Esperimento Belle II

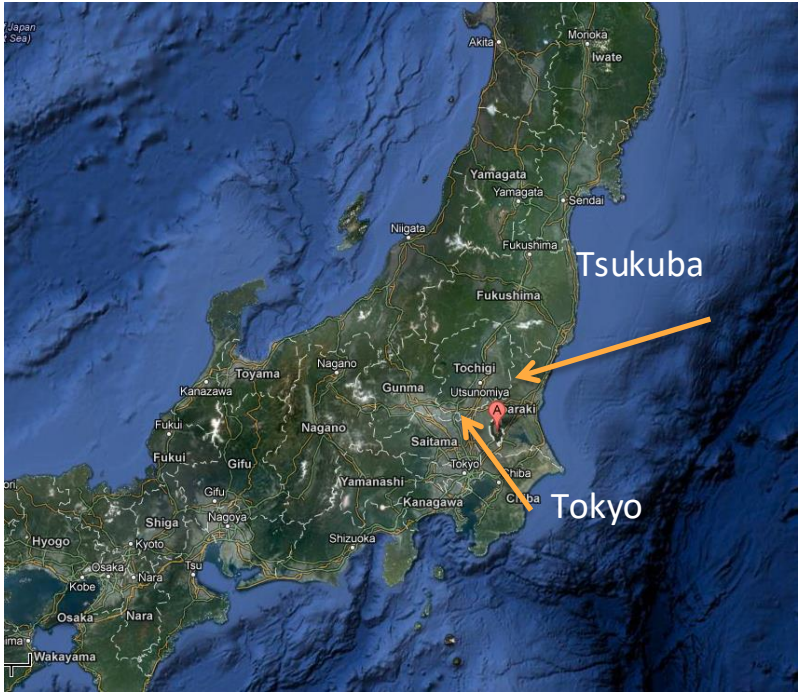
Riunione di Gruppo I Sezione INFN di Napoli – 16 Gennaio 2024

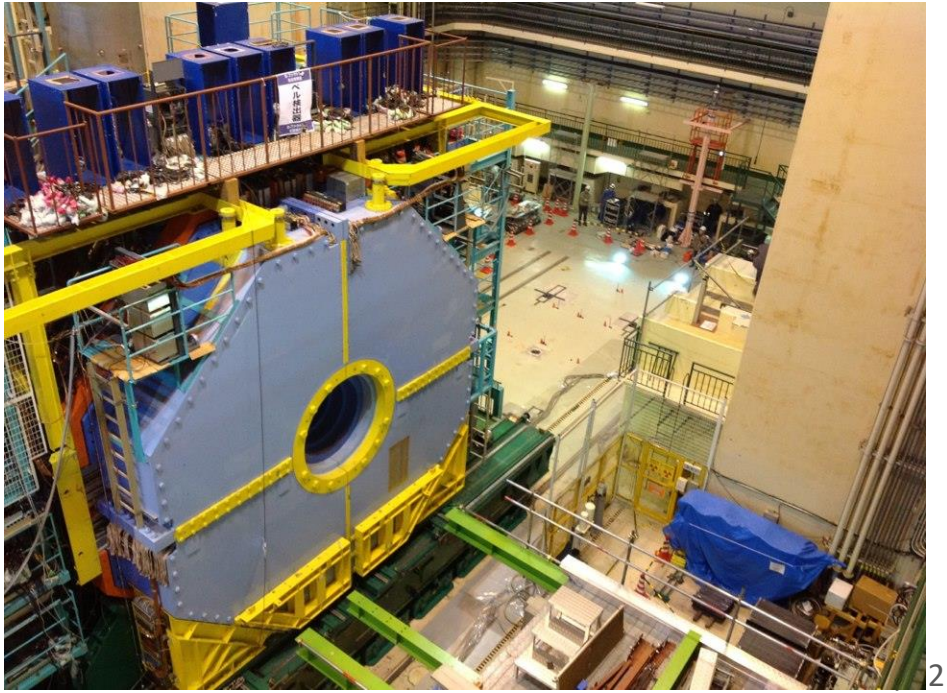
Guglielmo De Nardo, e M.Campajola, G. Gaudino, R. Giordano, M.Merola, M.Mirra, S. Pardi per i contenuti

Belle II @ SuperKEKB

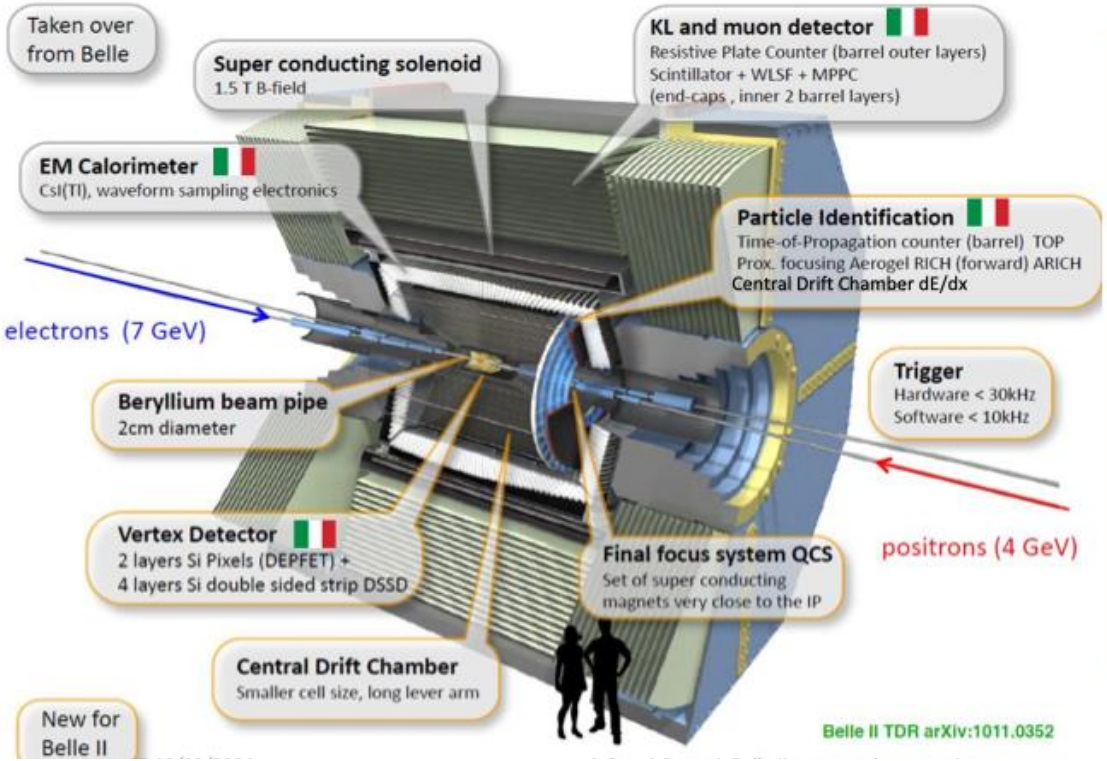
Fisica del Flavour nei decadimenti del beauty, charm e leptoni τ.
Ricerca di Fisica oltre il modello standard
complementare alle ricerche all' LHC

KEK: High Energy Accelerator Research Organization
124 Istituzioni in America, Europa ed Asia
8 sezioni INFN : LNF, Napoli, Padova, Perugia, Pisa, Torino, Trieste, Roma 3





The Belle II detector



- Excellent tracking performances
- 15 μm vertex resolution
- Hermetic detector: full event reconstruction to exploit kinematics constraint
- High photon efficiency (90% above 1.5 GeV momentum)
- Very good lepton ID:
  $\varepsilon(\mu)$~90% with 7% π mis-ID;
  $\varepsilon(e)$ ~86% with 0.4% π mis-ID
- Kaon ID in full momentum range:
  $\varepsilon(K)$~90% with 6% π mis-ID

Belle II unique capabilities

Exactly 2 quantum correlated B mesons at Y(4S)

No trigger bias – almost 100% for B pairs

Excellent efficiency and resolution in tracking as well as in detecting photons, K_L, π^0
→reconstruction of intermediate resonances
→Dalitz plot studies

Clean environment (w.r.t. to hadron machines) allows "full interpretation" of the event
→ powerful tool for physics with missing energy (many neutrinos) or fully inclusive analyses

Large sample of B, D, and τ with low background

Physics deliverables

Improved precision on CKM elements and UT angles

Measurement for CP violation phases

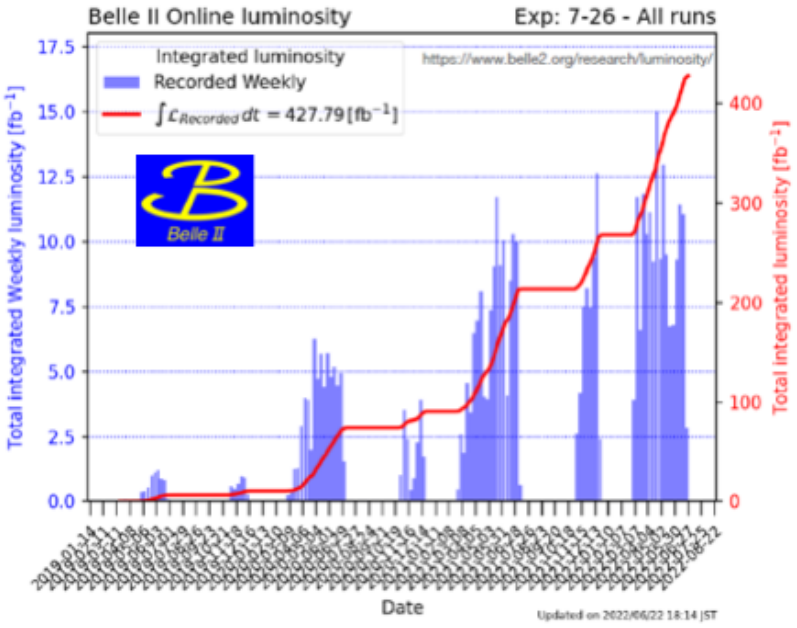
Inclusive measurements
$b \rightarrow s/d\ g$ $b \rightarrow s\ l\ l$

Missing energy modes
$B \rightarrow l\ \nu$ $B \rightarrow K\ \nu\ \nu$, $B \rightarrow X_{u,c}\ l\ \nu$

LFV in $\tau \rightarrow l\ \gamma$, 3l

Dark matter, Hidden sector, spectroscopy

Data sample: Run1 2019-2022 and 2024 data



Belle II collected about the BaBar statistics, but with improved analysis techniques often obtains higher sensitivities for most analyses.

Current analysis based on the Run 1 dataset of 400 fb-1. Additional 140 fb-1 collected in 2024 after long shutdown.

The rump-up of accelerator performances were limited by problems like the “Sudden Beam Loss”, whose cause and remediation are under study

2024 Data taking closed with a luminosity record of 5.1 10^{34} cm^{-2} s^{-1}.

Belle II Publications

- Journal papers statistics:
  - **49 published papers**;
  - + 8 more submitted/accepted;
  - + ~20 more in the pipeline (at or past the Collaboration Wide review stage);

- ~20 more physics results in the Winter Conferences time scale;
- First results using 2024 data in Summer 2025.

Coming soon:
new $B^+ \to \tau^+ \nu$ result!

From A.Gaz, A. Passeri talk to INFN pre-CD 19/12/2024

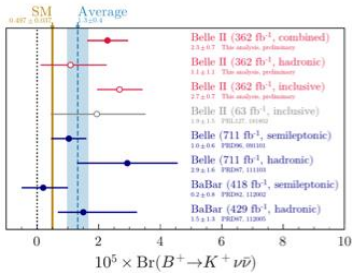
Evidence for B → K ν ν

Phys. Rev. D 109, 112006 (2024)

Hadronic Tag Analysis
"conventional"

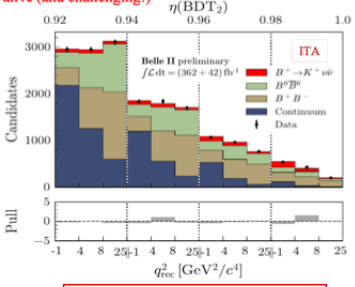
Efficiency
Purity

Inclusive Tag Analysis
innovative (and challenging!)



$\mu_{\mathrm{HTA}} = 2.2^{+1.8}_{-1.7}(\mathrm{stat})^{+1.6}_{-1.1}(\mathrm{syst})$

1.1σ above the background only hypothesis
0.6σ above the SM expectation



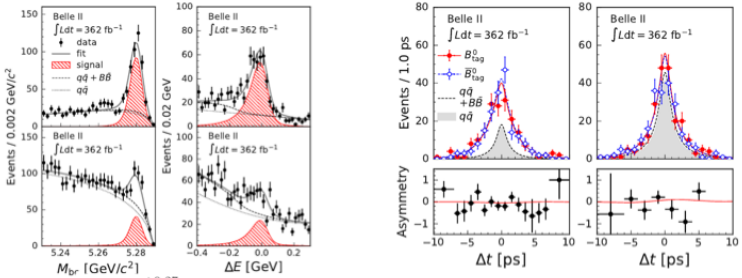
$\mu_{\mathrm{ITA}} = 5.4 \pm 1.0(\mathrm{stat}) \pm 1.1(\mathrm{syst})$

3.5σ above the background only hypothesis
2.9σ above the SM expectation

Time dependent $B^0 \to K_S \pi^0 \gamma$

- The SM predicst that the photon is ~100% right(left)-polarized for B^0 ($\bar{B}^0$) decays;
- Any significant CP violation would be a sign of new physics;

arXiv:2407.09139, accepted by PRL



$S = 0.00^{+0.27}_{-0.26} \pm 0.03\,, \quad C = 0.10 \pm 0.13 \pm 0.04$ for $K^{*0} \to K_S \pi^0$

$S = 0.04^{+0.45}_{-0.44} \pm 0.10\,, \quad C = -0.06 \pm 0.25 \pm 0.09$ for nonresonant $K_S \pi^0$

World leading precision!

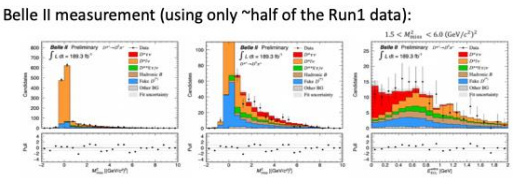
R(D*) measurement at Belle II

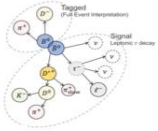
- Long-standing ~3σ anomaly in Flavor Physics:

$$R(D^{(*)}) = \frac{\mathcal{B}(\overline{B} \to D^{(*)}\tau^-\overline{\nu}_\tau)}{\mathcal{B}(\overline{B} \to D^{(*)}\ell^-\overline{\nu}_\ell)}$$

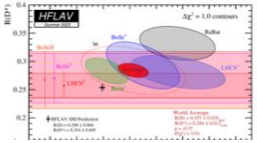
Phys. Rev. D 110, 072020 (2024)

- First Belle II measurement (using only ~half of the Run1 data):





$R(D^*) = 0.262\ ^{+0.041}_{-0.039}(\mathrm{stat.})\ ^{+0.035}_{-0.032}(\mathrm{syst.})$

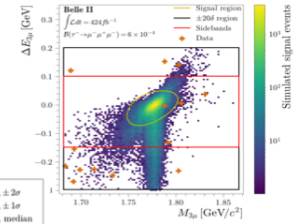


- Not yet competitive with the other measurements, but **40% better sensitivity** than Belle with equivalent luminosity!

Search for LFV in τ → μμμ decays

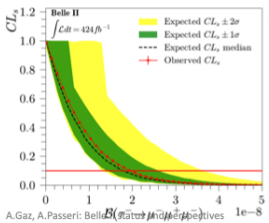
JHEP 09 2024, 062 (2024)

- Belle II will dominate the sensitivity fo Lepton Flavor Violation searches in the coming years;
- Competition with hadron machines only on few channels, most notably τ → 3μ;
- Compared to Belle/BaBar: more inclusive analysis and better control of the backgrounds;
- World leading upper limit!



Most stringent limit to date

	UL at 90% C.L. on $\mathcal{B}(\tau \to 3\mu)$
ATLAS	3.8×10^{-7} ($\mathcal{L} = 20.3$ fb^{-1})
LHCb	4.6×10^{-8} ($\mathcal{L} = 3.0$ fb^{-1})
CMS	2.9×10^{-8} ($\mathcal{L} = 131$ fb^{-1})
Belle	2.1×10^{-8} ($\mathcal{L} = 782$ fb^{-1})
BaBar	3.3×10^{-8} ($\mathcal{L} = 486$ fb^{-1})
Belle II	1.9×10^{-8} ($\mathcal{L} = 424$ fb^{-1})



Belle II Napoli 2025

Guglielmo De Nardo	80%
Alberto Aloisio	30%
Marcello Campajola	70%
Giovanni Gaudino	100%
Raffaele Giordano	30%

Mario Merola	100%
Marco Mirra	30%
Guido Russo	0%
Silvio Pardi	60%*

* Include attività sinergiche

TOTALE: 5.0 FTE

Attività

Calorimetro elettromagnetico (tutti)
Responsabilità sistema di monitoraggio temperatura e umidità, turni expert calorimetro
R&D lettura cristalli per studi di upgrade calorimetro
Studio background di fascio (Giordano)
FPGA-based hadron fluence monitor
Calcolo (Pardi, Russo)
Tier 2 computing dell'esperimento (con data center ReCaS → Ibisco)
Fisica e performance(De Nardo, Campajola, Gaudino, Merola, Mirra)
Misura del numero di mesoni B prodotti nelle collisioni alla Y(4S) (B counting)
Misura dell'efficienza di ricostruzione data-driven
Misura branching ratio decadimenti leptonici
Ricerca di segnali di Materia Oscura in processi e+ e- a bassa molteplicità

Belle II Napoli responsabilità e relazioni a congresso 2024

Responsabilità:

Marcello Campajola:	convener WG Trigger and Event Properties
Giovanni Gaudino:	MC Production Manager
Raffaele Giordano:	convener per ECL in upgrade WG
Silvio Pardi:	Belle II Computing Infrastructure Responsabile Computing Belle II Italia

Relazioni a Conferenze internazionali:

Mario Merola	**"Latest and near-future highlights from Belle II"** *Particle Physics and Cosmology in the Himalayas (BCVSPIN 2024)*
Giovanni Gaudino	**"Semileptonic and missing energy B decays at Belle II"** *XIII International Conference on New Frontiers in Physics (ICNFP 2024)*
Marcello Campajola	**"ALP searches at e+e- colliders, including Belle (II), BaBar and BESS III"** *The Axion Quest: 20th Recontres du Vietnam*
Guglielmo De Nardo:	**"Measurements of CKM matrix elements"** *Flavor Physics and CP Violation 2024 (FPCP 2024)*
Raffaele Giordano:	**Novel "FPGA-embedded SEU Monitors For The Belle II Experiment"** *Nuclear Science Symposium 2024 (NSS 2024)*

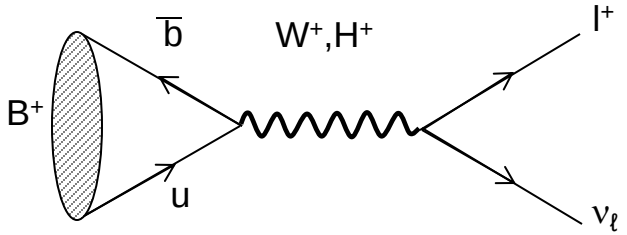
Highlights attività di Napoli 2024

- Fisica
- Studi di performance
- Outreach
- Upgrade del Calorimetro elettromagnetico

Physics Results

- Measurement of $B \rightarrow \tau \nu$ Branching Fraction
- Search of new particles in the *dark sector*

B meson purely leptonic decays $B \to l\,\nu$



Very clean theoretically…

…very hard experimentally

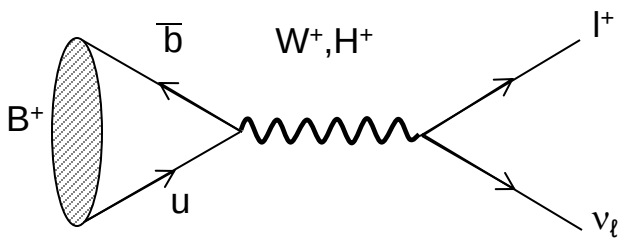
in the SM: $\mathcal{B}(B \to l\nu) = \frac{G_F^2 m_B}{8\pi} m_l^2 (1 - \frac{m_l^2}{m_B^2})^2 f_B^2 |V_{ub}|^2 \tau_B$

- Helicity suppression by a factor of m_l^2
- being a $b \to u$ transition sensitive to (and suppressed by) $|V_{ub}|$
- Hadronic uncertainty in the decay costant f_B (calculated with lattice QCD)

STANDARD MODEL PREDICTIONS

Mode	$\mathcal{B}(B^+ \to \ell^+ \nu_\ell)$	
$\tau\nu_\tau$	$(1.01 \pm 0.29) \times 10^{-4}$	*Accessible with current data sets*
$\mu\nu_\mu$	$\sim 0.45 \times 10^{-6}$	*Need Belle II statistics*
$e\nu_e$	$\sim 0.8 \times 10^{-11}$	*Beyond the reach of experiments*

B meson purely leptonic decays $B \to l\,\nu$

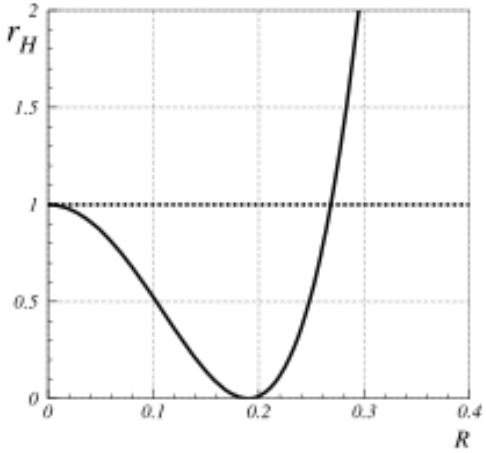


Sensitive to NP contribution (for example: a charged Higgs)

in 2HDM type II

$$\mathcal{B}(B \to l\nu) = \mathcal{B}(B \to l\nu)_{SM} \times r_H$$

$$r_H = (1 - \tan^2\beta\,\frac{m_B^2}{m_H^2})^2$$

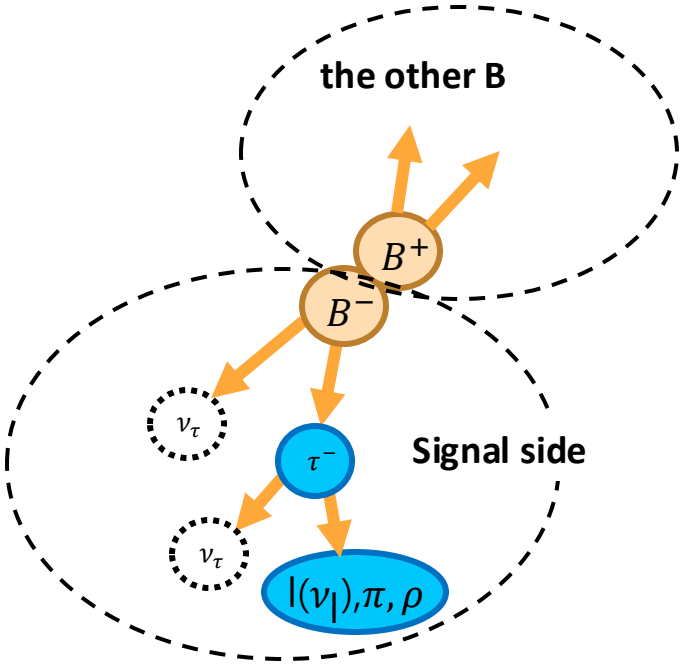


Possible test of Lepton Flavor Universality with:

$$R^{\tau\mu} = \frac{\Gamma(B \to \mu\nu)}{\Gamma(B \to \tau\nu)} \qquad R^{\tau e} = \frac{\Gamma(B \to e\nu)}{\Gamma(B \to \tau\nu)}$$

Golden Modes del programma di Fisica dell'esperimento

How to search for leptonic decays $B \to \tau \nu$ with $e^+ e^-$ B factories



$(l = e, \mu)$

Signal is searched through $\boldsymbol{\tau}$ decays (1-prong):

- $\boldsymbol{\tau \to e \nu_e \nu_\tau}$
- $\boldsymbol{\tau \to \mu \nu_\mu \nu_\tau}$
- $\boldsymbol{\tau \to \pi \nu_\tau}$
- $\boldsymbol{\tau \to \rho \nu_\tau}$ with $\boldsymbol{\rho \to \pi^{\pm} \pi^0}$

~71% of the τ Brancing Fraction

Weak experimental signature: a single charged particle on the signal

Experimental features to exploit:

- Large missing momentum and energy from many (2 or 3) neutrinos
- Particle Identification of the charged particle decay product
- Kinematics constraints from two body decays in sequence for hadronic channels, mass contraint for r channel

…evidence of the companion B meson and nothing else…

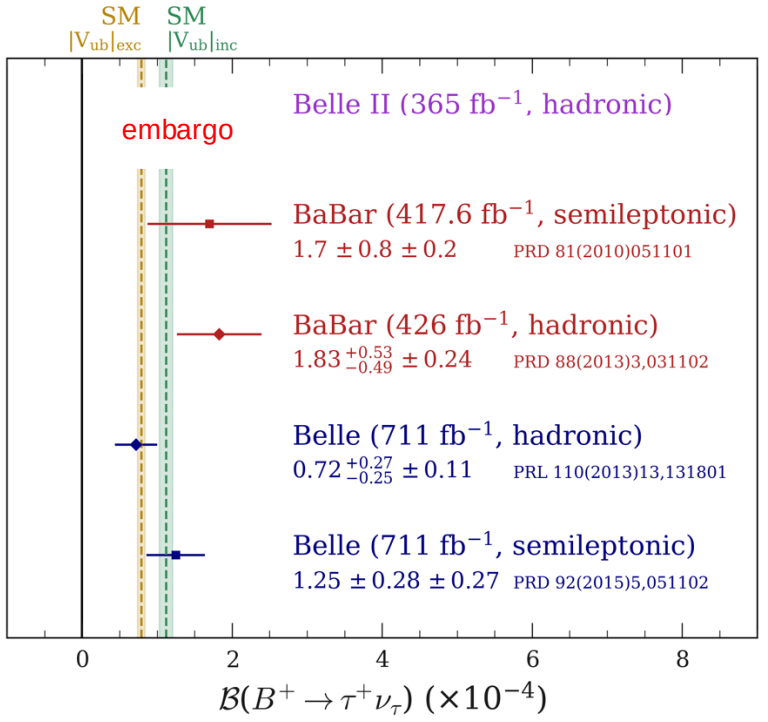
G. Gaudino PhD Thesis

Measurement of $\mathcal{B}(B \to \tau\nu)$

- *Measurement of the Branching Fraction of the B→τν decay with a hadronic tagging* analysis and paper draft completed the Collaboration Wide review n.1
- We expect to submit to Phys. Rev. D in a month.

Details and results
in a dedicated talks by Giovanni Gaudino

	$B(B \to \tau\nu)$ Had Tag	Luminosity
Belle	$\left(0.72^{+0.27}_{-0.25}(stat.) \pm 0.11(syst.)\right) \times 10^{-4}$	771 fb^{-1}
BaBar	$\left(1.83^{+0.53}_{-0.49}(stat.) \pm 0.29(syst.)\right) \times 10^{-4}$	426 fb^{-1}
PDG	$(1.09 \pm 0.24) \times 10^{-4}$	
SM	$(0.77 \pm 0.06) \times 10^{-4}$	

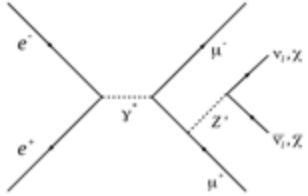


Dark sector at Belle II

Activity leaded by M. Campajola

Very successful Dark sector exploration from Belle II

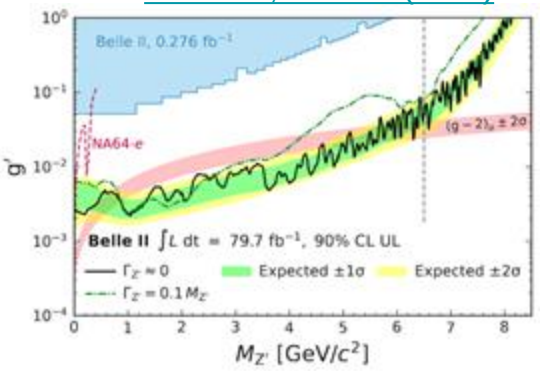
Napoli involvement on:



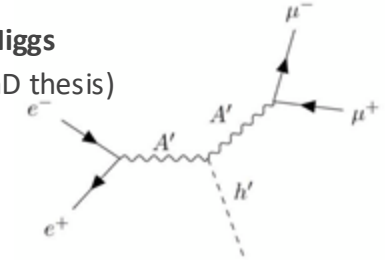
- Searches for an **invisibly decaying Z'**
  - First: PRL 124, 141801 (2020), (Marcello's PhD thesis)
  - Second: PRL 130, 231801 (2023)
  - **Third iteration of search ongoing:**
    - Improved analysis strategy with Run1 dataset (360 fb-1)
    - Extended interpretation to muonphilic scalar

  ➔ Expected to publish new results during 2025

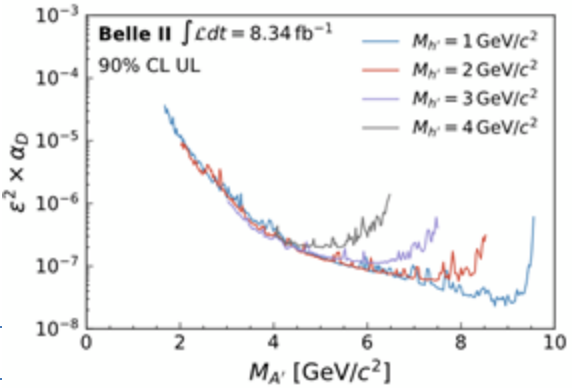
PRL 130, 231801 (2023)



- Searches for a (visible) **dark photon** and a (invisible) **dark Higgs**
  - First result in PRL 130 (2023) 071804 (Marcello's PhD thesis)
  - **Second interaction ongoing:**
    - Larger dataset x40
    - Improved analysis strategy
    - Extended model interpretation
      - Dark Higgs with mixing with SM Higgs
      - Exploring also different topologies: displaced Higgs decay within Belle II acceptance



PRL 130 (2023) 071804



Performances

- Trigger and Event Properties WG
- Determination of number of produced B-pairs (B counting)
- Determination of π^0 efficiency in data and MC
- Measurement of Background dose on detector

Performances

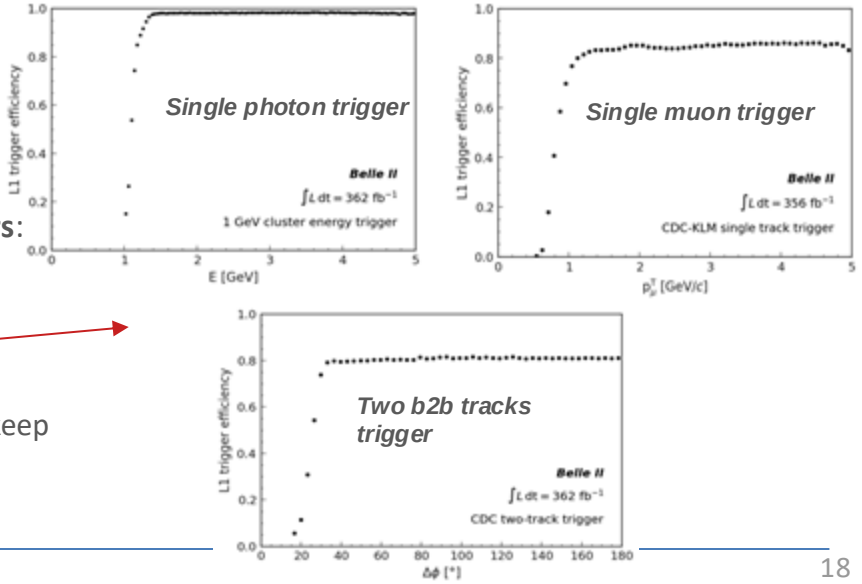
M.Campajola in charge of the coordination of the 'Trigger and event properties' WG

- Tasks: activities dedicated to studying the performance of L1 and HLT triggers, measuring beam parameters, integrated luminosity, and counting B mesons produced during data collection.

Trigger performances:

- **~100% efficiency for BB;**
- **very high efficiency for τ, dark topologies;**

  ➔ L1 including noteworthy **single/few objects triggers**:
  - single photon;
  - single track;
  - single muon.



Combined effort from physics, performance and hardware groups to keep immunity to beam background while achieving high efficiency for low multiplicity analyses

Activity leaded by M. Merola

B-counting

Motivation of B-counting

- N_{BB} important input for branching ratio measurements
- $N_{BB} = L \cdot \sigma_{BB}$ has high uncertainty due to the uncertainty on σ_{BB} (2-5%), we want to keep it below % !

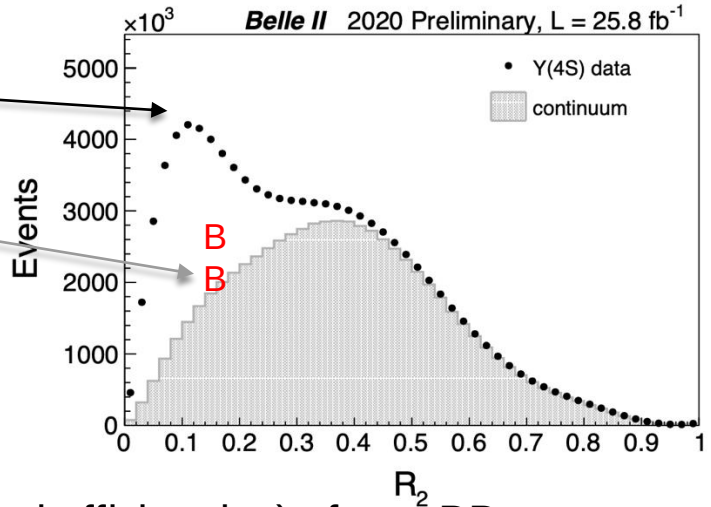
on resonance data

-

continuum

=

BB



We estimate the continuum component using off-resonance data: need to take into account the different cross sections (and efficiencies) of non-BB processes at off-resonance energy

B-counting methods

Two methods to determine N_{BB}:

$$N_{BB} = \left(N_{had}^{on-res} - R_{lumi} \cdot N_{had}^{off-res} \cdot \kappa\right) / \varepsilon_{BB}$$

- lumi-dependent: subtract the off-resonance data from on-resonance, assuming the off-resonance normalization given by the luminosity estimate

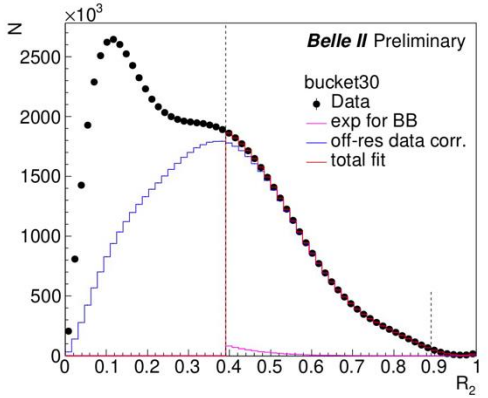
$$R_{lumi} = \frac{L^{on}}{L^{off}}$$

Ratio of measured luminosities

$$k = \frac{\sum_i \varepsilon_i \cdot \sigma_i}{\sum_i \varepsilon_i' \cdot \sigma_i'}$$

Efficiencies and cross sections of non-BB processes in on-peak and off-peak (primed quantities) data.

- lumi-independent: subtract the off-resonance from on-resonance determining the relative normalization of the off-resonance contribution with a fit



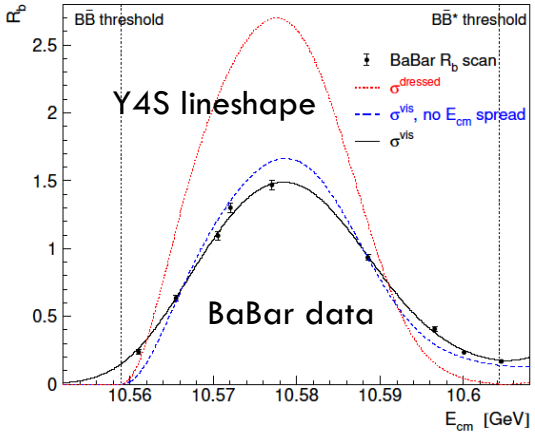
B-counting results

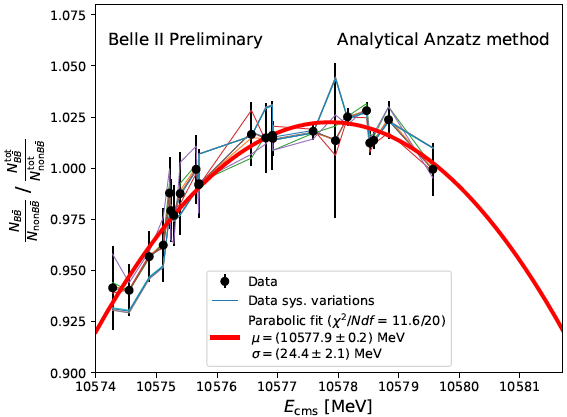
Two methods give consistent results withing the uncertainties (~1%).

Main systematic uncertainty: off-resonance choice, luminosity (lumi-based method) and fit function assumption (lumi-independent method)

Y(4S) lineshape well described by B-counting data

$$N_{B\bar{B}}/L = \sigma^{B\bar{B}\gamma}_{\mathrm{smeared}}(E_{\mathrm{cms}})$$





N_{BB} normalized to non-BB contribution to avoid luminosity dependency

Activity leaded by M. Mirra

π^0 efficiency corrections

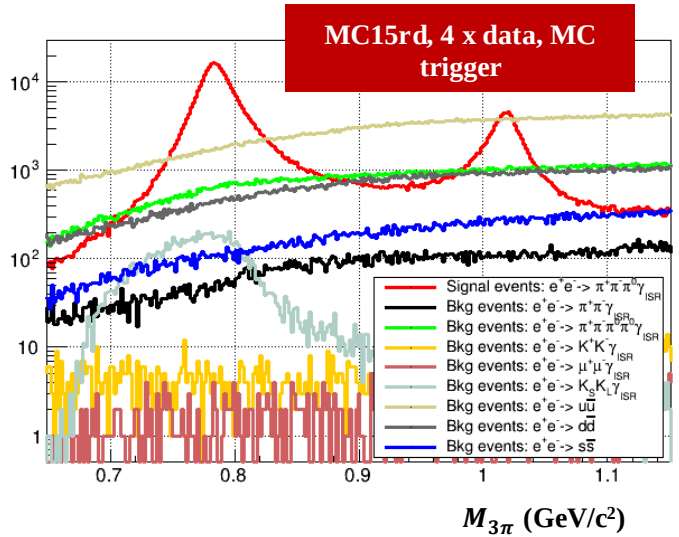
- Data/MC comparison of π^0 detection efficiency with the decay chain

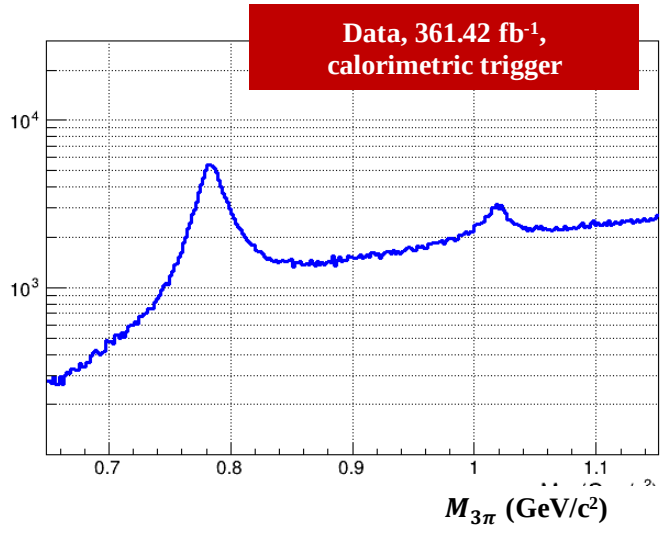
$$e^+e^- \rightarrow \omega(782)\gamma_{ISR} \rightarrow \pi^+\pi^-\pi^0\gamma_{ISR}$$

- Events with meson ω production selected using beam, and π^+, π^- , γ_{ISR} candidates. Kinematic fit to predict π^0 momentum : $e^+e^- \rightarrow \pi^+\pi^-\gamma_{ISR}p_{miss}$, with $p^2_{miss} = m^2_{\pi^0}$ as constraint

- Squared invariant mass of the 3 pion system

$$M^2_{3\pi} = \left(P_{\pi^+} + P_{\pi^-} + P_{\pi^0}\right)^{\alpha}\left(P_{\pi^+} + P_{\pi^-} + P_{\pi^0}\right)_{\alpha}$$

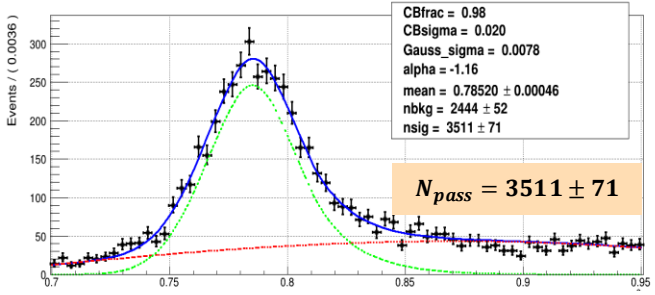




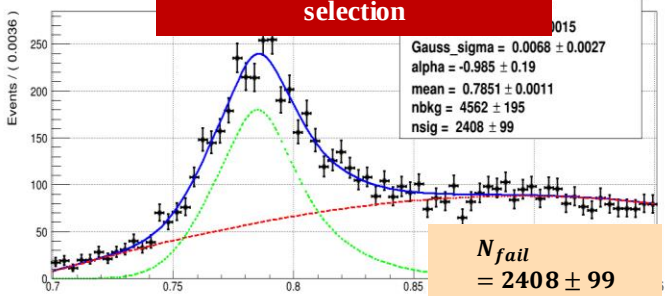
π^0 efficiency corrections

- Strategy for data and full MC (signal+main backgrounds): fit 2 statistically indipendent $M_{3\pi}$ distributions passing and failing the π^0 selection under test
- ε_{π^0} can be measured in bin of momentum and theta of the fitted π^0.

Data, EFF30 π^0 selection



Data, Not EFF30 π^0 selection



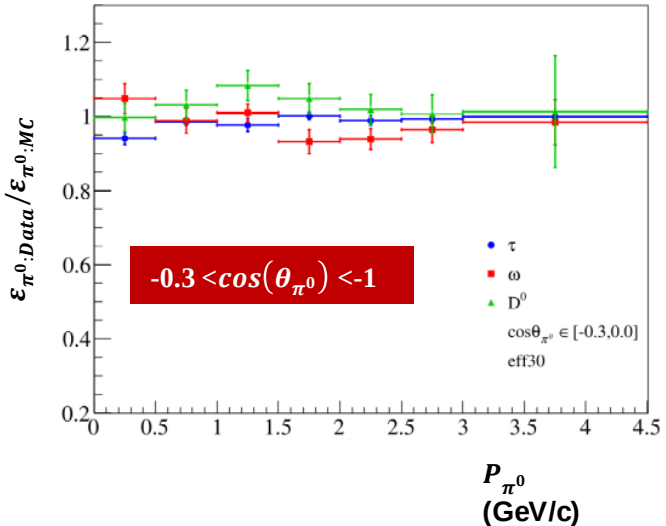
Fit model: Crystal ball + gaussian functions for signal and 2nd order polynomial for background

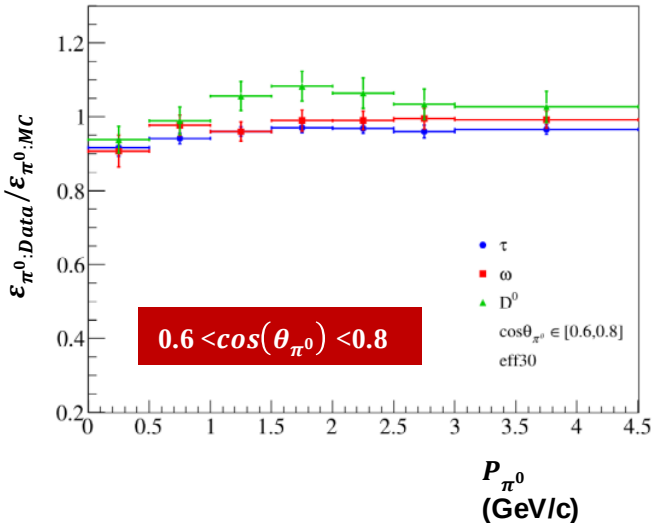
$$\varepsilon_{\pi^0} = \frac{N_{pass}}{N_{pass} + N_{fail}}$$

ε_{π^0} uncertainty computed via N_{pass} and N_{fail} uncertainty propagation

π^0 efficiency corrections

- Many efforts (Napoli - ω decays, Trieste - D^0 decays, Beijing - τ decays) on π^0 reconstruction systematic uncertainty coming from MC modeling: it is the main limitation for many analyses
- Several π^0 selections tested with the ω method, the only one that provides the absolute value of π^0 efficiency
- Systematic uncertainties evaluation ongoing on π^0 efficiency with the ω method coming from the selection of ω production events and $M_{3\pi}$ fit models

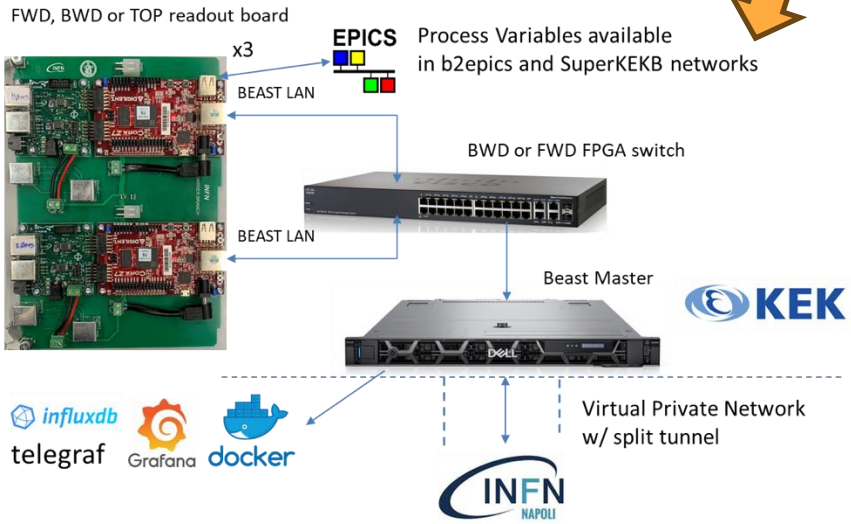


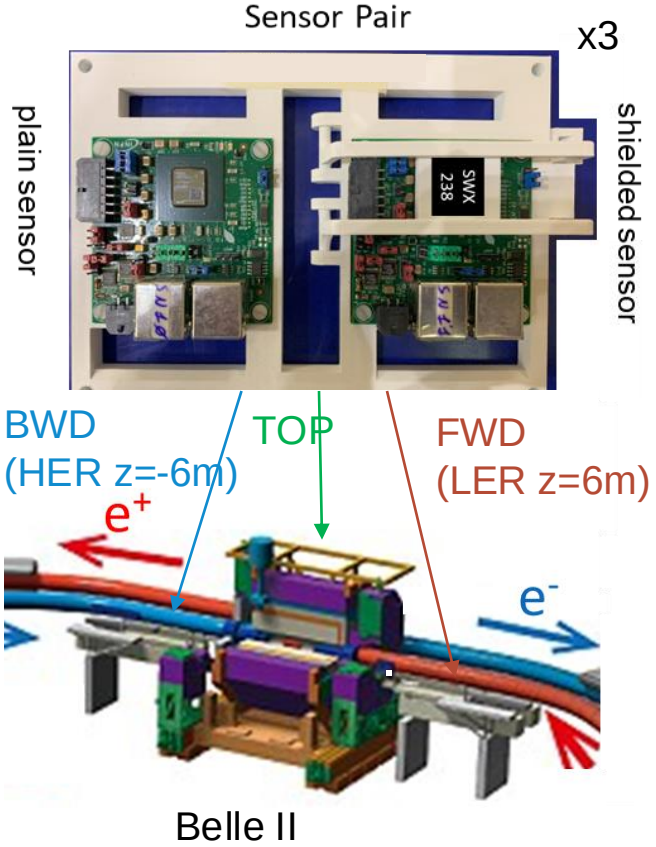


Activity leaded by R. Giordano

FPGA-embedded SEU Monitors at Belle II

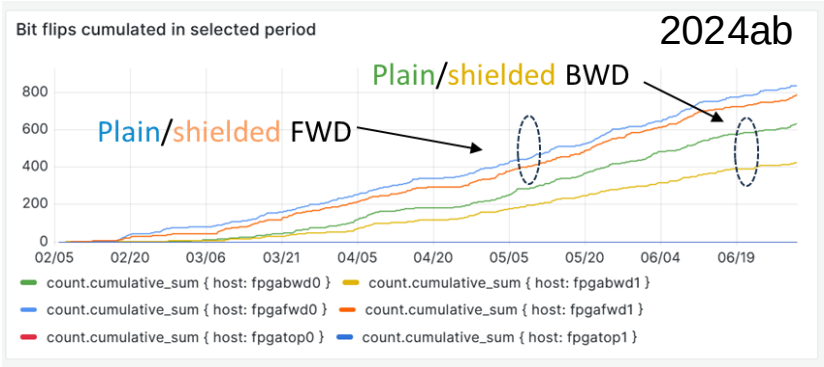
- Sensors arranged in pairs, unshielded (measures thermal+fast n) and shielded against thermal neutrons (measures fast n only)
- Thermal and fast neutrons fluence estimated by difference
- Three pairs installed around Belle II w/ readout system

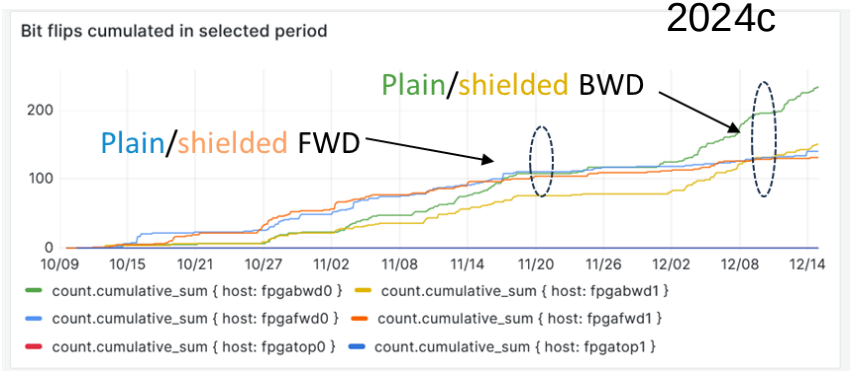




Operation in 2024

- Since 2024, new neutron-induced SEU monitoring system at Belle II is operating successfully
- Differential (shielded/plain sensors) concept proven with irradiation at JSI's TRIGA Reactor in Ljubljana, Slovenia
- FPGA-embedded sensors showing different SEU counts at forward, backward and atop Belle II volume (zero counts)
- Clear correlation with integrated beam currents (not shown)
- Preliminary estimates show different fast/thermal neutron components at e^+ vs e^- ring near Belle II
- Different trends between 2024ab and 2024c periods





Computing

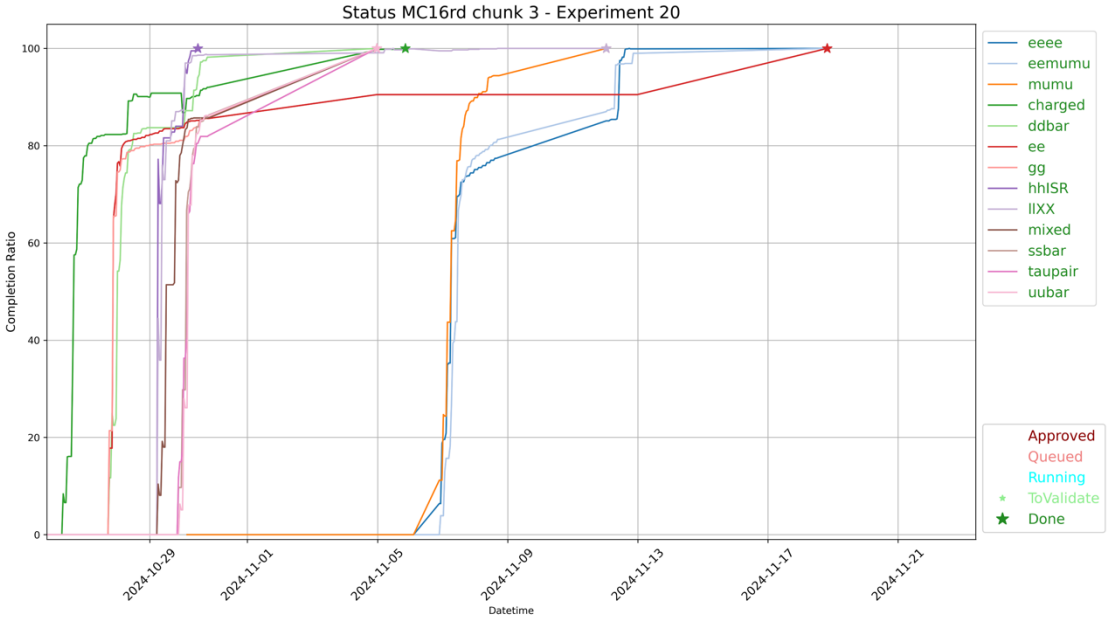
- Data production service
- Belle 2 Tier2 di Napoli
- Responsibility in Computing

Data Production

MC production manager: G. Gaudino

Responsibility of MC production for the entire collaboration.

- Develop scripts for MC production within the Belle 2 framework.
- Submit MC jobs to the Grid.



- Collaborate with the computing group to optimize Grid parameters and reduce production time, enabling parallel production of data and run-dependent MC (each run has the beam-background as in data).

- Monitor productions and facilitate the work of analysts, making their tasks as seamless as possible.

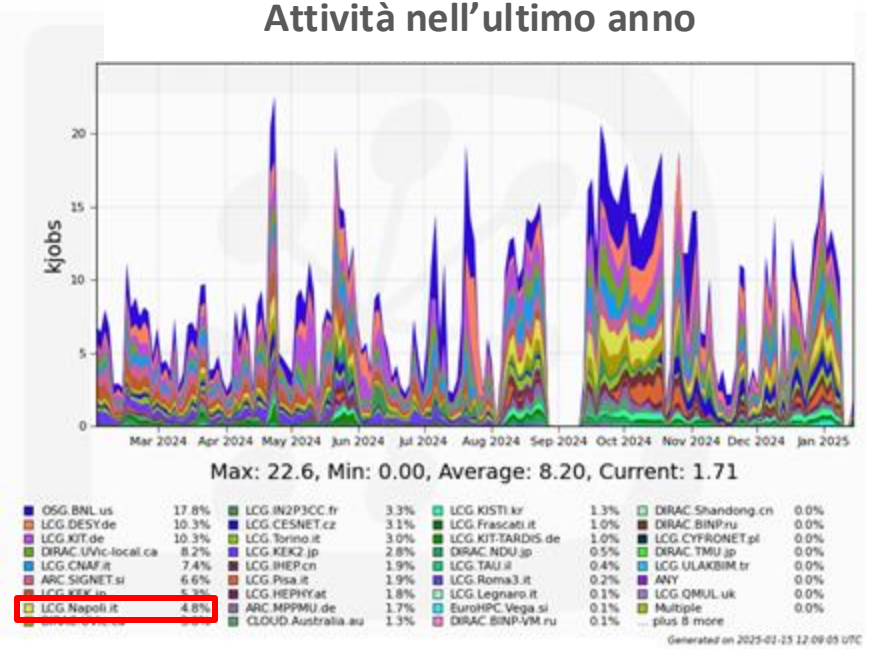
Computing - Il Tier2 di Napoli

Il sito di Napoli è uno dei maggiori siti della Collaborazione di Belle II ed uno dei più stabili in assoluto.

- Circa 3.000 Core pledged
- 2 PB di spazio Disco dedicati
- Connessione a 100Gbit/s verso la rete GARR.

Sito Utilizzato per l'Analisi Batch, Data Skimming, Data Merge, Produzione Montecarlo e lavora come infrastruttura di backup per altri Siti data comprovata la affidabilità dell'infrastruttura.

Attività nell'ultimo anno



Napoli 8th contributor su 58 siti, subito dopo i centri dedicati all'analisi dei RAW Data

Com

Il sito di N
Collabora
assoluto.

- Circ
- 2 PE
- Con

Sito Utiliz
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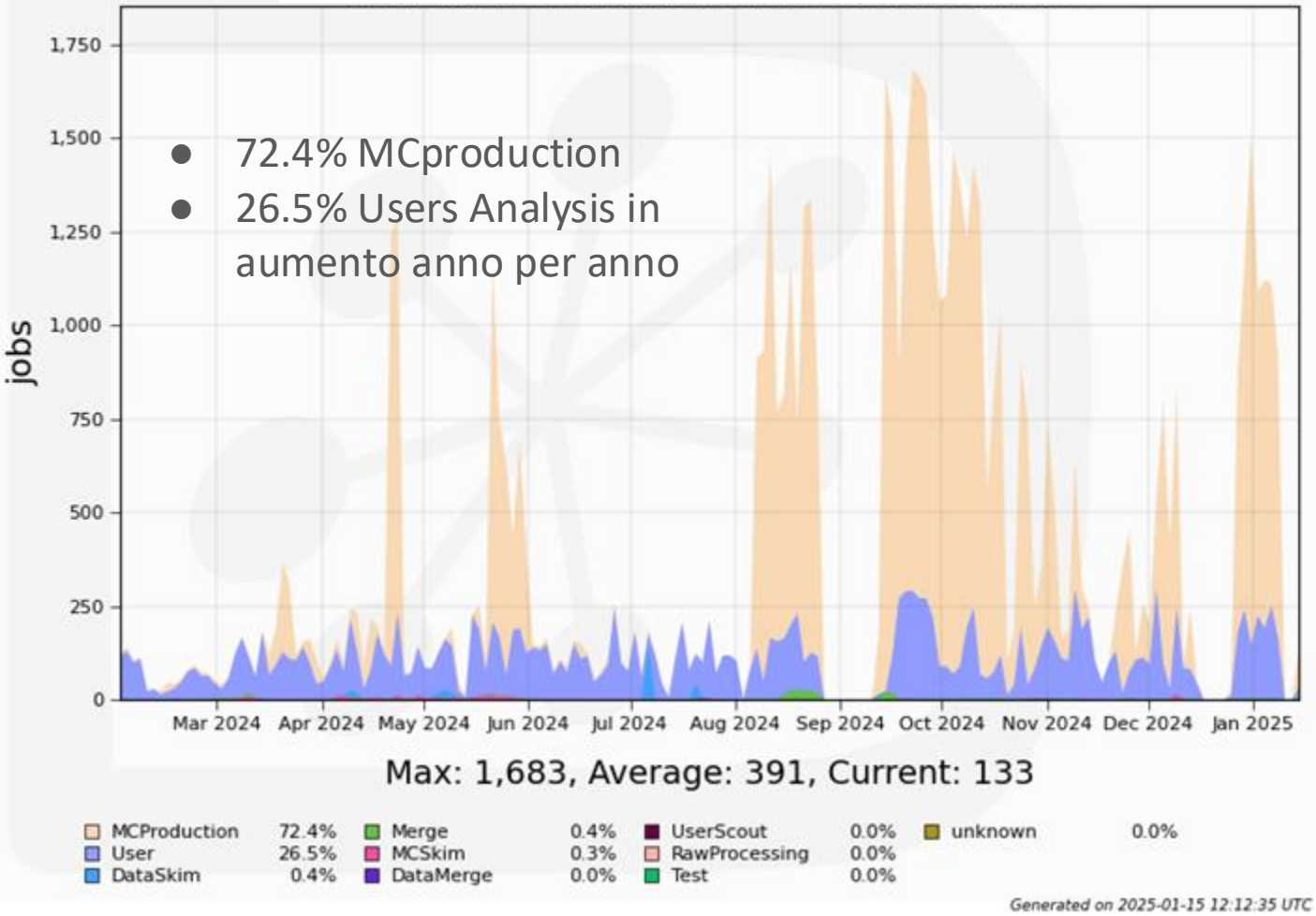
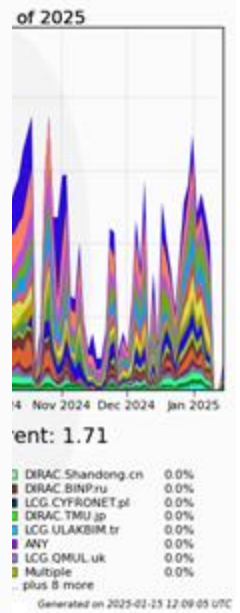


- 72.4% MCproduction
- 26.5% Users Analysis in aumento anno per anno



Attività di Coordinamento: Infrastructure and Network coordinator

Silvio Pardi - **Infrastructure and Network Coordinator** per la collaborazione Belle II
Computing Coordinator Italiano di Belle II.

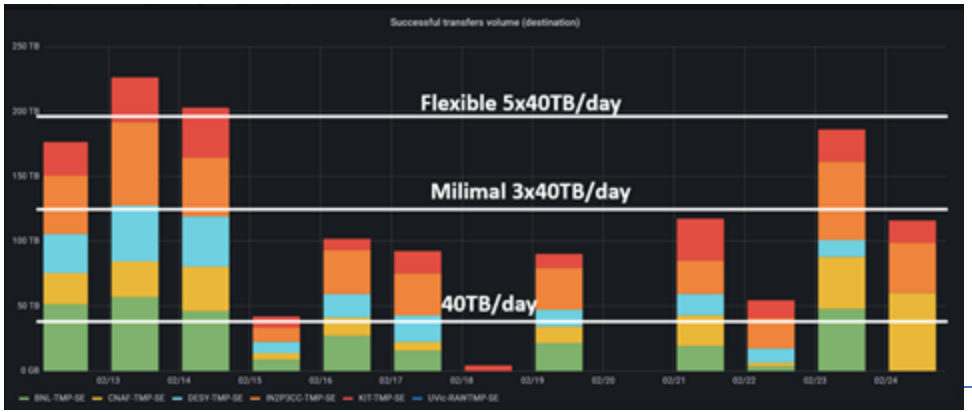
Gestione delle configurazioni e degli update dei 55 siti della collaborazione.

Nel 2024 sono stati seguiti dei cambiamenti epocali che hanno richiesto la riconfigurazione dell'intero sistema, le attività proseguiranno nel 2025. Questo include:

- **Dismissione del protocollo gridftp** sostituito con http per accesso allo storage Grid
- **Migrazione del sistema Operativo su tutti i siti** da CentOS7 ad Alma9.
- Razionalizzazione delle risorse dei siti.
- Setup e migrazione verso il **nuovo sistema di autenticazione basato su Token**.
- Configurazione di belle II nella rete mondiale della ricerca LHCONE/LHCONE

Networking and Data Challenge e Jennifer

Il Gruppo di Napoli ha **coordinato ed eseguito il Network Data Challenge di Belle II 2024** per l'intera collaborazione, testando i links di geografici di rete da KEK verso i RAW Data Center di BNL, CNAF, DESY, IN2P3CC, KIT, e UVIc insieme con il test degli esperimenti LHC, **raggiungendo picchi di 5 volte la banda necessaria** per il trasferimento dei dati da KEK, in regime di massima luminosità.



Nell'ambito dei progetti europei JENNIFER2/JENNIFER3 Silvio Pardi è r**esponsabile dei task di Computing** finalizzati al setup di tecnologie di rete e cloud comuni per gli esperimenti Belle II, T2K and Hyper-K.

Nei prossimi 3 anni sono previste attività d**i Data Challenge congiunto** tra i 3 esperimenti e lo studio per l'utilizzo di risorse **Cloud per il Machine Learning**, Produzione Monte Carlo e Analisi dati in Belle II, T2K e Hyper-K

Outreach

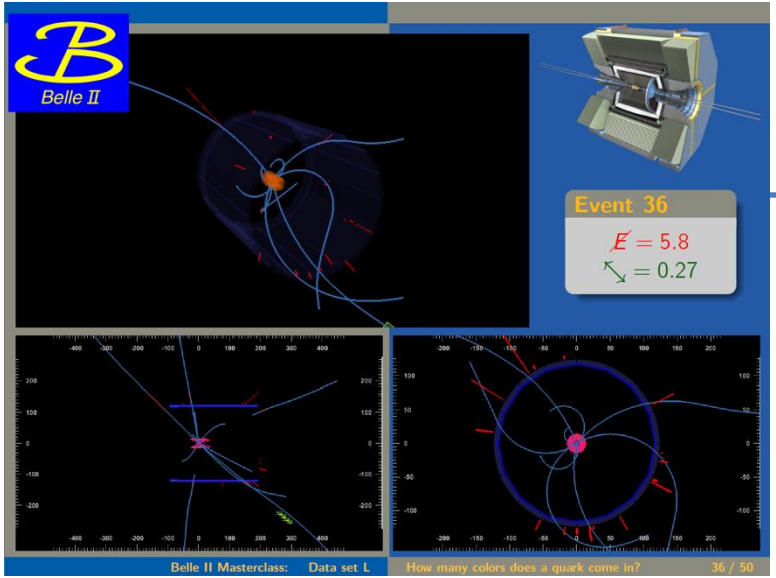
- Belle 2 Masterclass

Belle II Masterclass in Napoli

How many colors does a quark come in?

Coordinate da G. Gaudino e M. Merola

Counting the events and distinguish them, we can measure the number of the colors using the Belle II Event Display



$e^+e^- \to ?$
$\tau^+\tau^+$
e^+e^-
$\mu^+\mu^-$
$b\bar{b}$
$q\bar{q}$

We also make a quiz with prizes from KEK and the possibility to use Belle II VR for the winner of the quiz

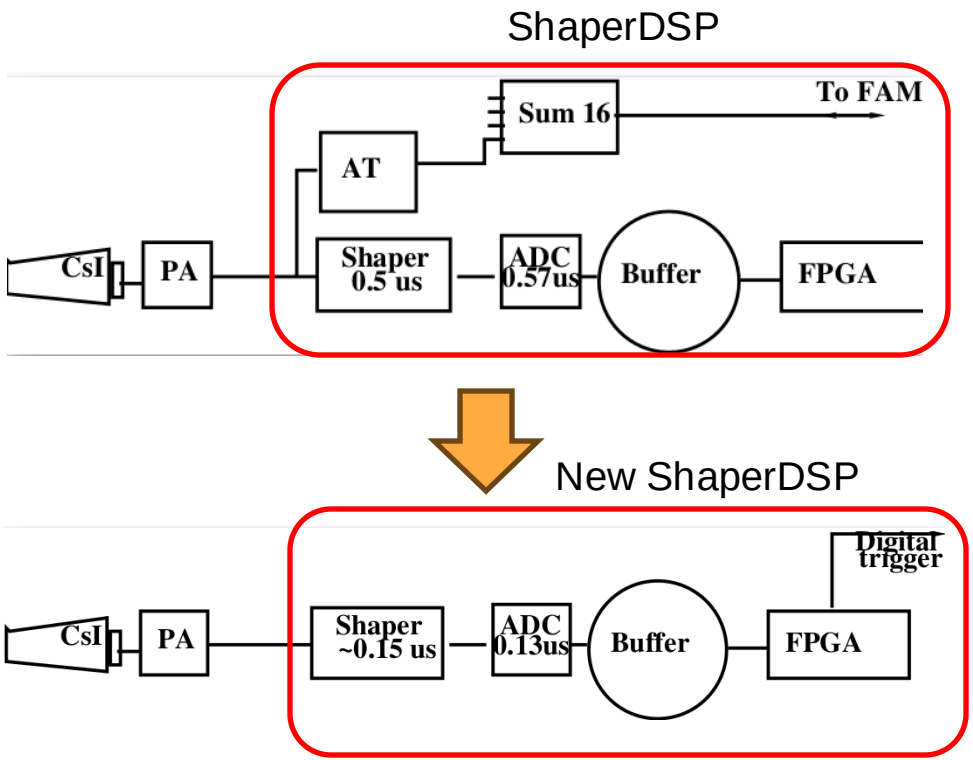
Upgrades

- ECL read-out electronics (near term upgrade)
- Replace PIN diode sensors with SiPM R&D (long term upgrade)

ECL Upgrade Plans

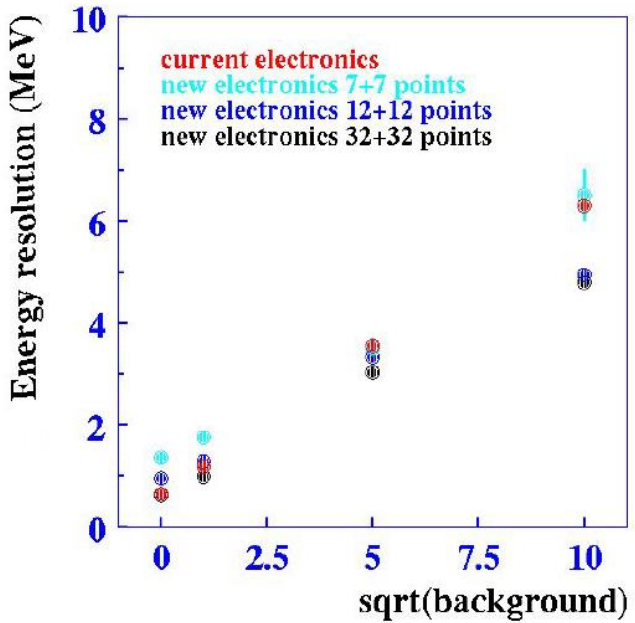
R. Giordano co-convener for ECL in the Belle 2 upgrade working group

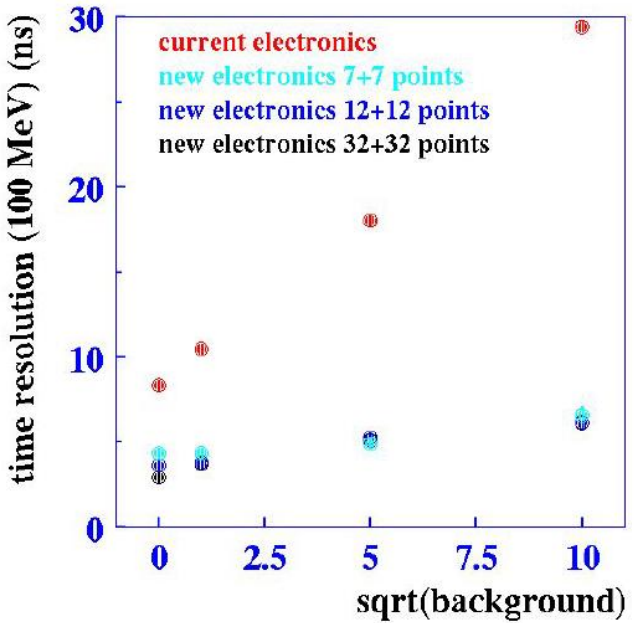
- Short-term (installed by 2029) upgrade of electronics under discussion
  - faster shaping (500 ns → 150 ns);
  - higher sample-rate digitizer (1.7 MHz → 7.9 MHz)
  - Higher-granularity trigger (4x4 → 1x1 cell)
  - new FPGA (Spartan-3 → TBD) for more complex online feature extraction and trigger
- New ShaperDSP + data collector board
- 5-6 M€ cost (very rough estimate), funding sources need to be identified
- INFN (NA and PG) is joining the development with BINP and KEK (TRG) groups
- Task responsibilities TBD



Upgraded-Electronics Simulations

- Very preliminary simplified simulations (from BINP) of new vs old electronics show
- Same energy resolution degradation with background does not improve
- Time resolution become immune to increase of backgrounds

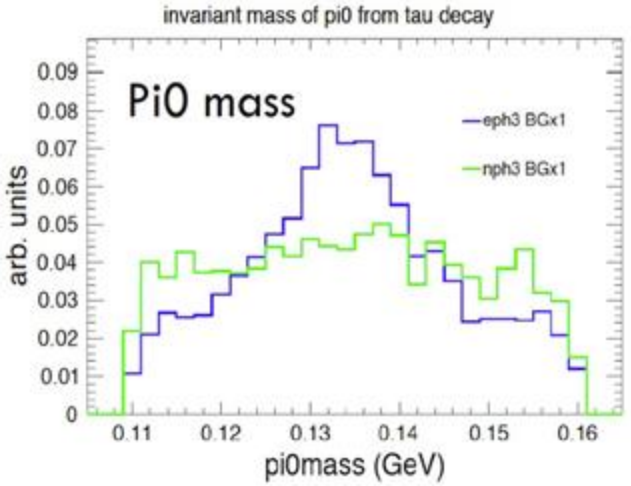




Longer-term ECL upgrade studies

Higher rate and **occupancy** with increasing luminosity:

- Low energy spectrum dominated by beam-background
- Performance degradation in the low energy region: impact **soft photons** and π^0 reconstruction



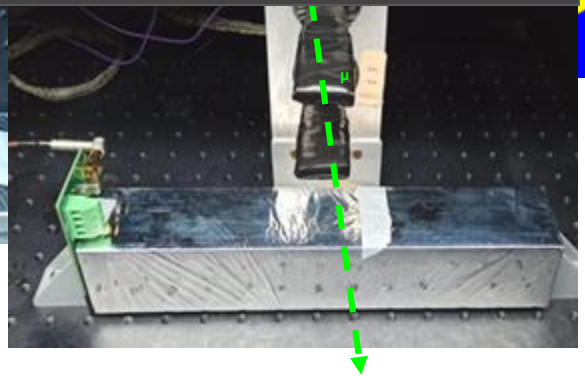
Possible solutions:

- **New crystals** with shorter decay time
  - **APD** + pure CsI studied in a past R&D JINST 12 C07032
  - high impact and very expensive solution
- Same CsI(Tl) crystals but **new photodetector**
  - fast **timing** for rejecting beam-background → need **internal gain**
  - require high dynamic-range (~10^4), must operate in high magnetic field

→ new R&D with **SiPM (M. Campajola, G.Gaudino)**

Longer-term ECL upgrade studies

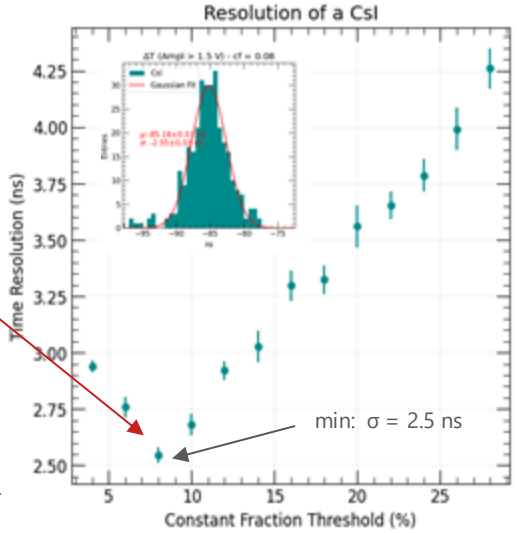
Napoli Test bench setup



Time resolution studies with SiPM:

- CsI(Tl) crystal (Belle-like)
  - energy deposited by MIP in CsI(Tl) ~ 40 MeV
- SiPM HPK S13360 family (6x6 mm^2)
- TIA pre-amplifier
- Plastic scintillators for trigger cosmics → use as time reference
- Oscilloscope to digitize signals

➔ ∽ **2 ns time resolution achievable**



Possible upgrade scenario:

- Add a SiPM channel for timing purpose:
  - simple and cheap;
  - good solution for timing at low deposited energy;
  - sub-optimal for amplitude measurement in the required dynamic range (loss of linearity);
- Amplitude (energy) measurement still done with pin-diode

Conclusions

- Il programma di Fisica di Belle II è unico e largamente complementare alle ricerche a LHC
- Iniziamo a produrre Fisica di precisione competitiva con il dataset Run1 di statistica comparabile a quella di BaBar
- Il 2024 è iniziato con serie instabilità di macchina cui si sta studiando una soluzione per il ramp-up della luminosità (abbiamo raggiunto i 5 10^{34} cm^{-2} s^{-1})
- Napoli contribuisce nei più rilevanti e qualificanti elementi del programma di Fisica, di operations di Computing e apparato, e nei programmi di upgrade del rivelatore.