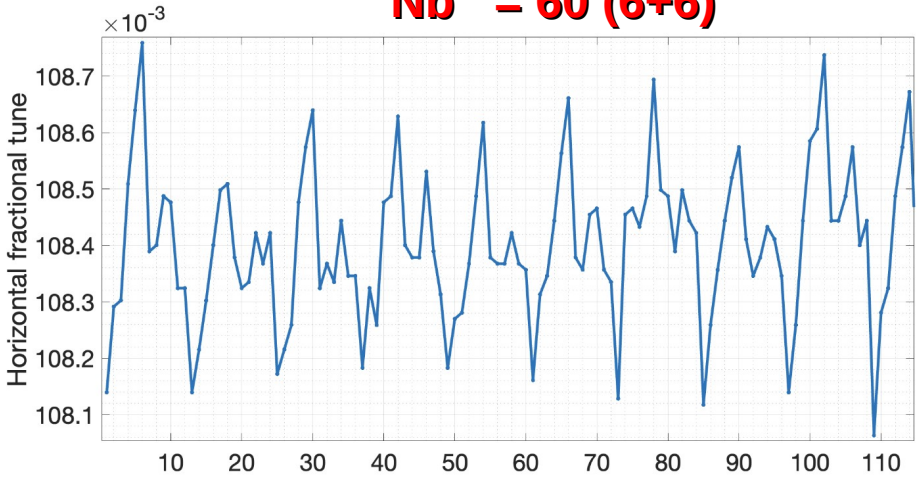
Beam current	**Measured tune shift**	**e^- density**
800 mA	7.0×10^{-3}	8.8×10^{13} m^{-3}
750 mA	6.3×10^{-3}	8.0×10^{13} m^{-3}
600 mA	4.8×10^{-3}	6.0×10^{13} m^{-3}
400 mA	3.3×10^{-3}	3.5×10^{13} m^{-3}

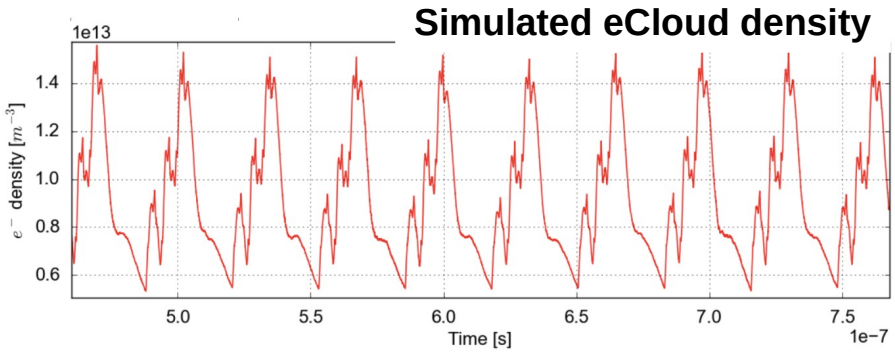
Ring characterization: eCloud simulation





I(e+) = 290 mA
Nb = 60 (6+6)





Etisken, O., et al., NIMA 1018 (2026) 171019

Storage Rings activity: PADME-X17

Outline

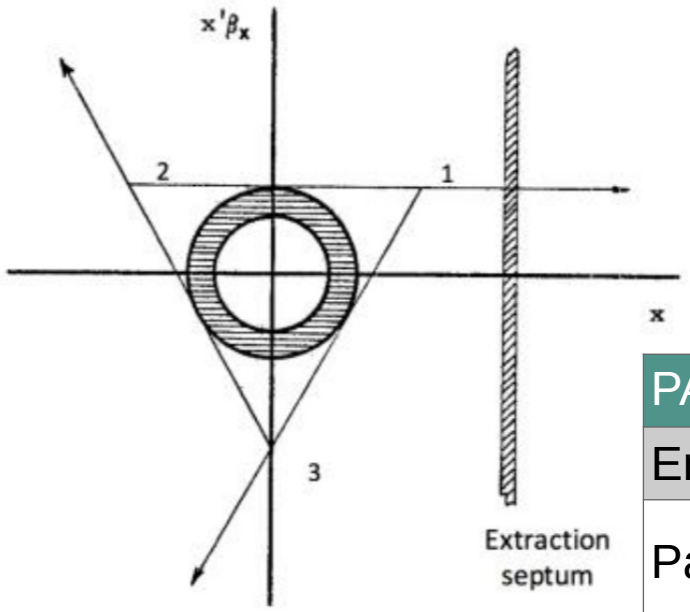
- DAFNE Present Status
  - Activity
  - eclo
- Single Ring-Mode Activity
  - **Pulse stretcher**
  - Synchrotron light source
  - Longitudinal Injection
  - Crystal collimations with leptons

PADME-X17 RunIII:
Bossi, F. et al., JHEP 11 (2025) 007.

Driven by PADME-X17 Run-III result
Case study to be ready in case of non conclusive results of Run-IV
Design based on PADME requirements
Potentially of interest to increase BTF beam variety

Resonant extraction: recap

P. Valente, INFN/17-15-LNF
S. Guiducci, IPAC2018-THPAK023



Separatrix:
Inside triangle – Stable
Outside - Unstable

Already proposed for PADME (POSEIDON-2017)

Third order resonant extraction

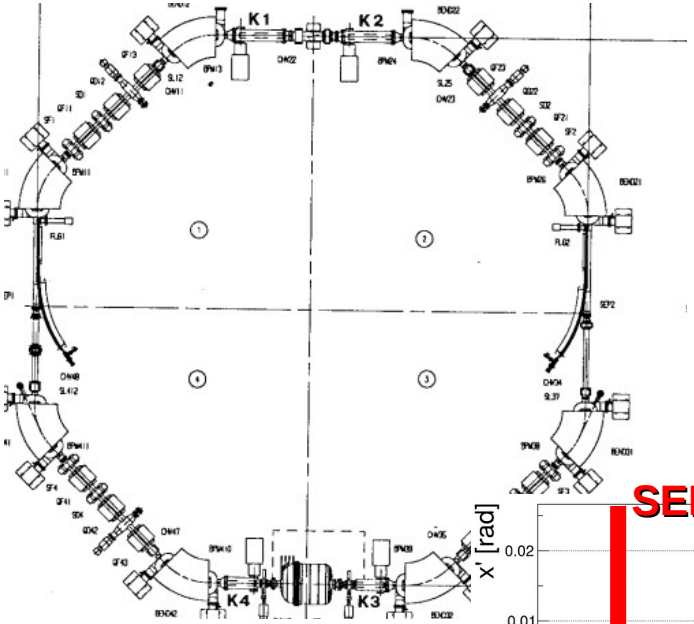
Main aspects described with Kobayashi Hamiltonian

Resonant conditions reached naturally by loosing energy for synchrotron radiation

PADME-X17 Beam requirements (Courtesy of M. Raggi)	
Energy (MeV)	280 ± 30 (tunable 1 MeV step)
Particle flux	1 POT/ns (max) 4×10^6 POT/s (min avg)
Energy spread	0.3% (max)
Divergence (target)	1 mrad (max)
Beam Spot (target)	1x1 mm^2

PRELIMINARY

Slow extraction from DAFNE damping ring



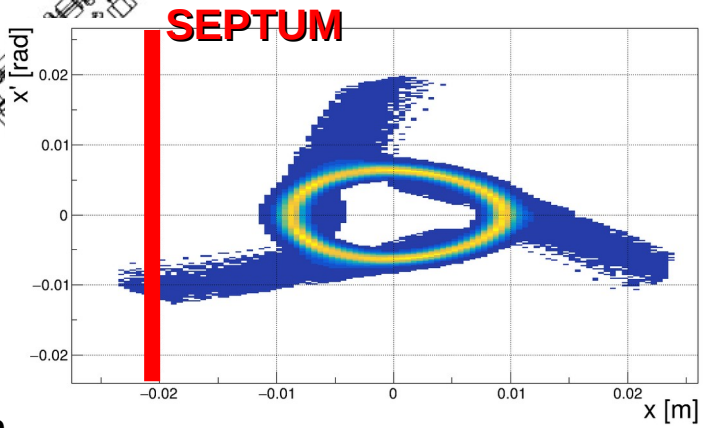
Small ring with **large energy acceptance** ☺

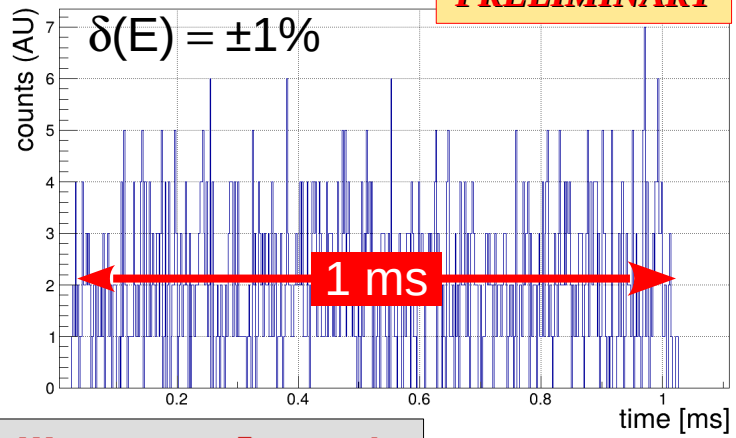
Already **existing extraction septum** ☺

Quadrupoles and Sextupoles in family ☹

Common Injection/Extraction transfer lines ☹

PRELIMINARY





Ring parameters:
E_0 = 300 MeV
Q_x = 0.325
ξ_x = -6.0
U_0 = 0.65 keV/turn

1 POT/ns×1ms = 10^6 POT/Spill ⇒ 5x10^7 POT/s

Conclusion

DAΦNE Future WG settled & operative

Several items under consideration

Monochromatization lattice under study

Study for pulse stretching with DR started

Further proposal are Welcome!

Selected references

- **DAFNE:**
  - C. Milardi, et al., IPAC2018, MOPMF088, *https://dx.doi.org/10.18429/JACoW-IPAC2018-MOPMF088*
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  - Foggetta, L. et al., IPAC21, THPAB113, *https://doi.org/10.18429/JACoW-IPAC2021-THPAB113*
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  - Bossi, F. et al., JHEP 11 (2025) 007, *https://doi.org/10.1007/JHEP11(2025)007*

Thank you!