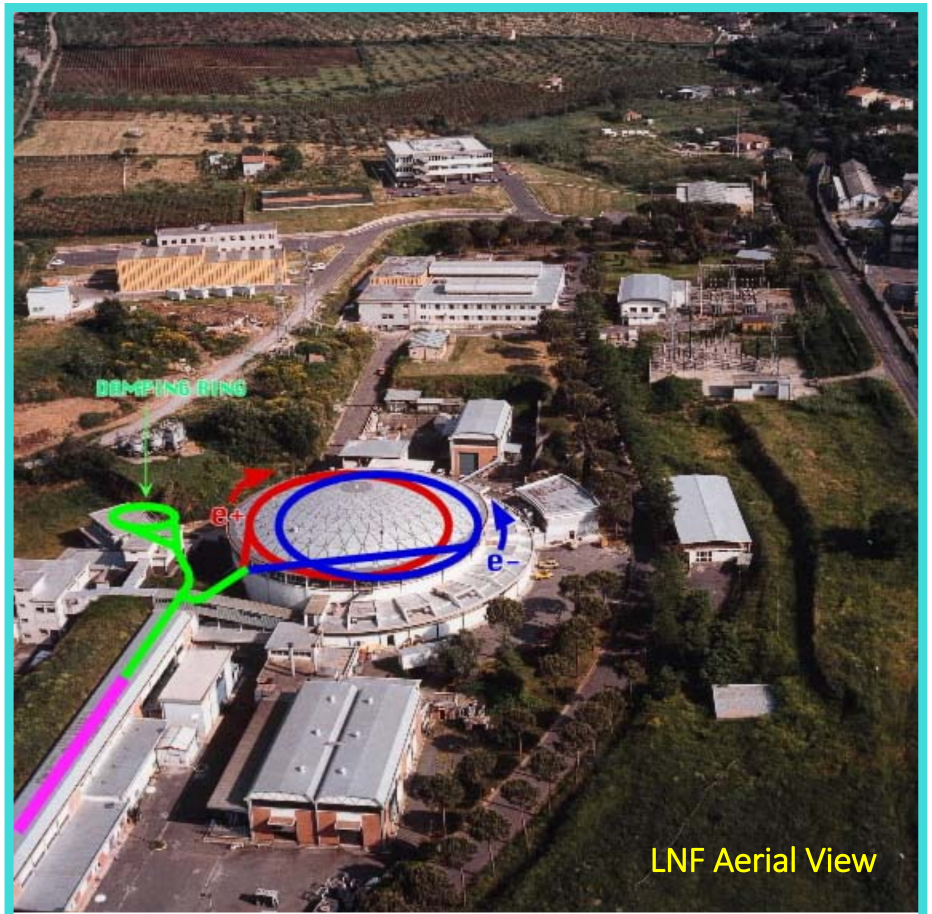
DAΦNE Setup and Optimization for the *kaonic deuterium run* of SIDDHARTA-2

Catia Milardi
on behalf of the DAΦNE Team

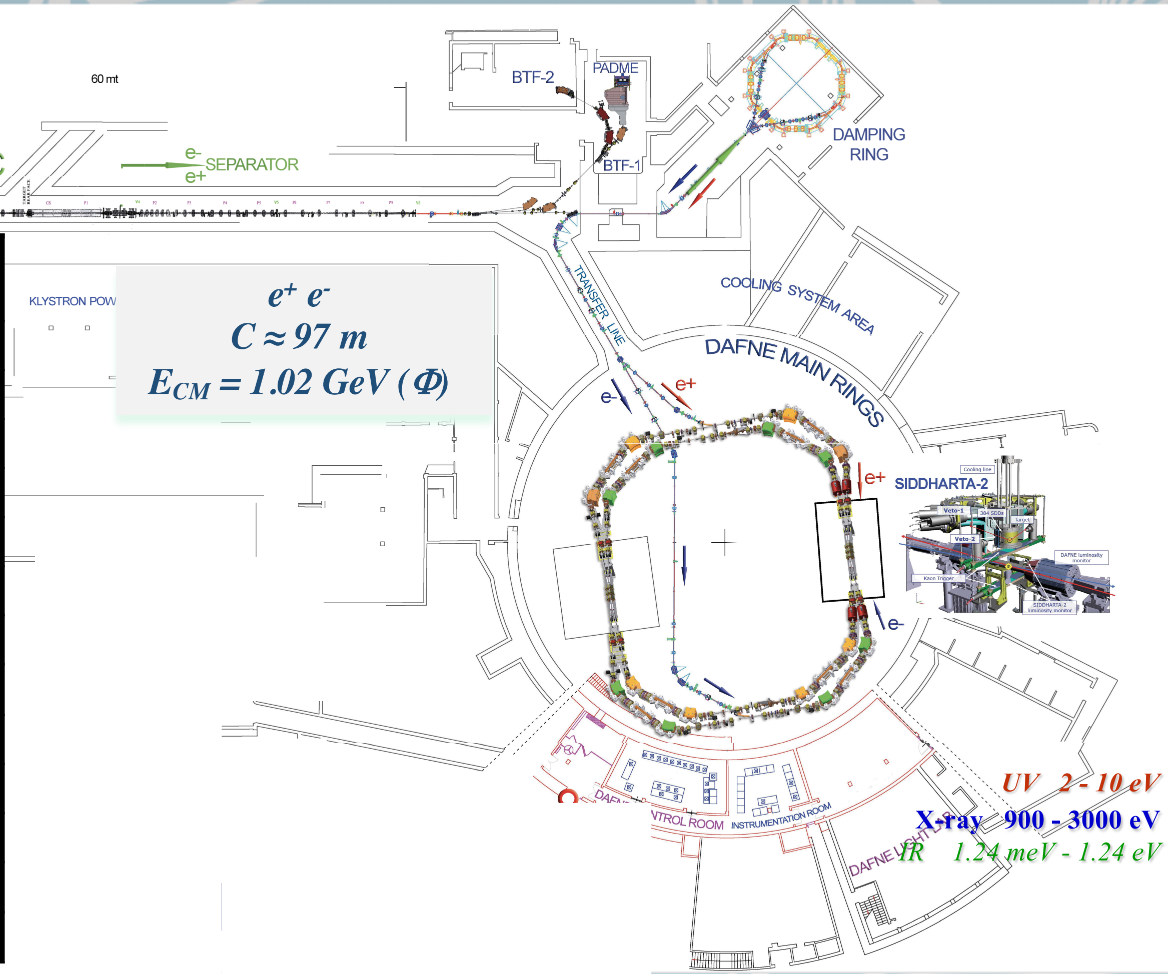


The DAΦNE Accelerator Complex

LINAC
e^+ 550 MeV
e^- 800 MeV

	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	1.7
β_y^* (cm)	1.80	0.8
σ_y^* (μm) low current	5.4	3.1
Coupling, %	0.5	0.5
Bunch spacing (ns)	2.7	2.7
I_{bunch} (mA)	13	15
σ_z (mm)	25	15
N_h	120	120

$e^+ e^-$
$C \approx 97$ m
$E_{CM} = 1.02$ GeV (Φ)



DAΦNE History & Plans

- DAΦNE is an electron-positron collider designed in the mid '90s, it came into stable operation in 2001.
- It was providing data in independent data-taking periods to:

  KLOE, **DEAR** and **FINUDA** experiments until 2007.

SIDDHARTA in 2008 ÷ 2009
KLOE-2 upgraded detector between November 2014 and March 2018.

Crab-Waist Collisions Scheme successfully implemented and tested

SIDDHARTA-2 **experiment** in 20019 ÷ 2024**,**

DAFNE-light Facility,
DAΦNE LINAC is securing data to two **BTF lines,** and
the **PADME** experiment.

Crab-Waist Colliders

Colliders	Location	Status
DAΦNE	Φ-Factory Frascati, Italy	In operation (SIDDHARTA, KLOE-2, **SIDDHARTA-2**)
SuperKEKB	B-Factory Tsukuba, Japan	Adoped CW collision in 2020 *World Luminosity record*
SuperC-Tau	C-Tau-Factory Sarov, Russia	Russian mega-science project
SuperTauCharm	Tau-Charm Factory Hefei, China	Proposed, significant R&D funding
FCC-ee	Z,W,H,tt-Factory CERN,Switzerland	91 km, CDR
CEPC	Z,W,H,tt-Factory China	100 km, CDR released in September 2018
Z-Factory	Novosibirsk, Russia	It will be presented in this WRK

SIDDHARTA-2 Run

Aimed at performing the first-ever measurement of kaonic deuterium X-ray transitions to the fundamental level.

*DAFNE is a unique machine for physics studies **requiring low-energy charged kaons with momenta below 140 MeV/c.***

DAFNE is, therefore, ideally suited for studying particle and nuclear physics in the sector of low-energy QCD with strangeness, even more as collisions at lepton machines naturally assure the minimal possible level of background on the detector with respect to hadron beam based experiments.

Achieving this goal, imposed to significantly reduce the signal-to-noise ratio detected by the experimental apparatus.

Preparation Activity for the SIDDHARTA-2 Run

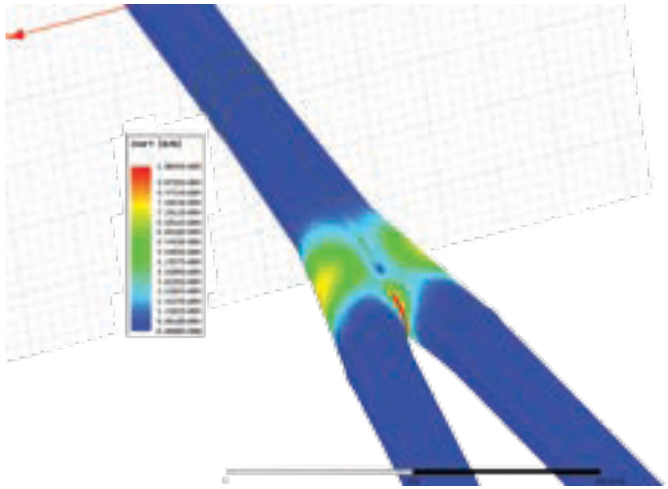
- A new Crab-Waist based Interaction Region was designed to host the SIDDHARTA-2 apparatus it includes:
  - new PM Quadrupoles for low-β section,
  - new Al beam pipe to fit with the new quadrupole apertures, paying great attention to the impedance budget of the new structure,
  - a new luminometer was installed in the IR in order to grant absolute and instantaneous luminosity measurement independently from the experiment.

- The PSs of the HV steering magnets in the e- and e+ rings were replaced with devices having 10 times higher accuracy and resolution.
- The capacitor bank of pulsed magnet PSs in the Transfer Lines were replaced.

- The longitudinal FBKs in the e- and e+ rings were upgraded by adopting the back-end, and the timing control based on QPSK.

- The injector system was provided with faster commutation procedure (TL and DR) and improved integrated diagnostics and simulation tools.

- The more than 500 PSs installed in the accelerator complex underwent a general maintenance.



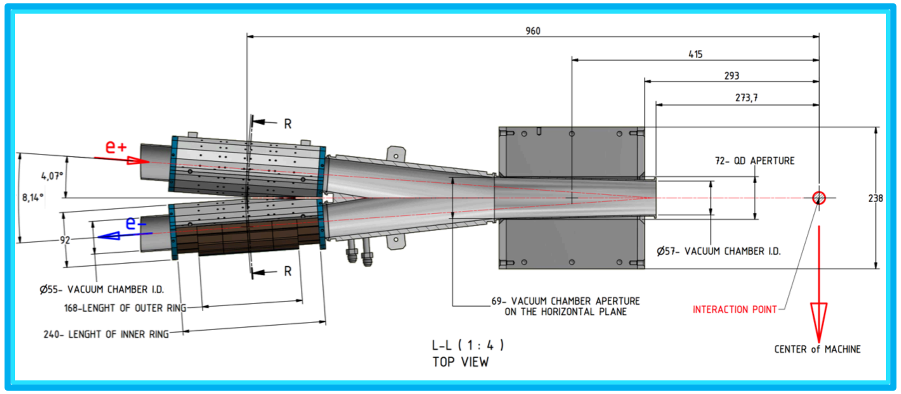
simulations with HFSS outlined the existence of two HOMs trapped in the Y-chamber at **frequencies of 1.863 MHz and 2.299 MHz**

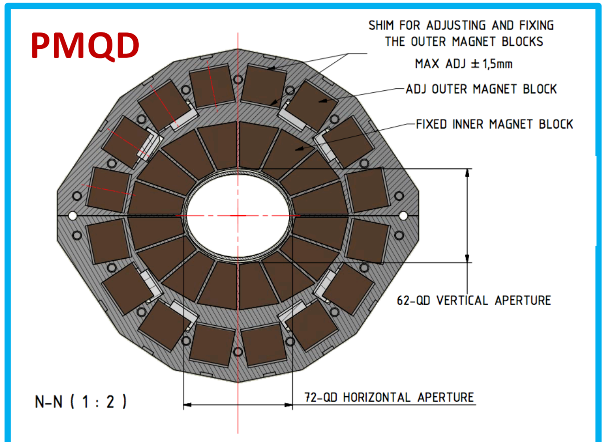
PMQs specifications

The design of the Permanent Magnets Quadrupoles installed in the low-beta of the IR was revised to:

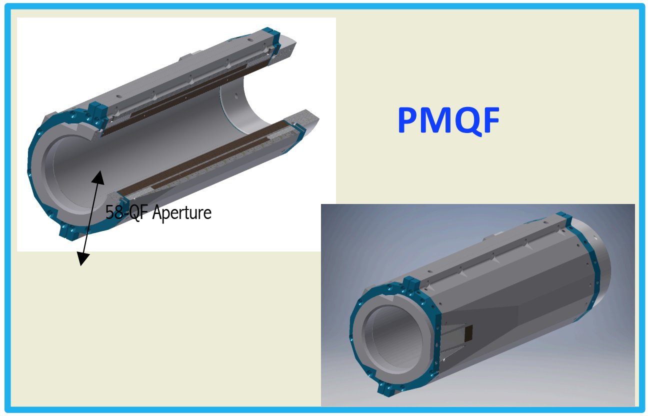
- reduce non linearities in the magnetic field,
- minimize the roll off off the field,
- ***provide larger stay clear aperture***.

New PMQs are Halbach type magnets made of SmCo2:17 designed in collaboration with the ESRF magnet group.





	PMQD	PMQF
Beam Pipe Aperture H-V (mm) at IP (I row) and at Y (II row) side	57 69 - 55	54
Inner Apert. With Case H-V (mm)	72 - 62	58
Outer Diameter H-V (mm)	238 - 220	95.6
Mech. Length Inner-Outer (mm)	220	168 - 240
Nominal Gradient (T/m)	29.2	12.6
Integrated Gradient (T)	6.7	3.0
Good Field Region (mm)	±20	±20
Integrated Field Quality |dB/B|	5.00E-4	5.00E-4
Magnet Assembly	2 halves	2 halves



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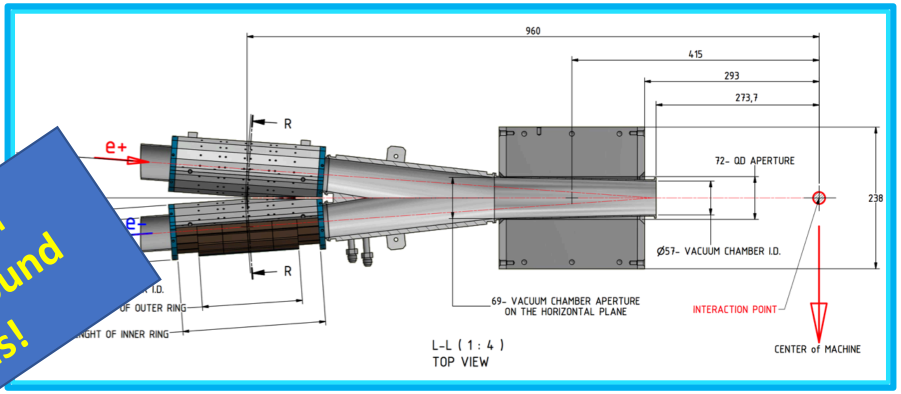
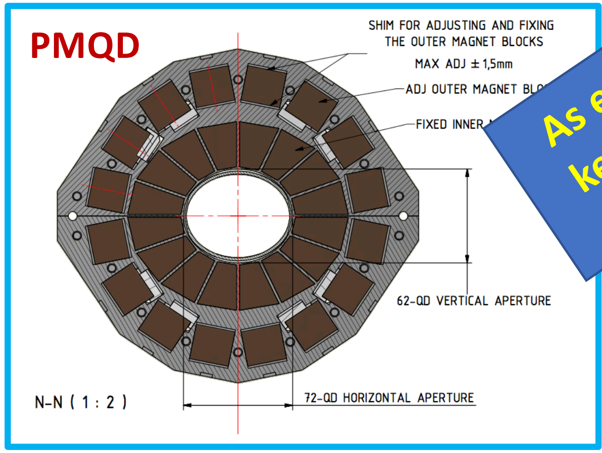


As expected this upgrade played a key role in reducing the background on the experimental apparatus!



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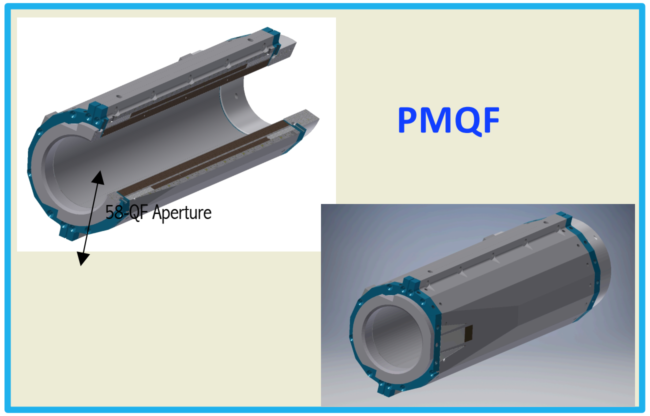


SIDDHARTA-2 Run Timeline

***Spt – Dec 2019* collider commissioning**

Mid Jan – March 2020 pandemic

***February – Jul 2021* resuming commissioning**

***Apr – Jul 2022* SIDDHARTINO run completed** *and preliminary run with Deuterium target*

The spectrum of the Kaonic hydrogen was measured with Improved precision

Apr – Jul 2023

The first Kaonic ^{4}He measurement (2021-2022)

Sep 15th – Dec 19th 2023

Periodical maintenance, and winter shutdown

First measurement of kaonic neon X-ray transitions (sub eV statistical accuracy)

Jan 18^{h} – Jul 8th 2024

Data taking with deuterium target and target calibration tests.

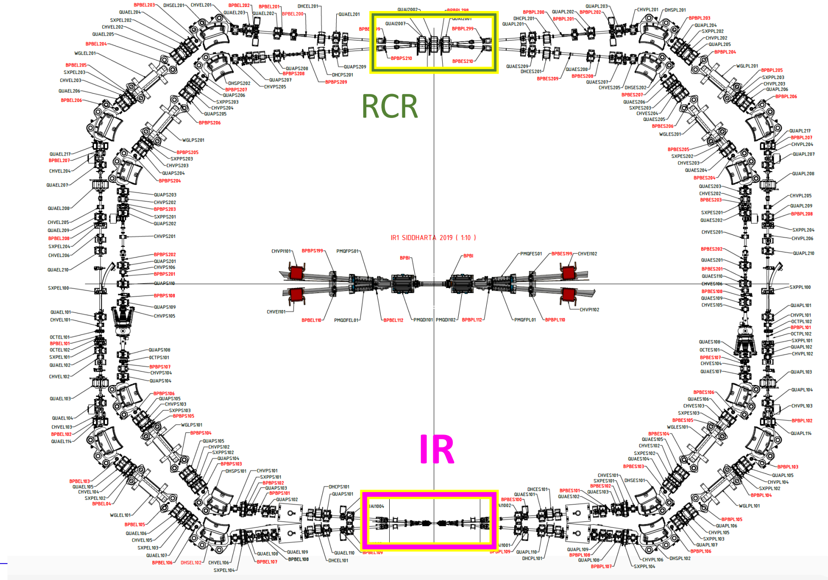
First measurement of the kaonic deuterium X-ray transition.

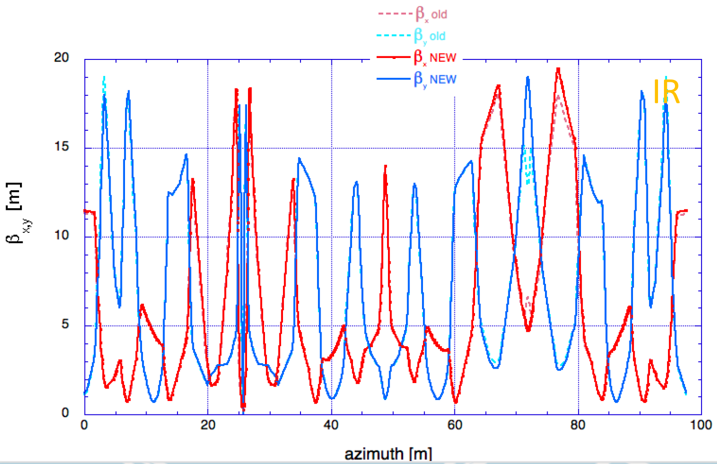
Main Rings Optics

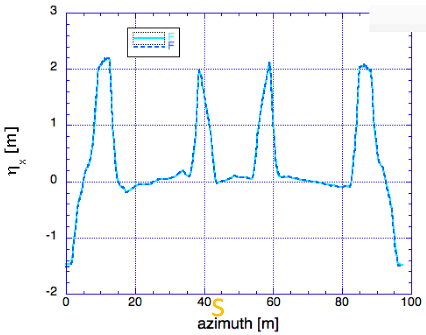
New Crab-Waist ring optics compatible with:

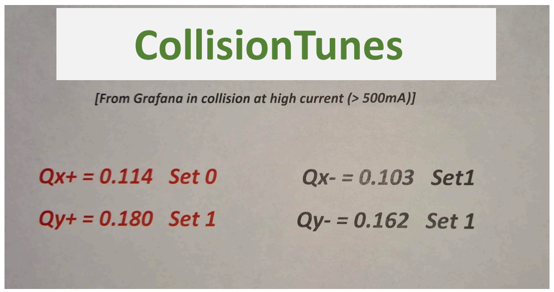
- new IR section;
- modified WIGGLER magnets;
- optimized Quadrupoles disposition in the straight sections;
- symplified focusing structure in the RCR, 2 QUADs where beams pass off-axis are switched off, thus eliminating spurious component in the large QUADs magnetic field.

New optics improves closed orbit correction allowing to reduce the total strength of the used steering magnets, thus also contributing to minimize vertical dispersion









Non-linear Optics

Sextupole magnets:

were set to correct chromaticity to zero,

Their alignment has been checked by **beam-based measurements**, in a few cases small closed orbit bumps have been applied to restore optimal alignment conditions,

one of the Crab-Waist sextupole in MRp required 1 mm mechanical alignment in the horizontal plane,

then they have **individually tuned in order to reduce the backgrou**nd shower on the detector and to improve the ring acceptance in injection,

At some point this iterative procedure required **improving vertical dispersion correction**

Crab-Waist Sextupoles have been progressively switched on, presently they are set at approximately 70% of their optimal strength.

Octupole magnets were used in the MRp only where they contribute to mitigate ***e-cloud*** induced effects by introducing Landau damping and to reduce background

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Non-linear Optics

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Run time optimization

The strengths of ***Crab-Waist Sextupoles*** have been progressively increased, up to **77% of their nominal value**. This allowed to improve instantaneous luminosity and background level control.

$$k_s = \frac{\chi}{2\theta} \frac{1}{\beta_y^* \beta_y^{sext}} \sqrt{\frac{\beta_x^*}{\beta_x^{sext}}}$$

Chromatic Sextupole and Octupole set-points have been **refined** according a comprehensive iterative optimization process, implemented experimentally, during data delivery, increasing:

- injection efficiency,
- beam lifetime,
- dynamic aperture,
- energy acceptance.

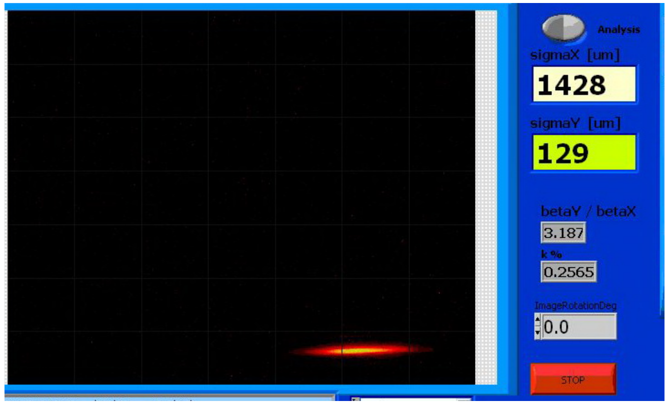
Energy aperture A_E

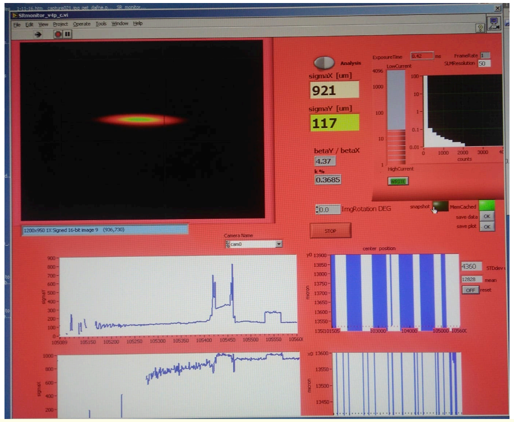
-3.8 MeV (-0.8%) ≤ A_E ≤ 3.1 MeV (0.6%)

This procedure led to a remarkable reduction of the background affecting the measurements, how it will be shown in the following.

Betatron Coupling Correction

Crab-Waist Optics
Linear lattice





Beam profile at the SLM

Betatron coupling correction implemented by:

- closed orbit correction
- stearing magnets strength minimization
- vertical dispersion tuning
- **rotating the 2 PMQF of the low-β in the IR**

After correction:

κ ~ .3 % for both beams

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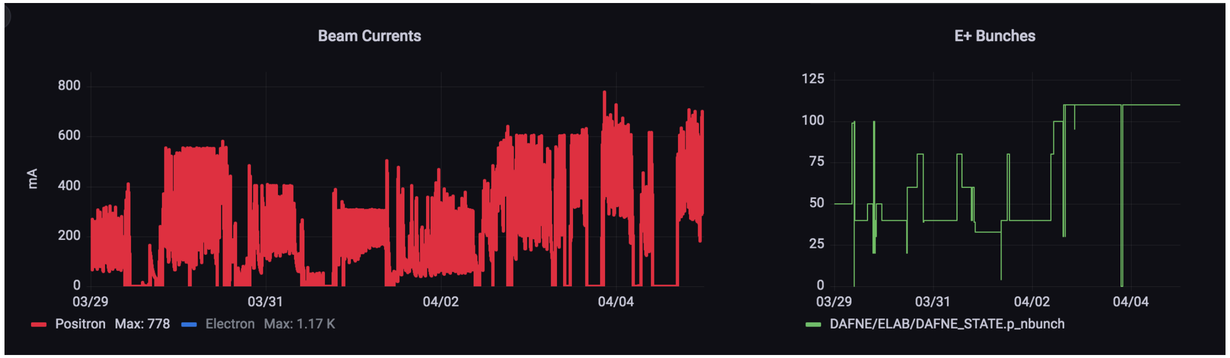
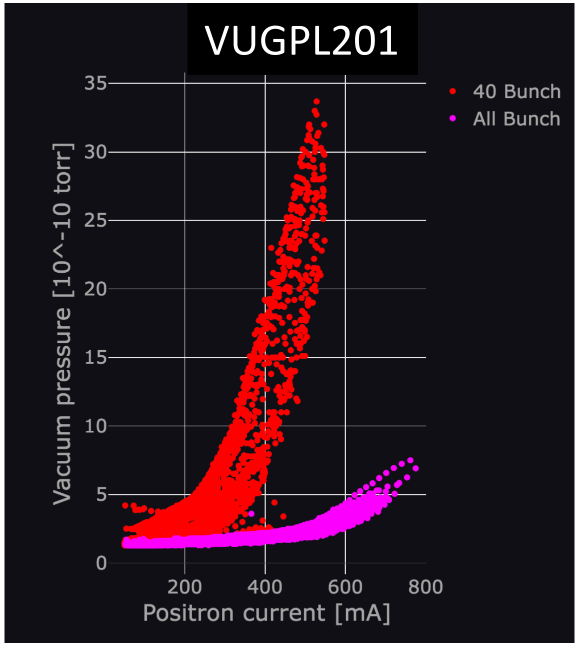
Vacuum and Beam Dynamics

Scrubbing Dedicated Runs

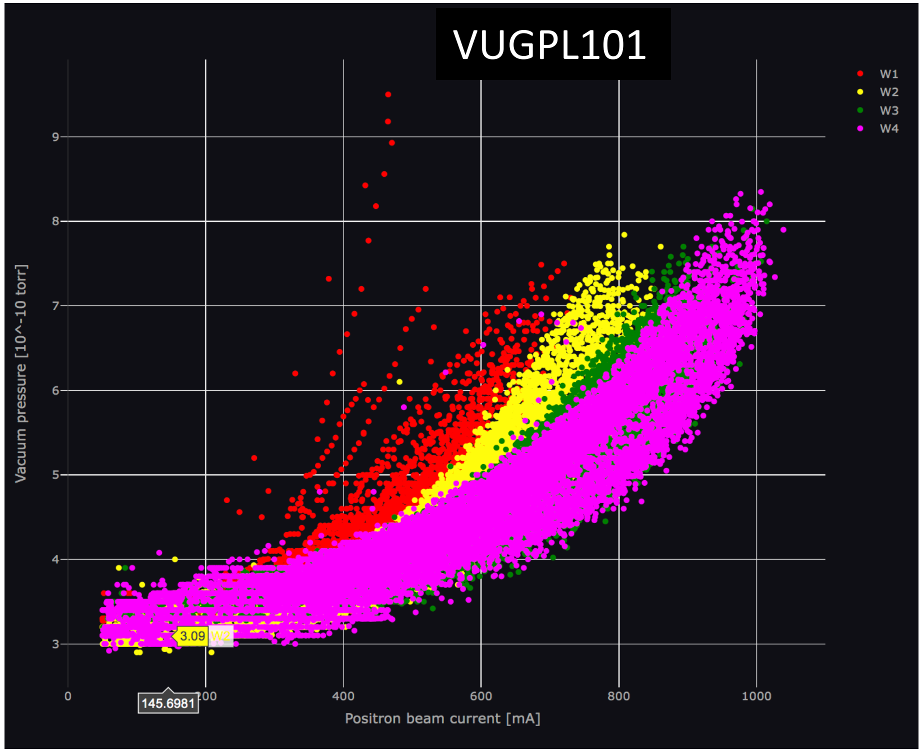




In the first stage of the operations dedicated beam **conditioning**, and beam ***scrubbing runs.***

Scrubbing was carried out using 40 bunches pattern with 2 empty buckets spacing and switching off solenoids to enhance e-cloud activity.

Scrubbing during Operations



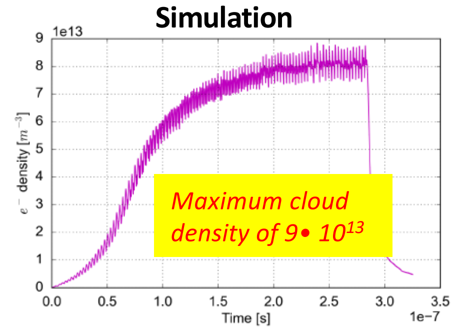
110 contigous bunches

Pressure rise at VUGPL101, different colors represents values measured during four consecutive weeks

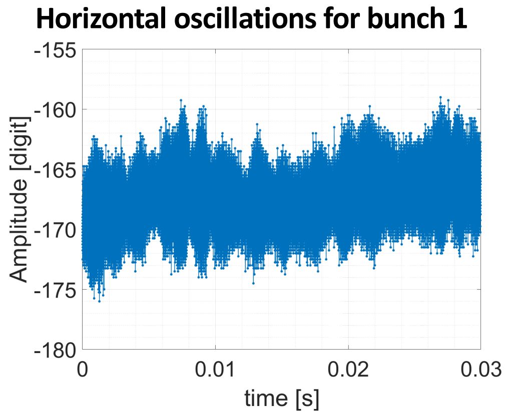
E-cloud studies in the Positron Ring

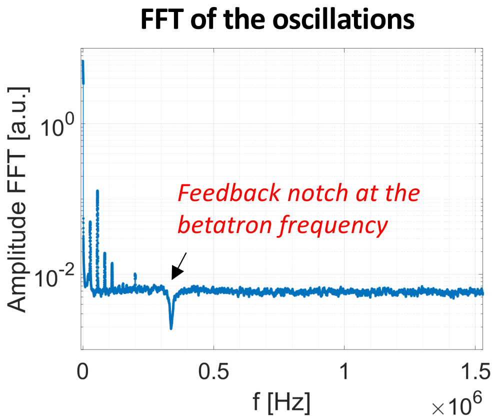
Tune-shift measurements

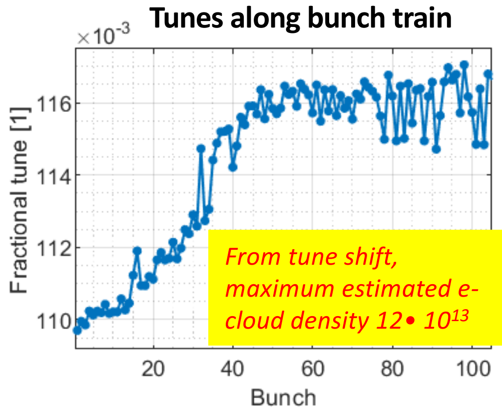
- The **electron-cloud instability** is a major limitation for positron beams at DAΦNE.
- **The transverse feedback** front-end was used as a **diagnostic tool** to evaluate this instability.
- Bunch transverse oscillations digitized by the ADC are analyzed to **compute the fractional tunes,** which is determined with a **resolution of 10^{-5}.**



Data refer to 105 positron bunches in DAFNE, 800 mA average current, FBKs ON







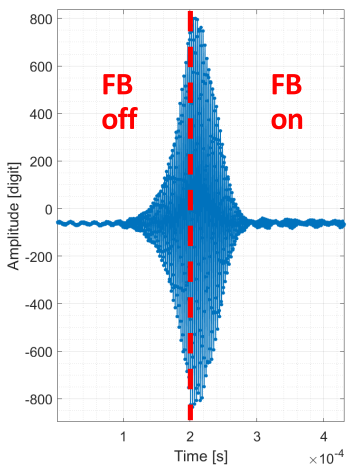
E-cloud studies in the Positron Ring

Grow-damp measurements

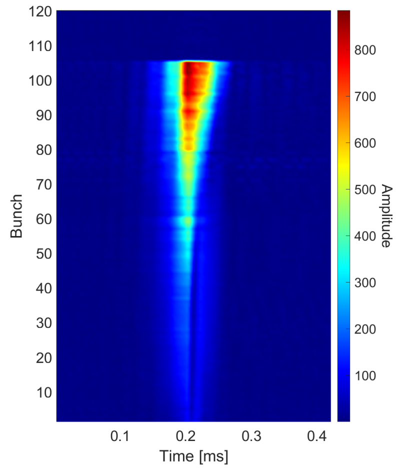
- Grow-damp measurements: horizontal feedback off for a short time.
- A quasi-online analysis computes the grow rates of the coupled-bunch modes.
- This analysis is a useful diagnostic tool to evaluate the strength of the electron-cloud induced oscillation modes as a function of the e^+ beam stored current and for different filling patterns.

Example: 105 consecutive positron bunches, 720 mA average current, feedback off for 0.2 ms

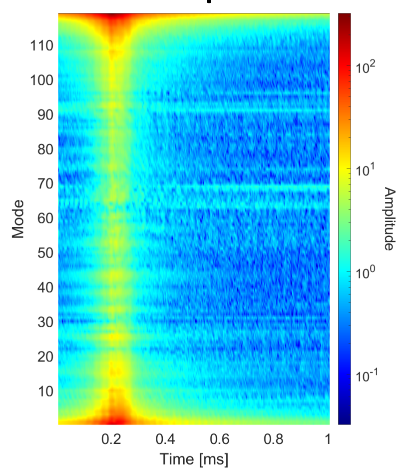
Oscillations of bunch 105



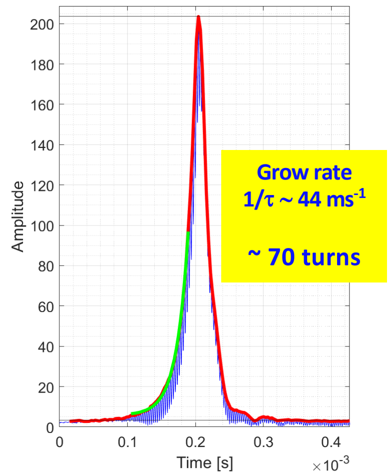
Oscillation amplitudes



Mode amplitudes



Amplitude of mode 119

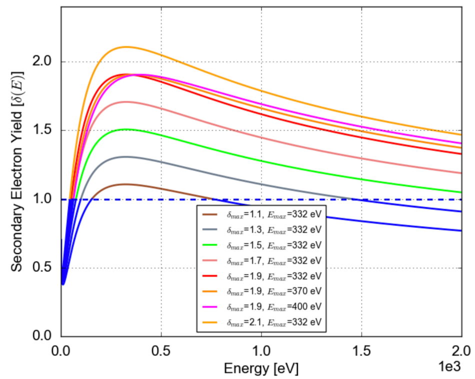


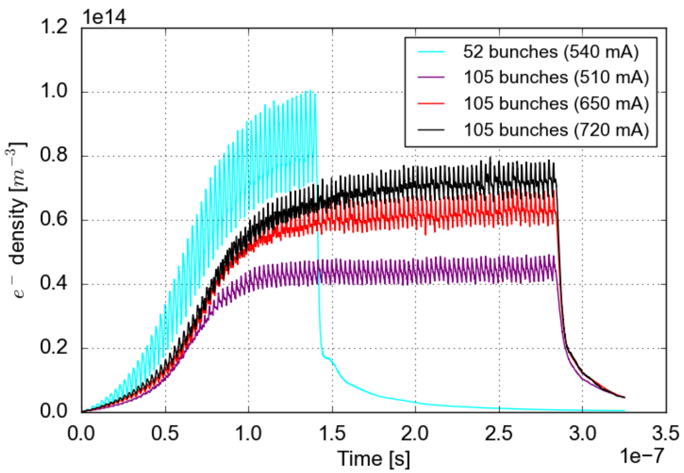
E-cloud Simulations

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





	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}

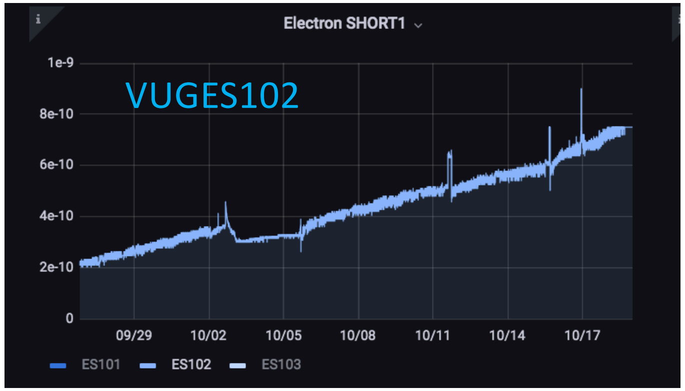
Beam current	**Measured tune shift**	**e^- density**
800 mA	7.0×10^{-3}	8.8×10^{13} m^{-3}
750 mA	6.3×10^{-3}	8.0×10^{13} m^{-3}
600 mA	4.8×10^{-3}	6.0×10^{13} m^{-3}
400 mA	3.3×10^{-3}	3.5×10^{13} m^{-3}

Vacuum Leak in the Electron Ring

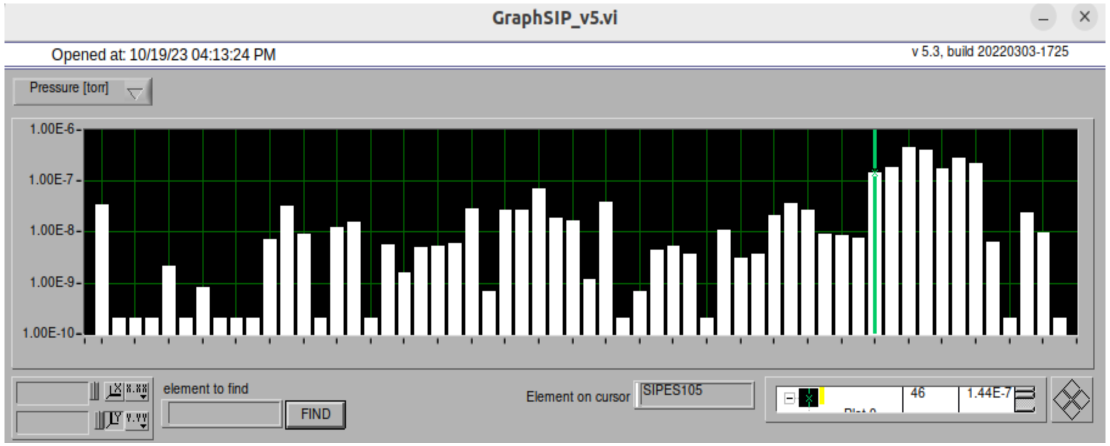
Electron beam dynamics observations and tuning

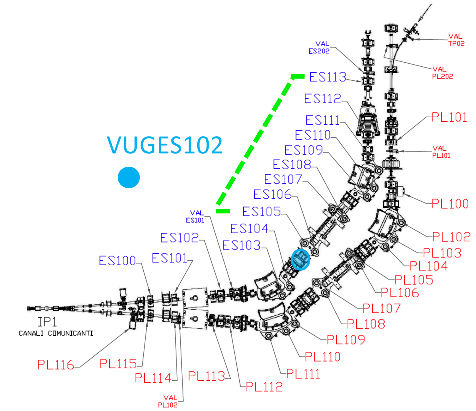
- Vertical tune had to be lowered wrt the nominal one.
- Strong vertical instability appeared, even in single beam mode, it was damped by beam-beam only for current of the e+ beam lower than 750 mA, above this threshold the e- beam blew up vertically, luminosity dropped as background increased suddenly.
- Poor lifetime.
- Flip-flop.
- Sudden beam losses above 1.5 A.

All these effects were largely mitigated by decreasing the number of bunches from 110 to 95.



Electron beam was clearly affected by ion trapping although there was no clear evidence of vacuum issues.





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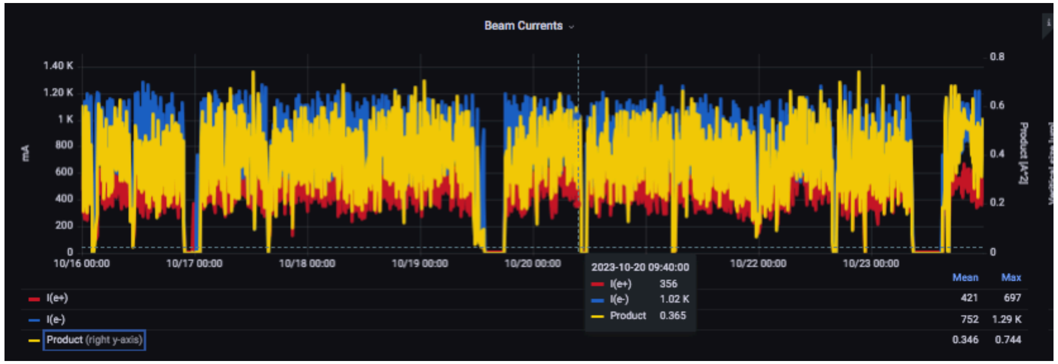
Collisions

the intervention to fix the elusive vacuum leak was prepared in the week 16 - 23 October



Maximum beam currents in 95 bunches:

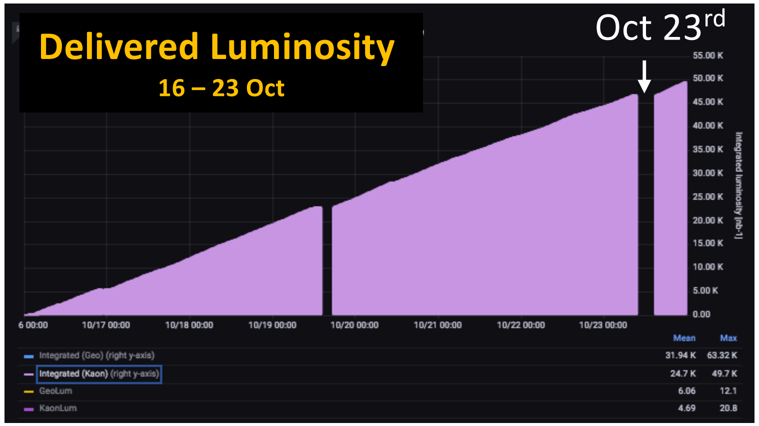
$I^+ = 0.7$ A

$I^- = 1.3$ A

Few interruptions were planned in order to:

- check vacuum equipment,
- install tools to search for the leak,
- find out the leak, which was on a flange of an absorber in the ES1 arc.

50 pb^{-1} delivered with a 89% uptime.



Collisions After Vacuum Leak Fixing

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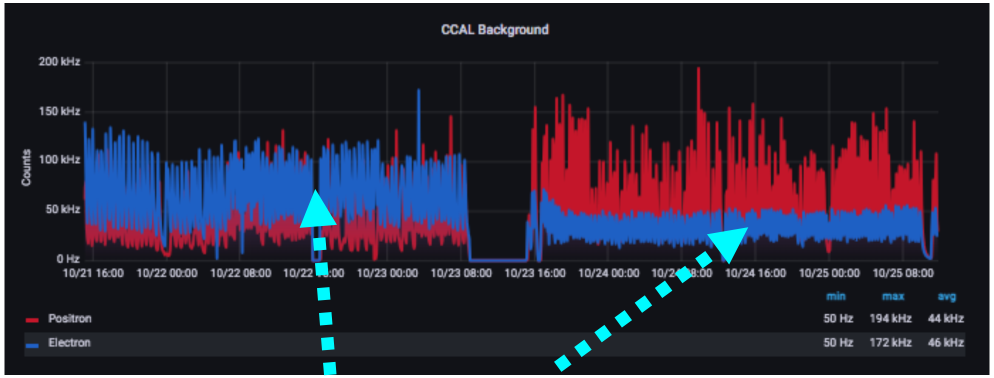
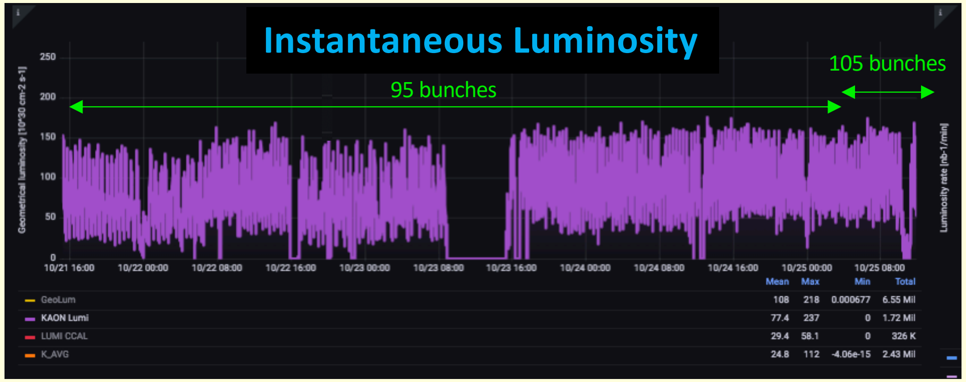
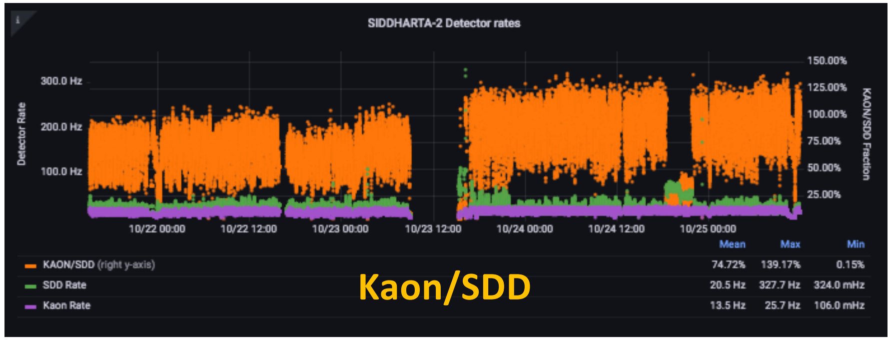
Huge reduction of several backgroung parameters was oserved

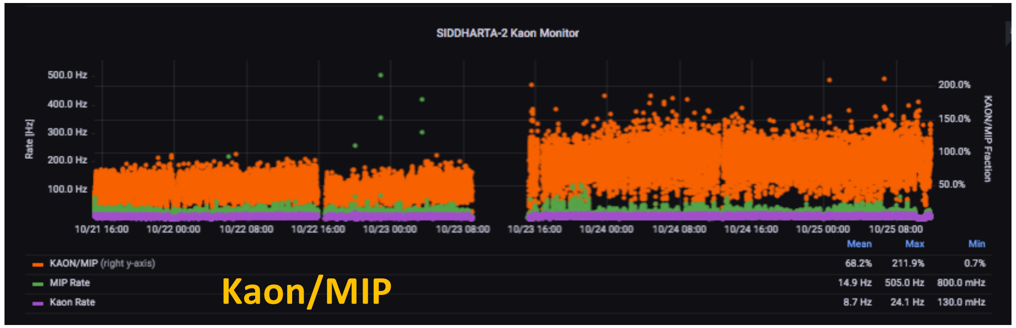


Counting rate out of coincidence of the CCAL luminosity monitor

Collisions with 105 bunches without e^- beam vertical blow up







Beam Dynamics
RF and Feedback Systems

RF and Feedback Systems

A harmful interference between ***longitudinal instabilities and beam-beam interaction*** was cured by tuning the **mode-0 feedback of the RF in MRp**, that at high current was in anti-damping.

A rather large difference in the spread of the synchronous phases of the two beams was eliminated by tuning the phase loop of the RF in MRp. This allowed to **restore uniform beam current distribution along the e^+ batch and, in turn, to equalize beam-beam kick for different bunch pairs.**

Sudden electron beam losses occurring above a current threshold in the range 1- 1.1 A. have been cured after a meticulous fine-tuning of the ***low-level RF feedback amplifier*** and ***mode-0 feedbac***k.

Luminosity & Background Optimization

Luminosity and Background Diagnostics

DAΦNE **luminosity** measurement relies on two devices:
CCAL (Crystal CALorimeters), and Gamma monitors, used for machine tuning.

- CCAL measures the Bhabha scattering events at small angle, it consists of two identical crystal calorimeters installed in front of each permanent magnet defocusing quadrupoles of the low-β in the IR
- Gamma monitors are gamma bremsstrahlung proportional counters which are installed on both sides of the IR where the two beam pipes split

These detectors, thanks to the very high rates, can be efficiently used as real-time tools during machine luminosity optimization.

However, they cannot provide a reliable absolute luminosity measurement since CCAL has not yet been properly calibrated, and the gamma monitor is heavily affected by beam losses.

The absolute measurement of the collider luminosity is provided by the SIDDHARTA-2 detector *based on charged kaon flux measurement.*

Luminosity and Background Diagnostics

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The **background** level on the experimental apparatus (BCK) is monitored, in real-time, by counters based on Kaon over Minimum Ionising Particle rate (Kaon/MIP), and Kaon over Silicon Drift Detector rate (Kaon/SDD) also provided by the SIDDHARTA-2 experiment.
CCAL also provides a powerful BCK diagnostics, mostly in injection.

Kaon/SDD was used as a main data quality parameter, L_{HQ} , to discriminates whether data can be used for physics analysis or not.

Data Quality Threshold $L_{HQ} \geq 0.6$

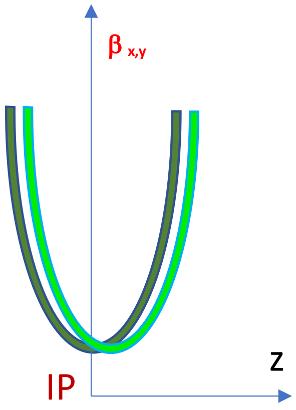
Luminosity Optimization

Optimal luminosity conditions have been attained by:

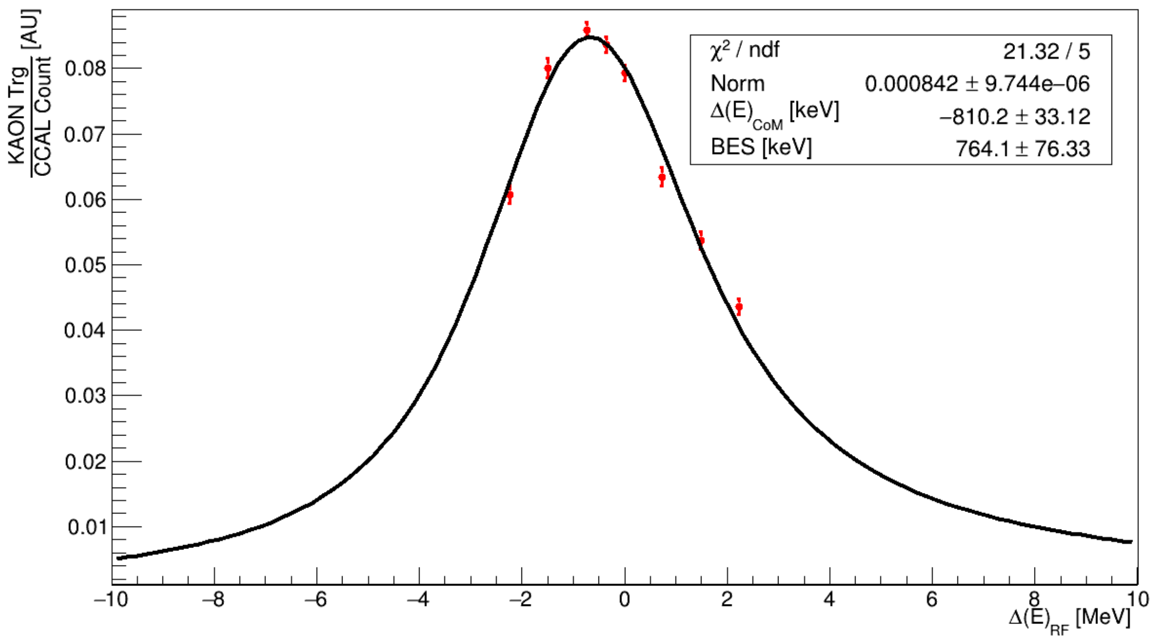
- scanning one beam through the other at the IP using:
  - Position and angle closed bumps in the transverse plane,
  - moving the phase of one of the two beam RF cavity to perform longitudinal overlap.

- moving the waist of each beam using orthogonal $\alpha^*_{x,y}$ closed bumps, **waist overlap gave ~ 15% increase in terms of instantaneous luminosity**.

All the bumps for luminosity optimization in the transverse plane have been computed by using the ring optics model.



Energy Scan



ΔE_{CM} = - 760 keV

-0.7% variation for each beam

7% gain in terms of charged kaon yield

Energy scan as a function of the absolute energy deviation w.r.t. the starting point of the scan, the fitting function includes radiative corrections and the beam energy spread is left as free parameter.

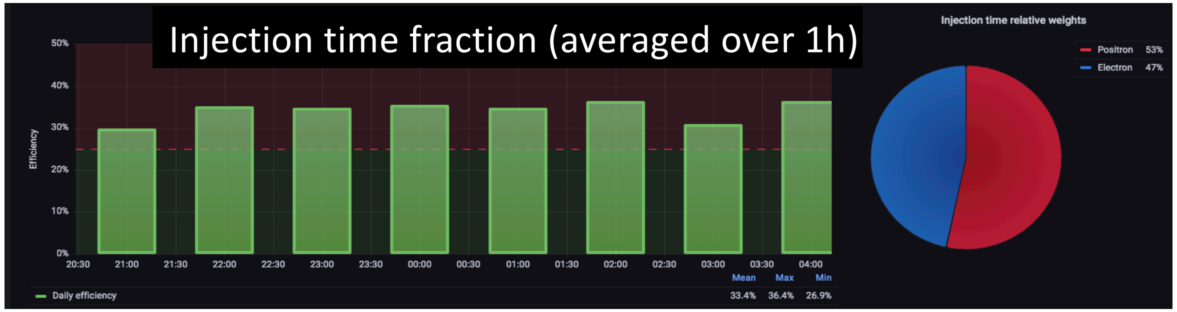
Injection

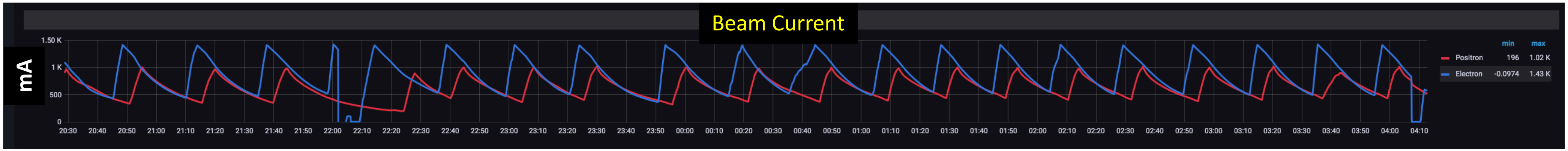
LINAC was operated at 25 Hz, Injection in the MRs was performed at 2 Hz and at 1 Hz for the e^- and the e^+ beam respectively.

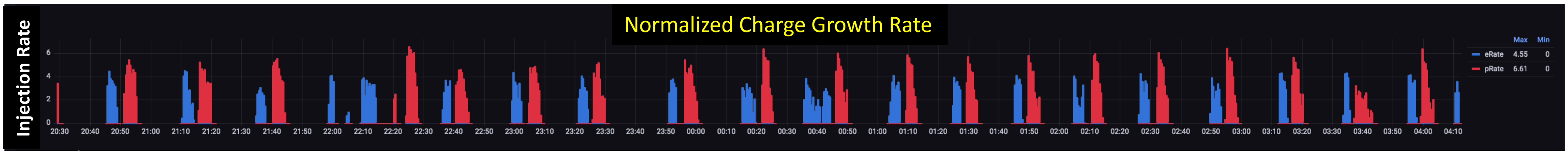
Optimal Injection efficiency was in the range of 70% ÷ 80% for both beams, with a transport efficiency along the Transfer Lines close to 100%.

Reproducibility was poor.
Injection required continuous and careful optimization of the injector system.

Optimal injection condition were essential in order to achieve high beam intensity, and to properly setup all the subsystems responsible for beam stability.







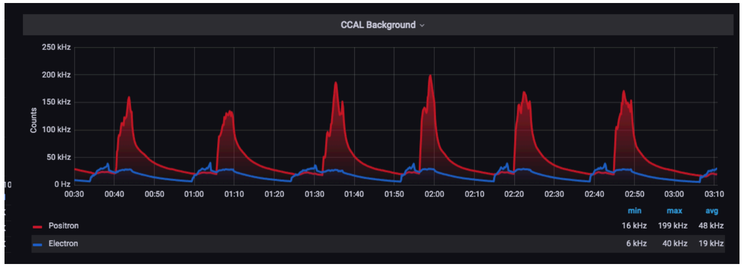
Injection induced Background

In a collider there are two different kinds of backgrounds produced during the injection and costing phase respectively.
They require completely different analysis and mitigation approaches.

Injection background has been considerably reduced by optimizing injection efficiency, and by properly steering the stored beam orbit in the injection sections.
This reduced the background down to acceptable levels for the e^- beam, but it did not work as well for e^+ one.

For this reason, *vertical dimension of the e^- beam are artificially increased* during injection, by using a calibrated skew quadrupoles bump.
In this way the beam-beam kick on the weaker e^+ beam was reduced, thus avoiding rapid lifetime drops and sudden background bursts.

LINAC works at 25 Hz
Injection in MRs:
2 Hz for e-
1 Hz for e+



Background Optimization during Costing

Background Diagnostics

During commissioning background optimization process was largely based on the counting rate out of coincidence provided by the CCAL luminometer.
At regime background level was monitored, in real-time, by counters based on Kaon/Mip rate, and Kaon/SDD rate provided by the SIDDHARTA-2 detector.

Kaon/Mip and Kaon/SDD increased by a factor of 1.4 and 3, respectively.

Improvements were due to:

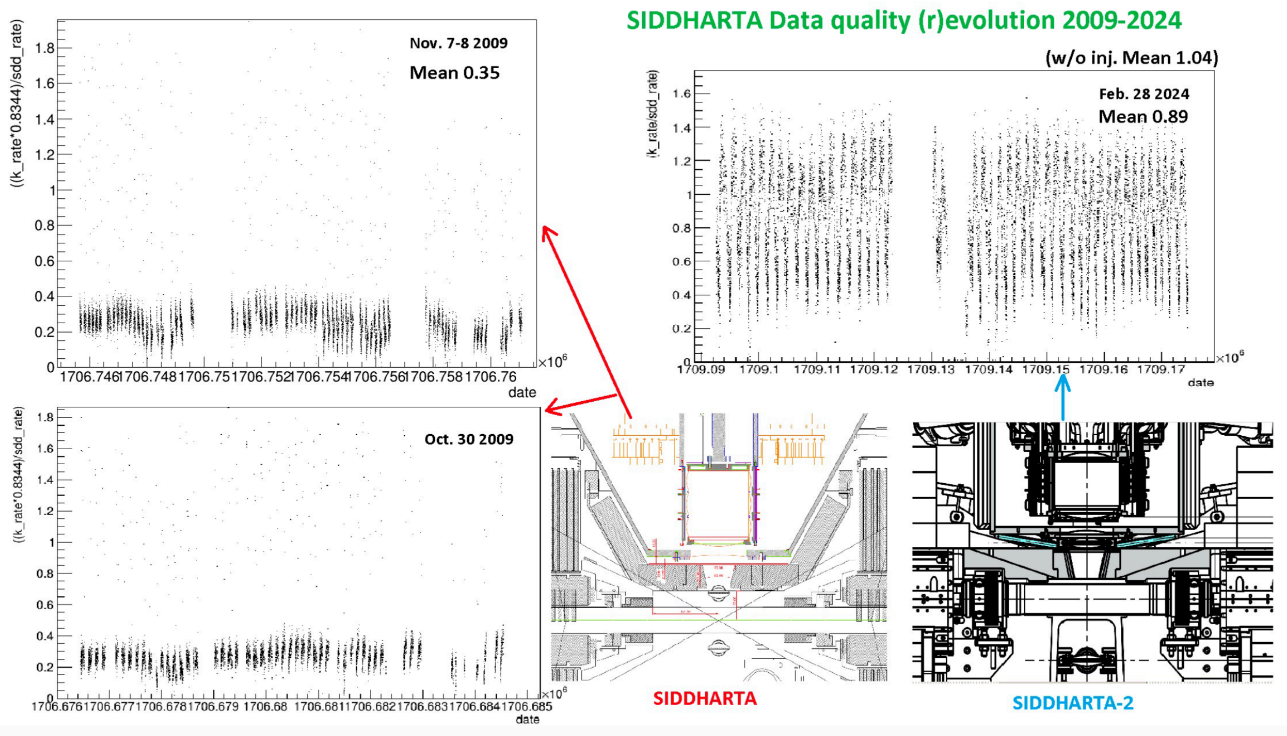
- collimators optimization,
- linear and non-linear optics fine tuning,
- RF cavity and feedback systems configuration, a strong correlation was observed between voltage of the RF cavities and background, reducing the voltage by few 10 of KV a 15% Kaon/MIP rate was measured,
- beam dynamics stability enhancement.

Injection efficiency also played a relevant role especially as far as the background during injection is concerned.

Background Reduction

Physics events delivered to SIDDHARTA-2 experiment exhibit a signal to noise ratio 3 time higher w.r.t. the 2009 run. This was evaluated taking into account the acceptance of the new detector components: kaon trigger, and SDD. Other analysis parameters such as trigger efficiency, and veto system have not been included.

Preliminary analysis indicates this improvement is in large part due to the collider configuration, and to the new design of the PMQD installed in the low-beta of the interaction region.

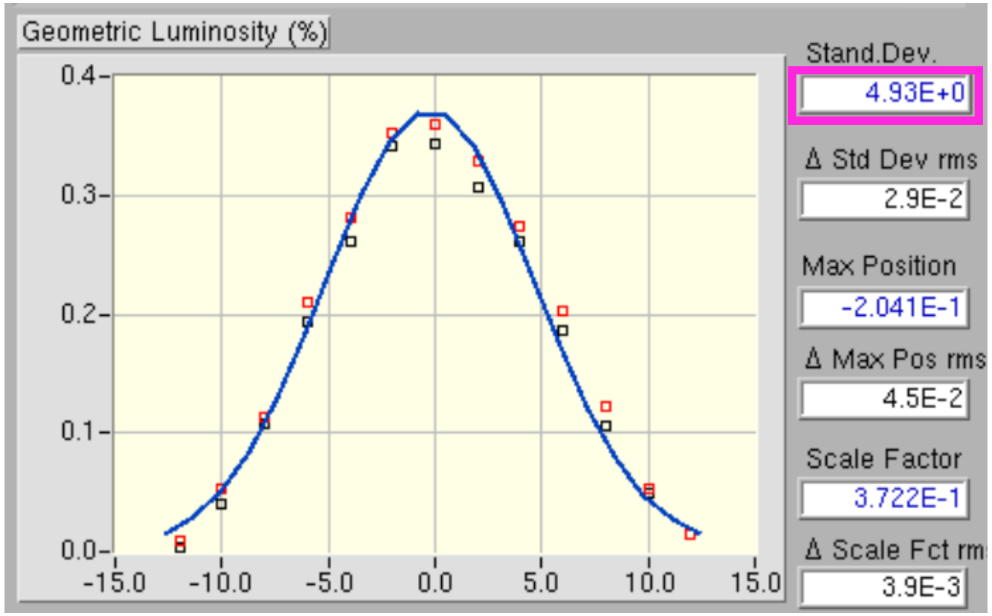


(Analysis from M. Iliescu)

Vertical Beam-Beam Scan

Collisions with low single bunch current

$I^- = 73$ mA
$I^+ = 75$ mA
$n_b = 80$



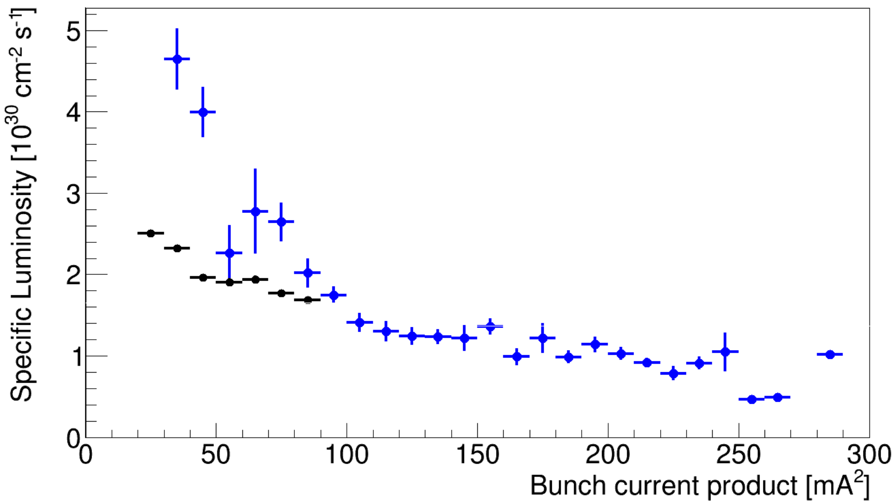
$$\Sigma_y = \Sigma_y^{meas} * 0.88$$

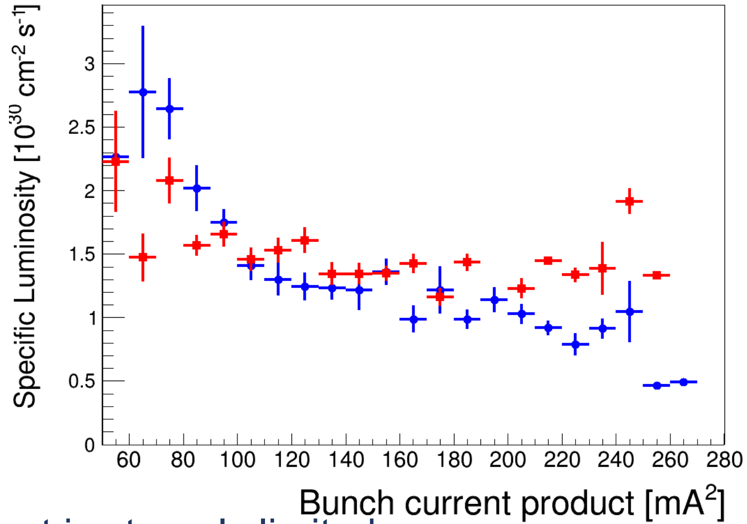
$$\Sigma_y = \sqrt{\sigma_{ypos}^2 + \sigma_{yele}^2}$$

$$\boldsymbol{\sigma_y = 3.07\ \mu m}$$

Lowest σ_y ever measured at DAΦNE

10 bunches collisions





During normal operations the single bunch current is strongly limited.
Neglecting collective effects (**10 bunches collisions**) the specific luminosity is almost twice the one normally obtained with 110 bunches (black).

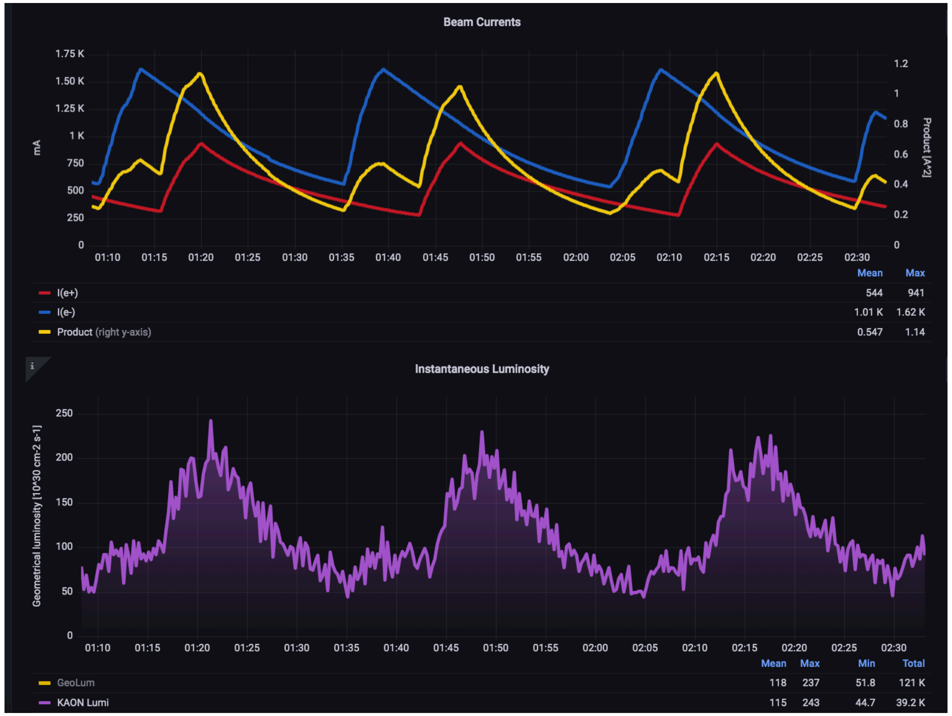
With higher value of the Crab-Waist Sextupoles it is possible to reach even higher specific luminosity at high bunch current.

DAΦNE Performances during data delivery

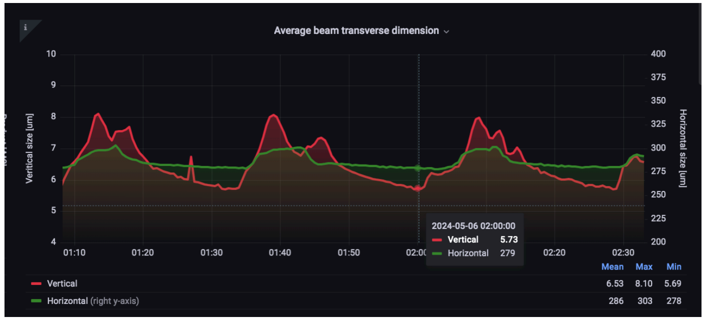
Peak Luminosity

$L_{peak} = 2.4 \bullet 10^{32}\ cm^{-2}s^{-1}$

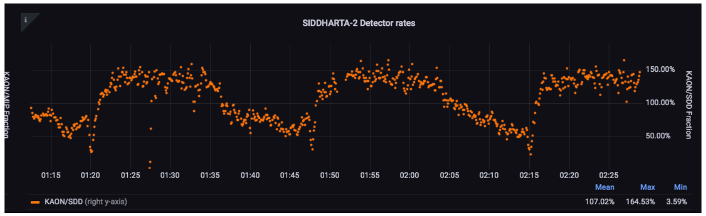
$I^-_{peak} = 1.14$ A
$I^+_{peak} = 0.89$ A



Average value of the convoluted transverse beam dimensions



Kaon/SDD



L_{HQ} ~ 97%

3h Integrated Luminosity

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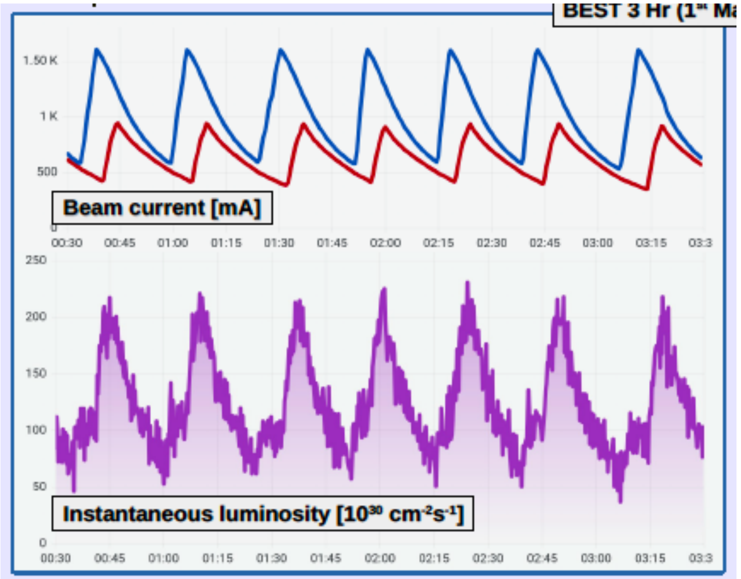
Laboratori Nazionali di Frascati

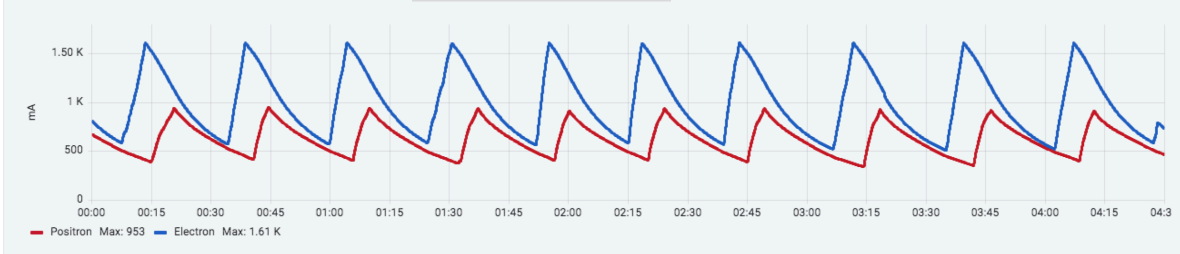
Best $\int_{3h} L = 1.33\ pb^{-1}$

Optimal BCK levels, and L_{HQ} factor.

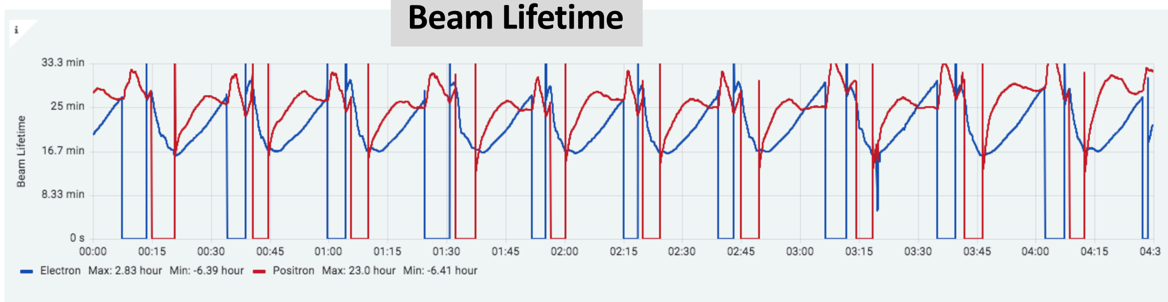


May 1st 2024

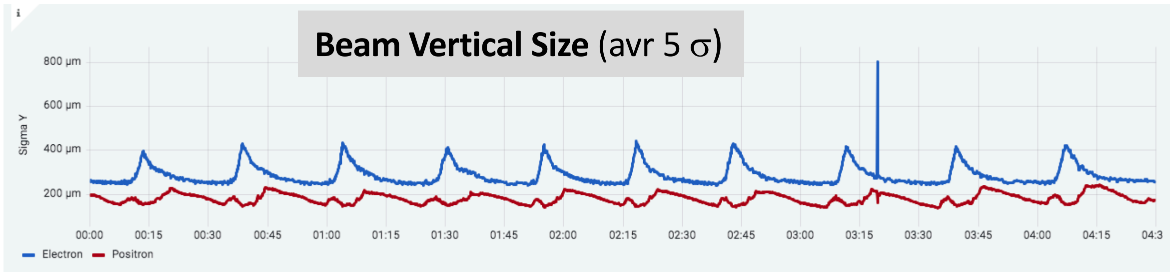
Beam Currents



Beam Lifetime



Beam Vertical Size (avr 5 σ)



Daily Integrated Luminosity

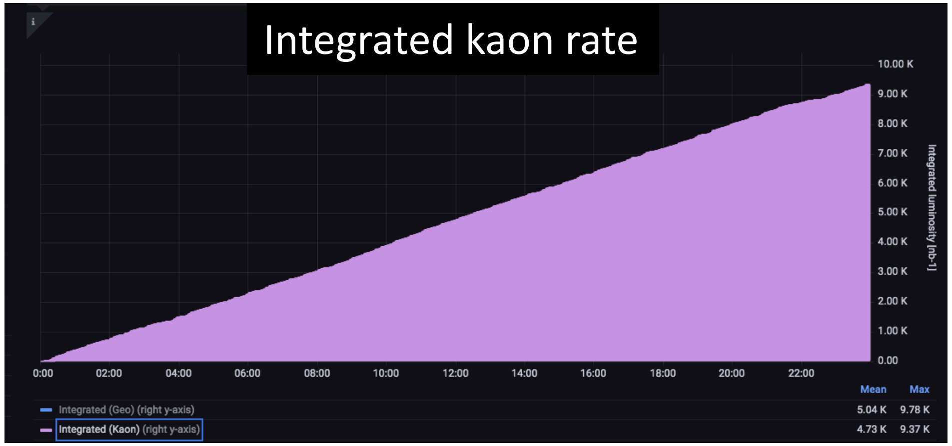
Daily integrated luminosity

$$\int_{day} L = 9.4\ pb^{-1}$$

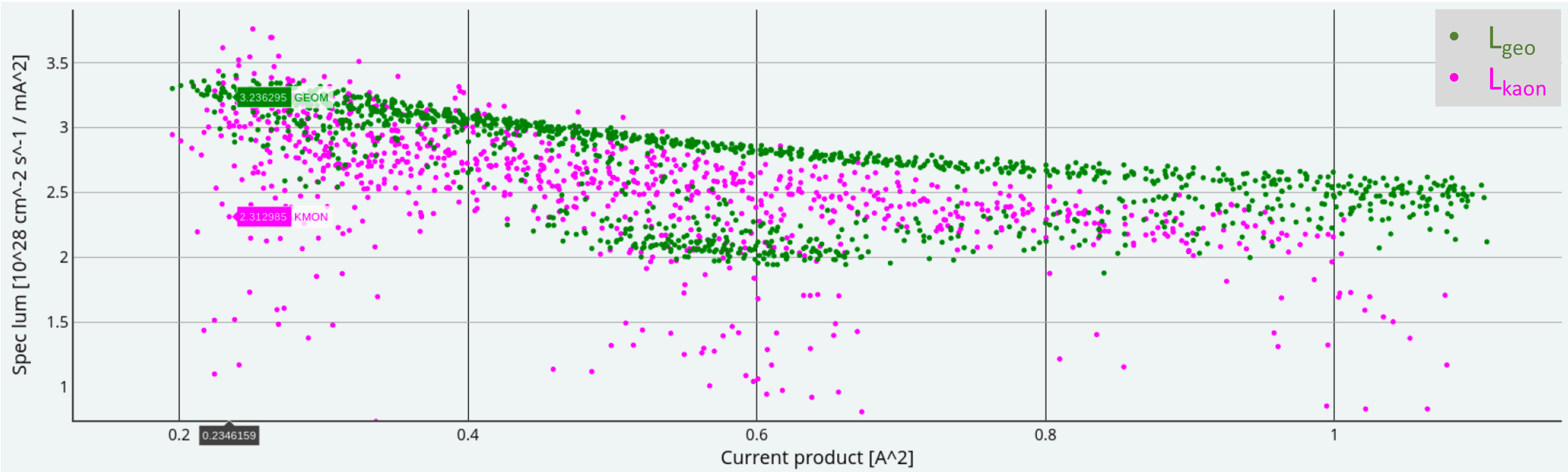
$I^{-}_{MAX} = 1.65$ A

$I^{+}_{MAX} = 1.0$ A

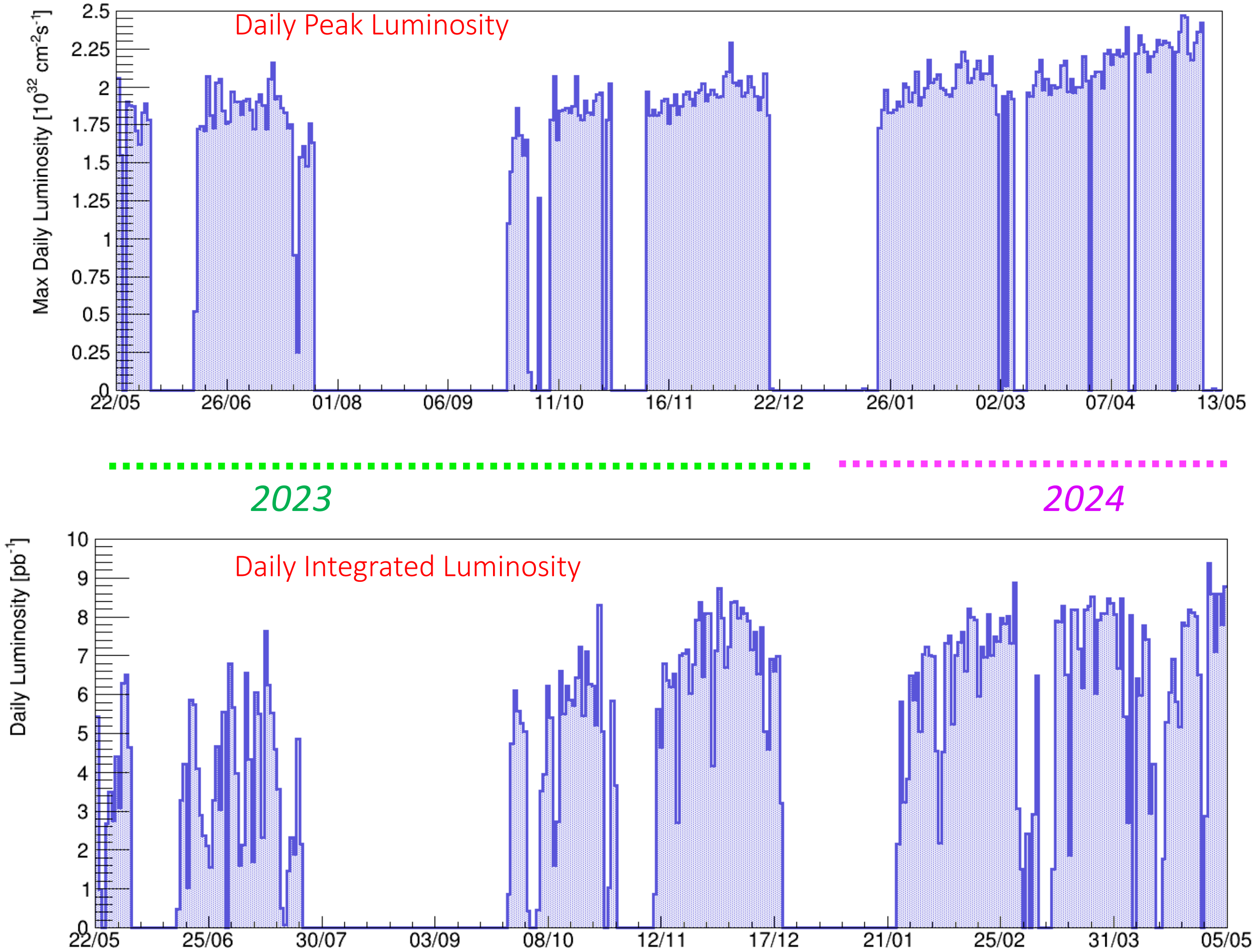
$L_{HQ} \sim 96\%$



Specific Luminosity



Luminosity Trends



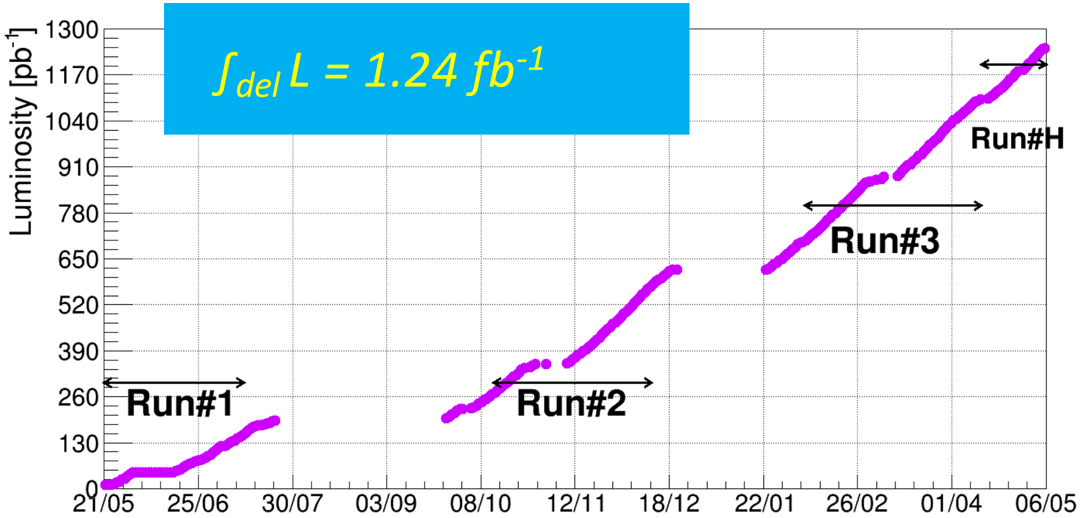
Total Integrated Luminosity

DATE	L_{acq} [pb^{-1}]	L_{acq} [pb^{-1}] $L_{HQ} \geq 0.6$	Good Data %
Run-1 (21/05/23 ÷ 21/07/23)	196	164	84
Run-2 (13/10/23 ÷ 11/12/23)	344	276	80
Run-3 (06/02/24 ÷ 12/04/24)	435	375	86
Run-H for calibration (12/4/24 ÷ 6/5/24)	153	140	91,5
Total	1128	955	85

The fraction of high-quality data increased significantly along the time thank to collider adiabatic tuning, and machine studies.

Signal to noise ratio was 3 times higher wrt the one measured in 2009.

It was evaluated taking into account the acceptance of the new detector components: kaon, trigger, and SDD.



DAΦNE Performances Summary

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Instantaneous peak Luminosity achieved at DAΦNE is about an order of magnitude higher than the one obtained at other colliders operating in the low energy range.

	DAΦNE KLOE (2005)	DAΦNE CW upgrade tested with SIDDHARTA (2009)	DAΦNE (CW) KLOE-2 (2014)	DAΦNE (CW) SIDDHARTA-2 (2024)
L_{peak} [$cm^{-2}s^{-1}$]	$1.50 \cdot 10^{32}$	$4.53 \cdot 10^{32}$	$2.38 \cdot 10^{32}$	$2.4 \cdot 10^{32}$
I^- [A]	1.4	1.52	1.18	1.29
I^+ [A]	1.2	1.0	0.87	0.887
ε_x [mm mrad]	0.34	0.28	0.28	0.28
$N_{bunches}$	111	105	106	110
$\int_{1h} L$ [pb^{-1}]	0.4	0.79	0.67	0.41
$\int_{day} L$ [pb^{-1}]	9.8 (seldom)	14.98	14.3	9.37
$\int_{1h} L$ [fb^{-1}]	3.0		6.8	1.24
ξ_y	0.0245	0.0443 (0.09 w.s.)	--	--

Conclusions

DAΦNE successfully concluded the SIDDHARTA-2 run.

Providing to the experiment a data sample of the order of **1.24 fb^{-1}** considerably larger than the requested one (800 pb^{-1}).

Physics events evaluated on the base of preliminary conservative considerations exhibit a **signal to noise ratio 3 time higher** with respect to the one measured in 2009

While delivering data to SIDDHARTA-2 DAFNE also powered BTF and the DAΦNE- Luce SR laboratory.

Presently the collider is in stand-by .

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Thank you for your attention

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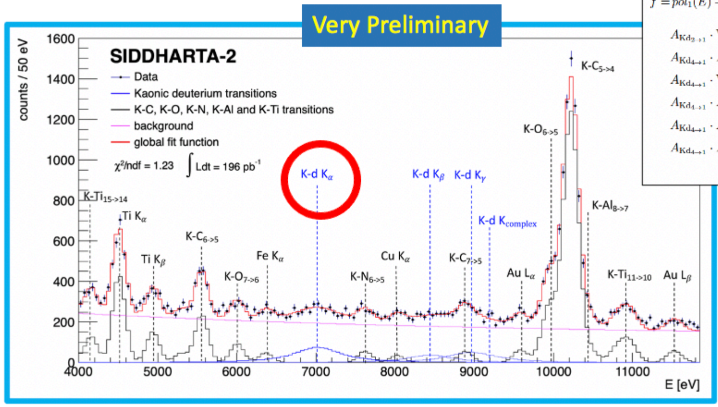
The first kaonic deuterium measurement



$$
\begin{aligned}
f = {} & pol_1(E) + \exp(E) + \sum_i \mathrm{Gauss}(A_{Gi}, E_i, \sigma) + \mathrm{Tail}(A_{Ti}, E_i, \beta, \sigma) + \\
& A_{\mathrm{Kd}_{2\to 1}} \cdot \mathrm{Voigt}(E_{2\to 1}, \sigma, \Gamma_{1s}) + \\
& A_{\mathrm{Kd}_{4\to 1}} \cdot A_{rel_{3\to 1}} \cdot \mathrm{Voigt}(E^{e.m.}_{3\to 1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) + \\
& A_{\mathrm{Kd}_{4\to 1}} \cdot \mathrm{Voigt}(E^{e.m.}_{4\to 1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) + \\
& A_{\mathrm{Kd}_{4\to 1}} \cdot A_{rel_{5\to 1}} \cdot \mathrm{Voigt}(E^{e.m.}_{5\to 1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) + \\
& A_{\mathrm{Kd}_{4\to 1}} \cdot A_{rel_{6\to 1}} \cdot \mathrm{Voigt}(E^{e.m.}_{6\to 1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) + \\
& A_{\mathrm{Kd}_{4\to 1}} \cdot A_{rel_{7\to 1}} \cdot \mathrm{Voigt}(E^{e.m.}_{7\to 1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s})
\end{aligned}
$$

"The **most important experiment to be carried out in low energy K-meson physics today** is the **definitive determination of the energy level shifts in the K−p and K−d atoms**, because of their direct connection with the physics of KN interaction and their complete independence from all other kinds of measurements which bear on this interaction".
R.H. Dalitz (1982)

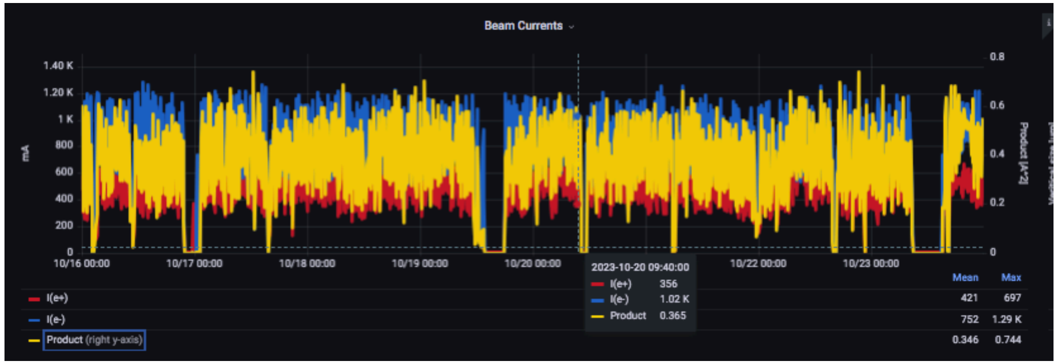
$$\varepsilon_{1s} = E^{meas}_{2p\to 1s} - E^{e.m.}_{2p\to 1s} = -816 \pm 53\ (\mathrm{stat}) \pm 2\ (\mathrm{syst})\ \mathrm{eV}$$
$$\Gamma_{1s} = 756 \pm 271\ (\mathrm{stat})\ \mathrm{eV}$$

(Courtesy of the SIODDHARTA-2 Collaboration)

SPARE SLIDES

Collisions

the intervention to fix the elusive vacuum leak was prepared in the week 16 - 23 October



Maximum beam currents in 95 bunches:

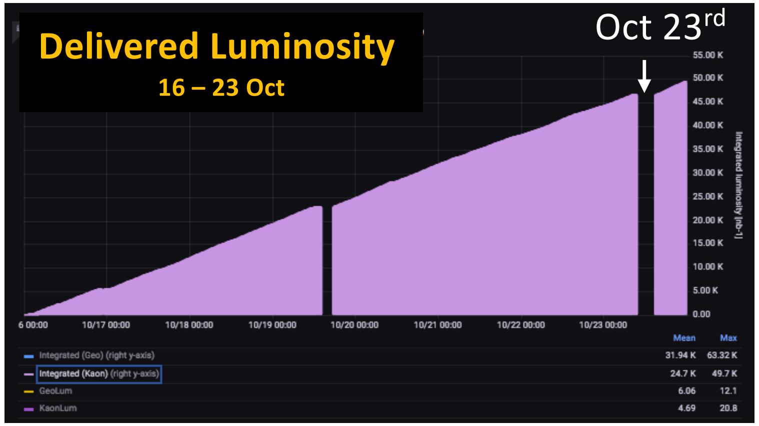
$I^+ = 0.7$ A

$I^- = 1.3$ A

Few interruptions were planned in order to:

- check vacuum equipment,
- install tools to search for the leak,
- find out the leak, which was on a flange of an absorber in the ES1 arc.

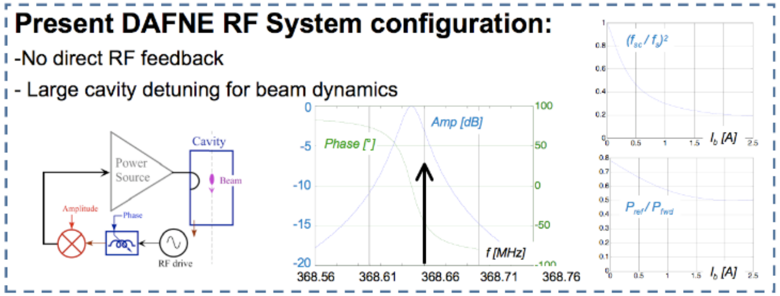
50 pb^{-1} delivered with a 89% uptime.

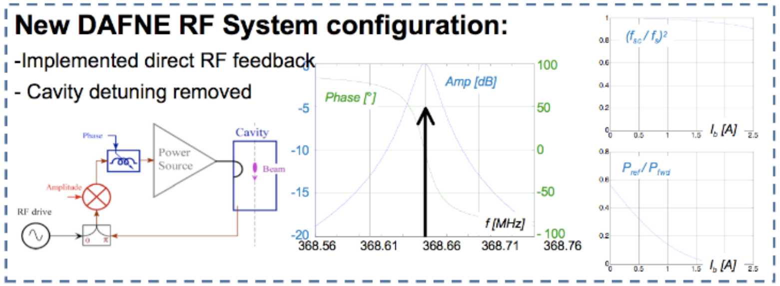


Low Level RF Feedback

A direct RF feedback system in the low level RF is being developed to:

- reduce the cavity detuning angle
- increase the overall efficiency
- limit the reduction of the coherent '0-mode' synchrotron frequency with beam current





High power sections have also been modified in order to reduce power consuption

2010

The Enduring interest in DAΦNE

The DAΦNE lepton collider has been powering physics research at the LNF since almost 20 years.

This has been possible because DAΦNE implemented and successfully tested, with detectors of different complexity, a new collision scheme: the ***Crab-Waist Collision Scheme***.

The *Crab-Waist* concept was conceived, implemented, and tested in about two years, and allowed to increase the DAΦNE luminosity by about a factor three, reducing at the same time the background on the detector.

SuperKEKB adopted Crab-Waist in 2020 achieving world record luminosity securing the BELLE-II detector data taking as well.

RF and Feedback Systems

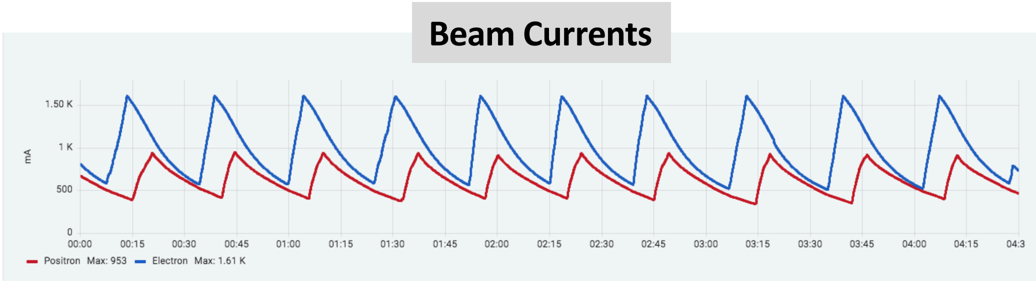
Each DAΦNE ring is equipped with **three independent FBK** systems dedicated to mitigate longitudinal, horizontal, and vertical instabilities.

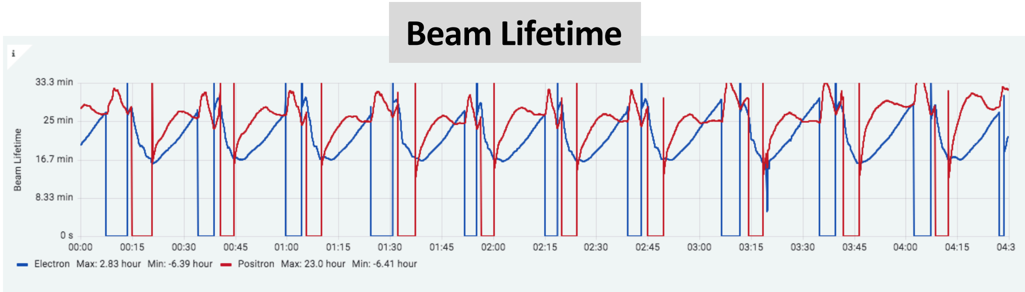
Each RF cavity has its own feedback systems
All major components of RF and FBK systems were **checked**, damaged amplifier in the low-level RF feedback chassis of the MRe RF, and some minor components such as attenuators and filters installed in the FBK chains were replaced.

The different system operation **setups were tuned**, at first in single beam operation mode and moderate current, then setups were refined in collision and at high current, having special care in avoiding destructive interference among different systems, and between systems and beam-beam interaction.

Specific luminosity vs beam current product
3.5
3
2.5
2
1.5
Spec lum [10^28 cm^-2 s^-1 / mA^2]
0.2
0.4
0.6
0.8
1
1.2
Current product [A^2]


DAFNE / DAFNE_GENERAL
2024-05-01 00:00:00 to 2024-05-01 04:30:00
DCS
Dafne State
COLLIDING
BTF Beam
OFF
Dafne BeamTime Category
InjectionPos 16%
InjectionEle 18%
Colliding 66%
Injection fraction
Efficiency
Mean Max Min
Daily efficiency 34.3% 39.3% 29.3%
E+ Bunches
110
E- Bunches
110
Beam Lifetime
Electron Max: 2.83 hour Min: -6.39 hour
Positron Max: 23.0 hour Min: -6.41 hour
Accumulator Current
Current Max: 18.7
CurrentBuffer Max Max: 29.9
CurrentBuffer AVG Max: 17.5
Beam Currents
Positron Max: 953
Electron Max: 1.61 K
Beam vertical size (avg=5s)
Sigma Y
Electron
Positron
Beam horizontal size (average)
Sigma X
Electron
Positron
Radiofrequency
Frequency
Bunch
RF Max: 368.667 MHz Min: 368.667 MHz
NBunch Max: 110 Min: 110
LUMI Trigger


Beam Currents
1.50 K
1 K
500
0
mA
00:00 00:15 00:30 00:45 01:00 01:15 01:30 01:45 02:00 02:15 02:30 02:45 03:00 03:15 03:30 03:45 04:00 04:15 04:3
Positron Max: 953
Electron Max: 1.61 K


Beam Lifetime
33.3 min
25 min
16.7 min
8.33 min
0 s
Beam Lifetime
00:00 00:15 00:30 00:45 01:00 01:15 01:30 01:45 02:00 02:15 02:30 02:45 03:00 03:15 03:30 03:45 04:00 04:15 04:3
Electron Max: 2.83 hour Min: -6.39 hour
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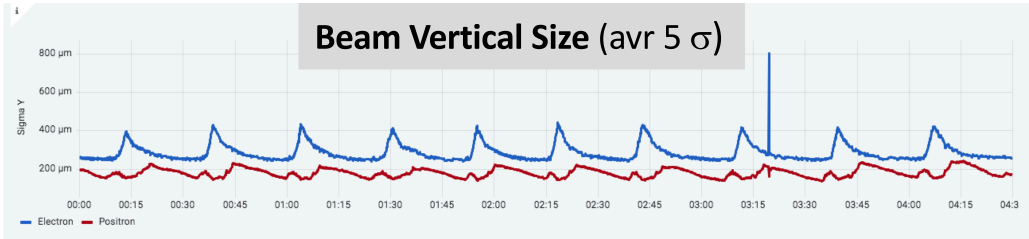

Beam Vertical Size (avr 5 σ)
800 µm
600 µm
400 µm
200 µm
Sigma Y
00:00 00:15 00:30 00:45 01:00 01:15 01:30 01:45 02:00 02:15 02:30 02:45 03:00 03:15 03:30 03:45 04:00 04:15 04:3
Electron
Positron

MRe Beam Dynamics

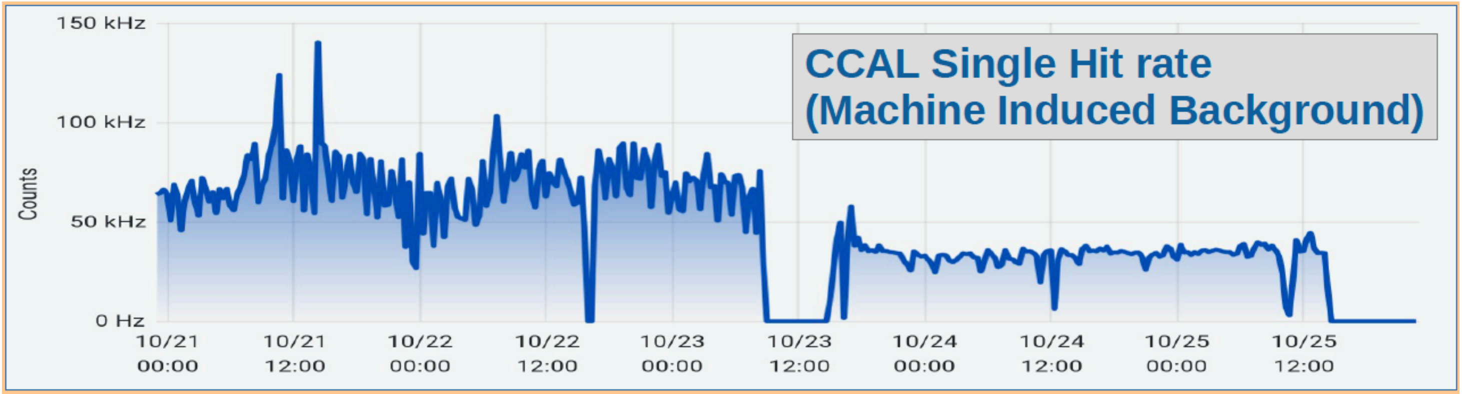
Vacuum

Machine was operated with standard luminosity

$L_{peak} \sim 1.8\ 10^{32}\ cm^{-2}s^{-1}$

but it caused higher background rates on the detector

Vacuum leak mitigated in Oct 2023, and again in Jan 2024 leading to further background improvements and to use 110 in collisions.



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