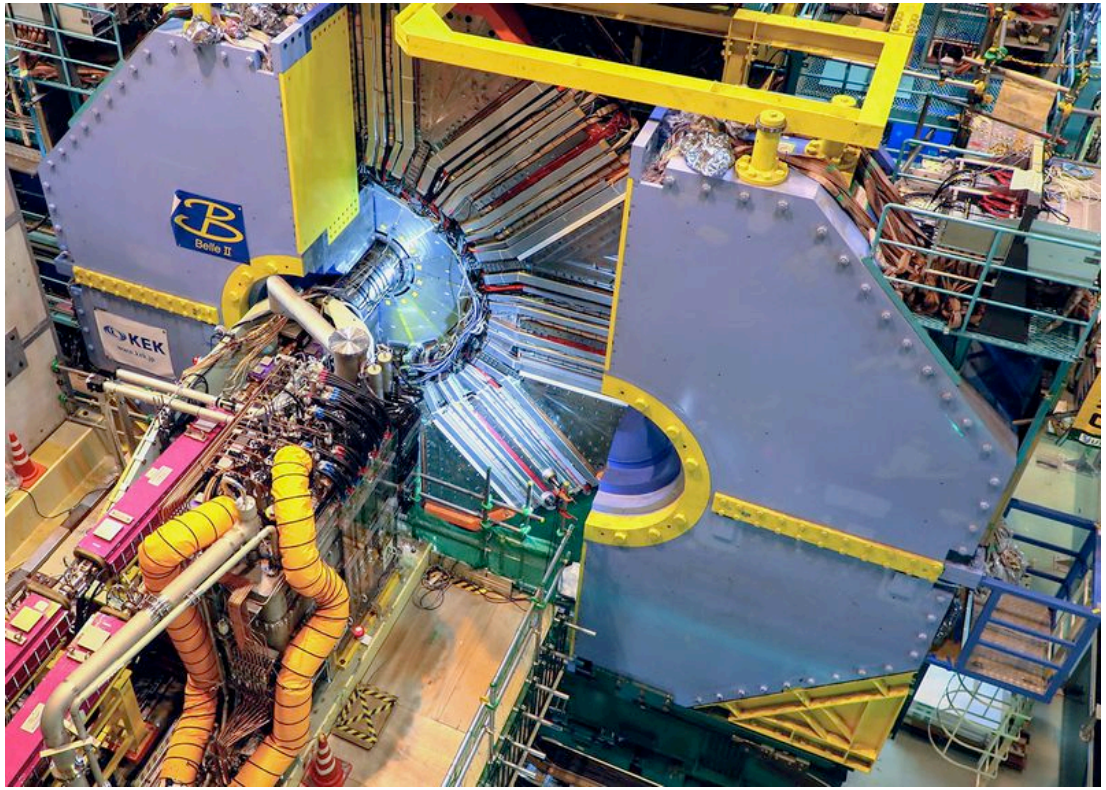
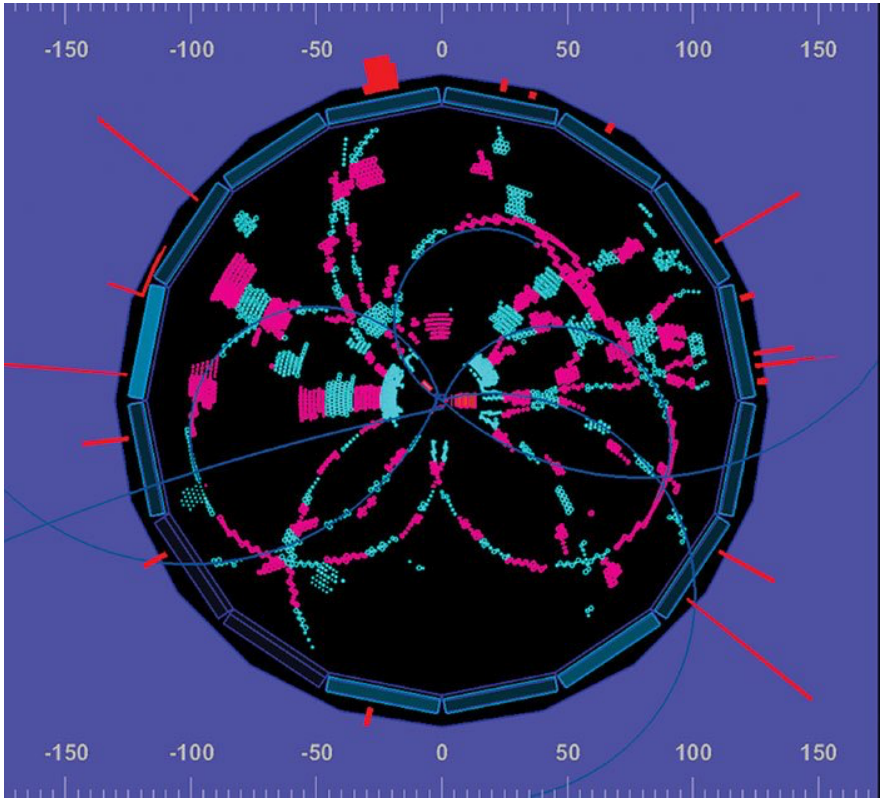




Belle II Experiment
Status and prospects

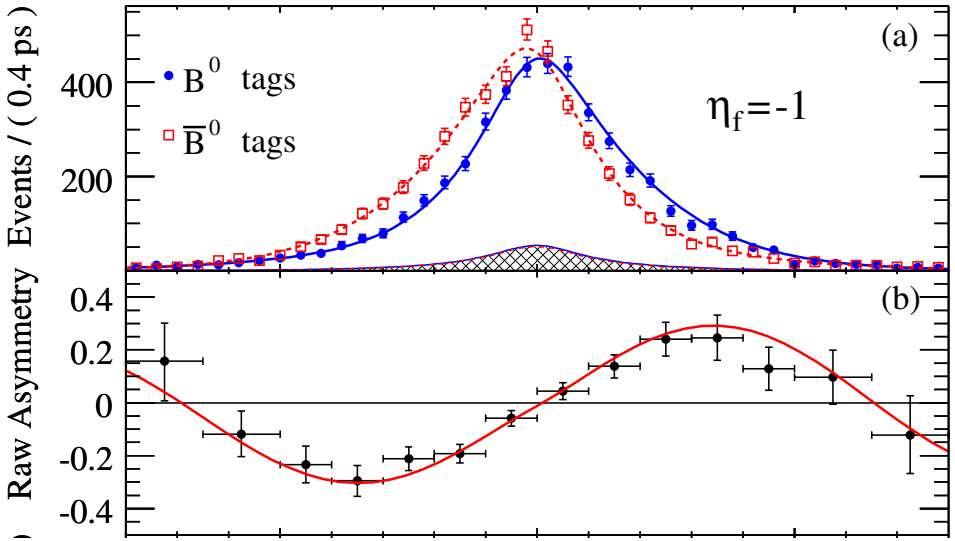
Guglielmo De Nardo

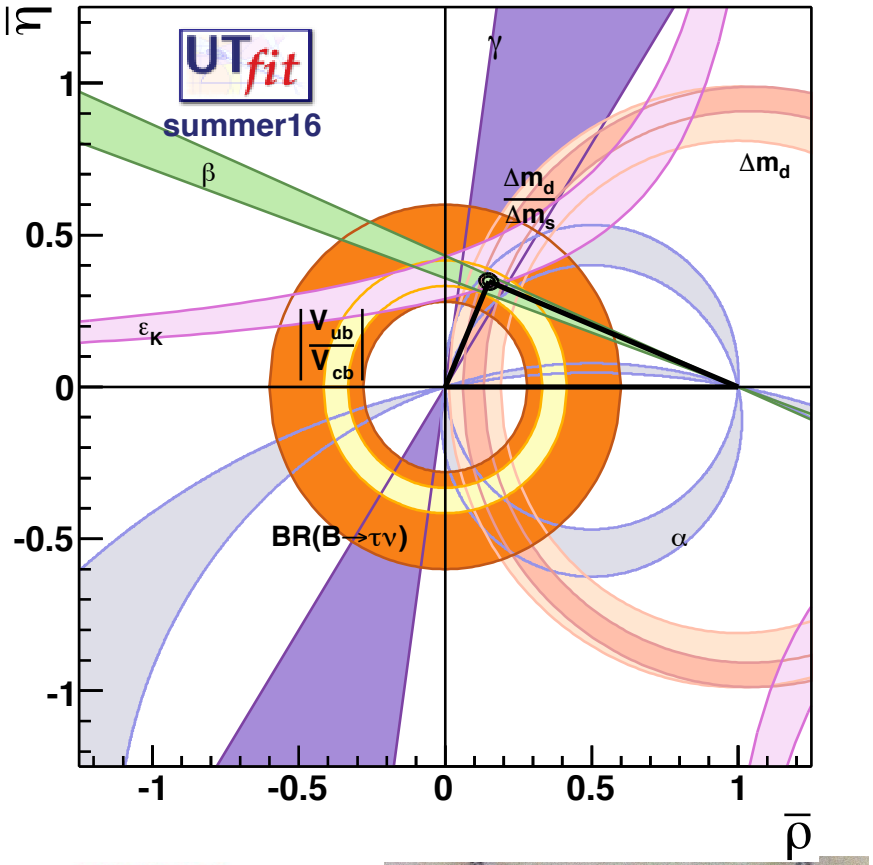
Università di Napoli Federico II e INFN

Riunione di fine anno del Gruppo I di Napoli

Napoli, December 21 2021

BaBar and Belle B-factories





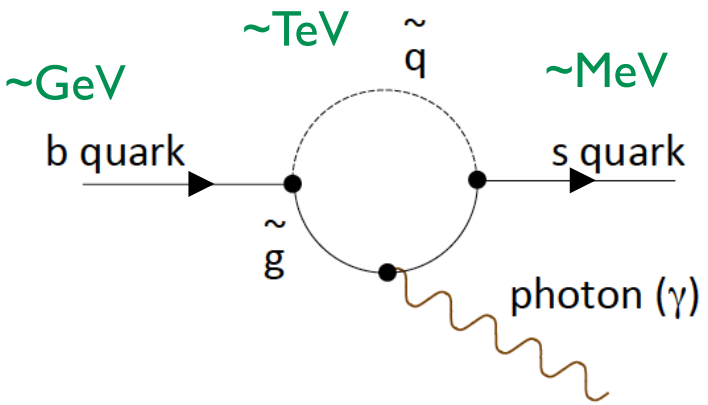
Successful experimental program
Established CP violation in B system and remarkable consistency of the CKM mechanism of the SM

Nobel Prize in Physics In 2008 awarded to Kobayashi and Maskawa

2008

Why Flavour at higher luminosity

Precise measurements of physics processes forbidden, suppressed or precisely predicted in the Standard Model → sensitivity to more fundamental physics



Hot topics nowadays:

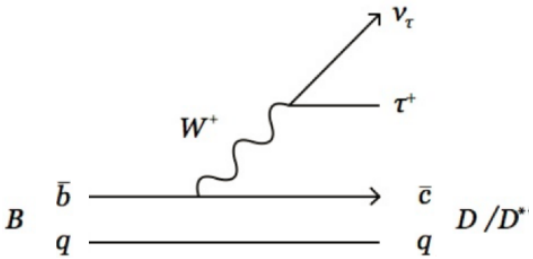
departure from Lepton Flavour Universality seen at past B-factories and LHCb

$$R(D^{(*)}) = \frac{\mathcal{B}(B \to D^{(*)}\tau\nu)}{\mathcal{B}(B \to D^{(*)}\ell\nu)} \quad R(K^{(*)}) = \frac{\mathcal{B}(B \to K^{(*)}ee)}{\mathcal{B}(B \to K^{(*)}\mu\mu)}$$

Anomalies in b→c and b→s transitions

b→cτν

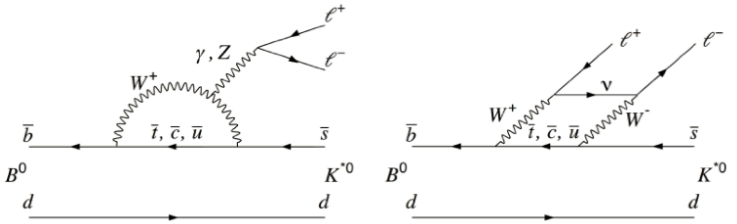
Tree, BF ~ O(10^{-2})



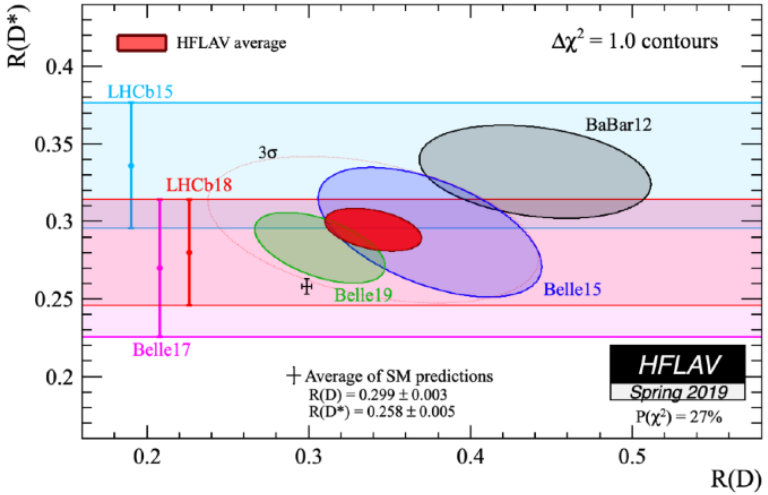
$$R(D^{(*)}) = \frac{BF(B \to D^{(*)} \tau \nu_\tau)}{BF(B \to D^{(*)} l \nu_l)}$$

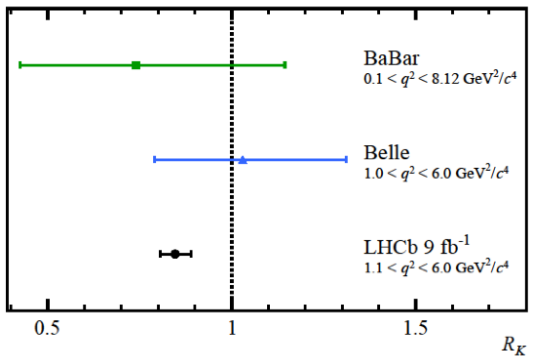
b→sl⁺l⁻

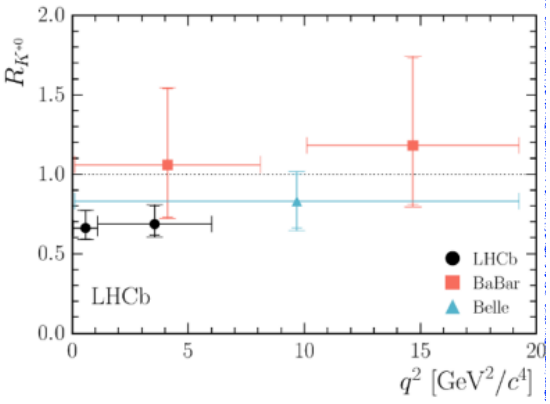
Loop, BF ~ O(10^{-6})



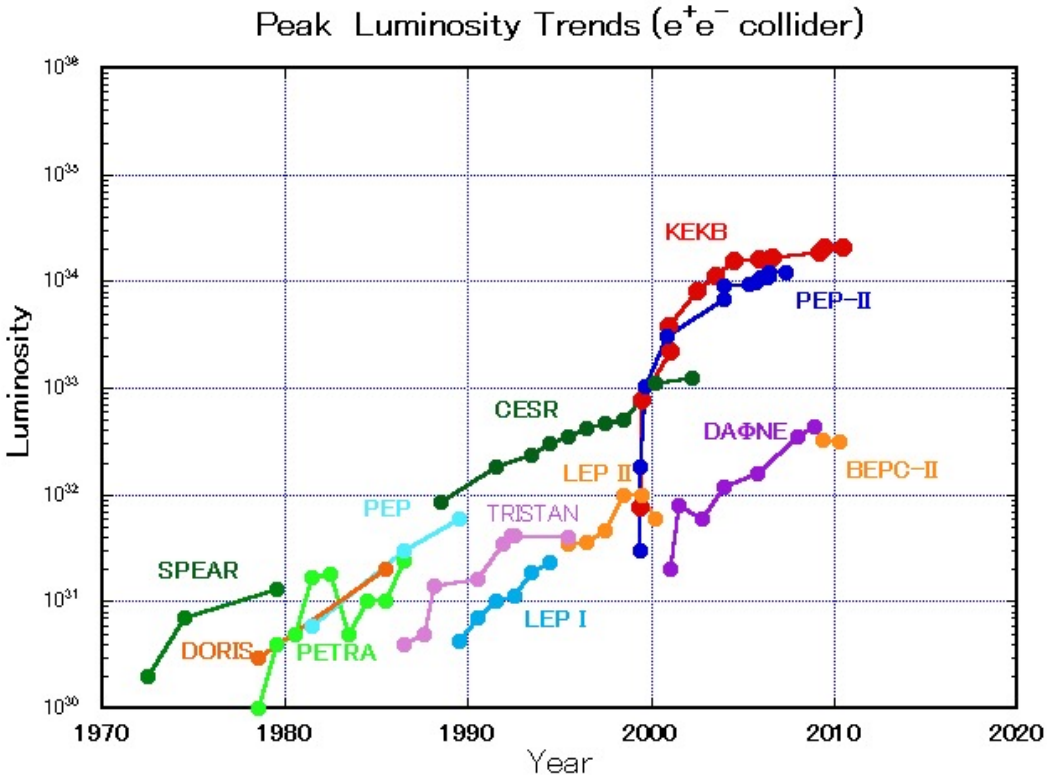
$$R_H = \frac{\mathcal{B}(B \to H\mu^+\mu^-)}{B(B \to He^+e^-)} \qquad H = K, K^*, X_s, \ldots$$







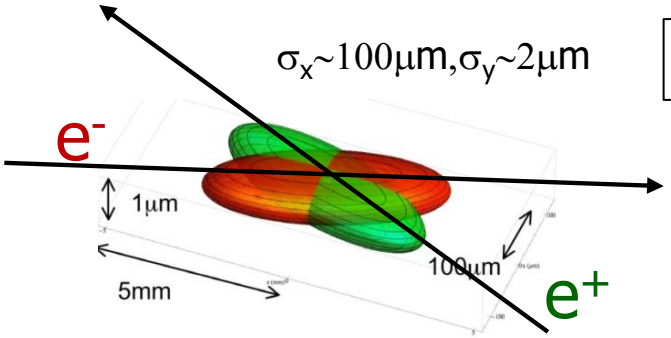
From KEKB to SuperKEKB



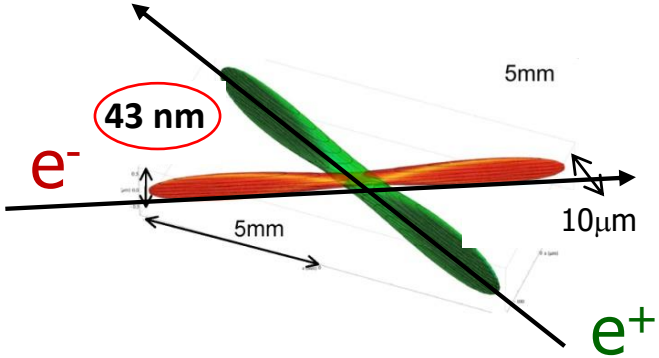
Critical issues at L = 8 x 10^{35} $cm^{-2}s^{-1}$

Higher event rate (x40)
- trigger rate, DAQ, computing

Higher machine backgrounds
- radiation damage
- occupancy
- fake hits and pile-up in the calorimeter



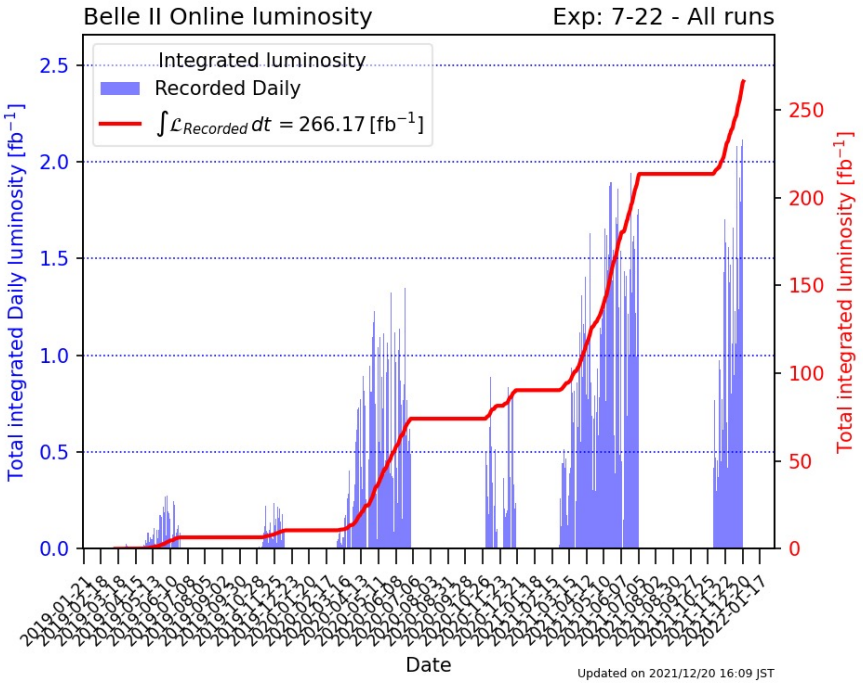
Nano-Beam scheme



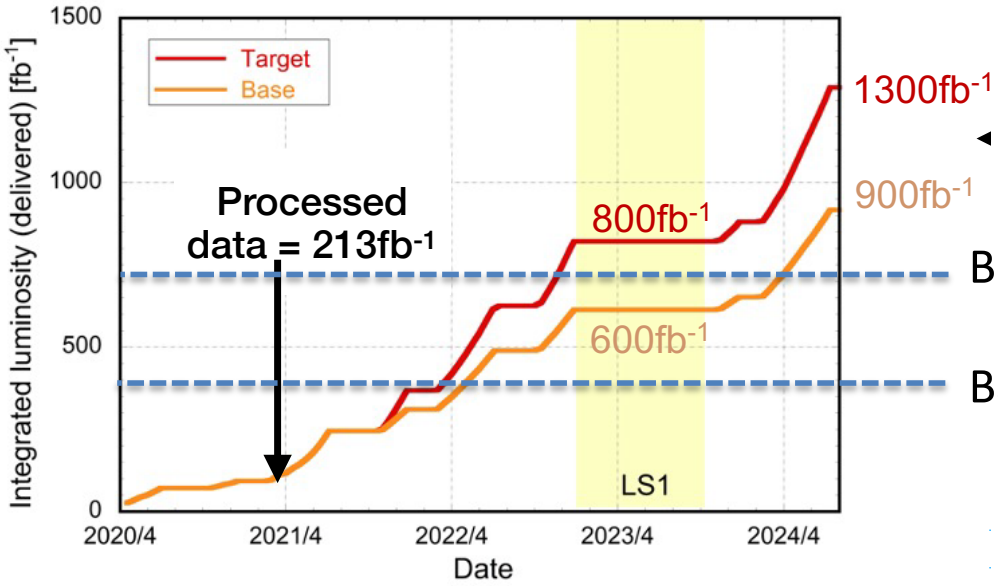
Luminosity profile

Data taken till summer: 213 fb^{-1}
Data taken till 20 dec 21: 266 fb^{-1}

World record istant. lumin.: 3 10^{34} $cm^{-2}s^{-1}$
World record daily int. lumin.: 2 fb^{-1} / day



Data taking plan for next 5 years



1300fb^{-1}

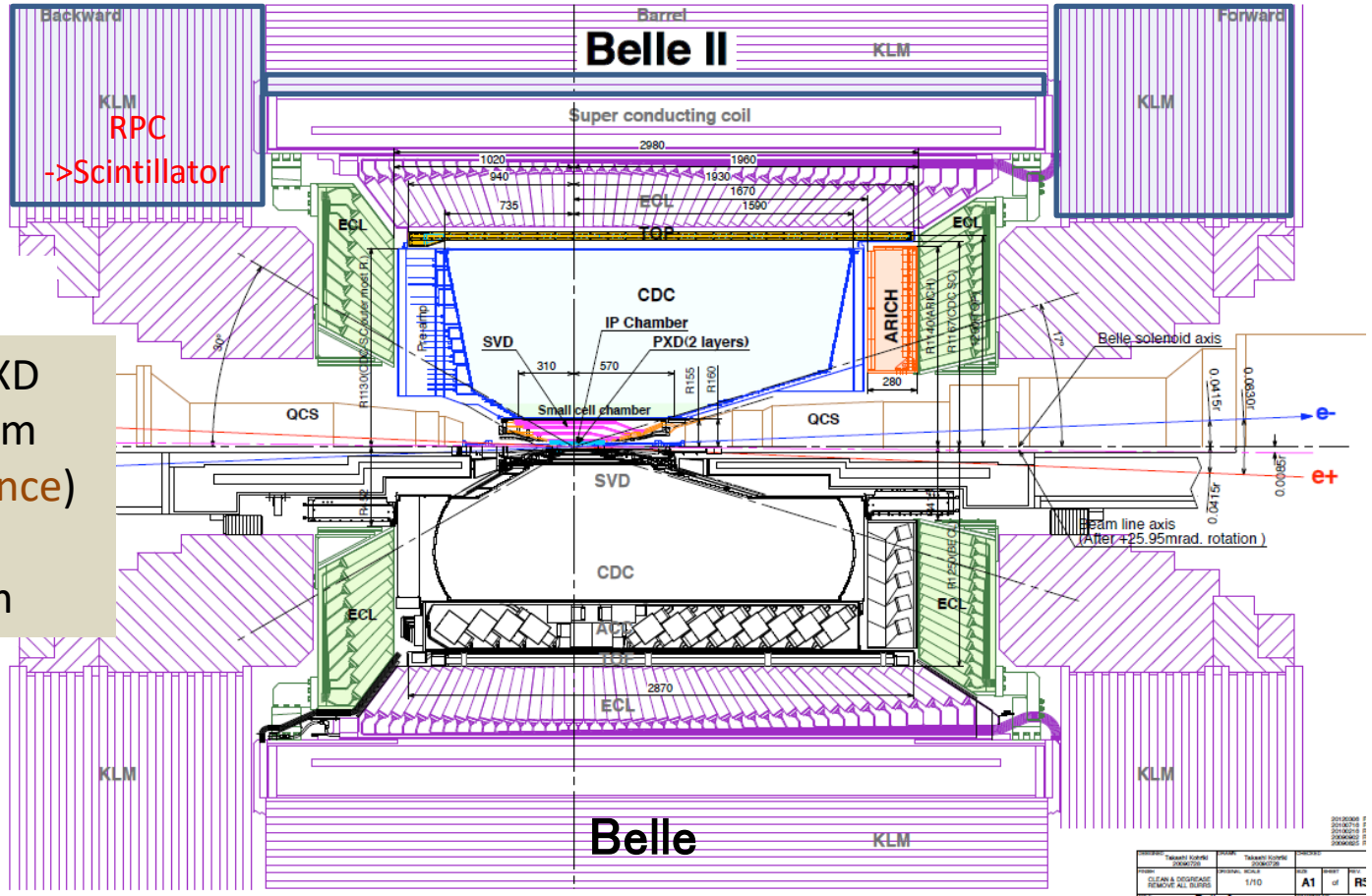
900fb^{-1}

Belle Y(4S) dataset

BaBar Y(4S) dataset

From Belle to Belle II detector

Belle II VXD
R=14-140mm
(Ks acceptance)
Belle SVD
R=20-88mm



SVD 4 layers (DSSD)	→	2 DEPFET + 4 DSSD
CDC:		small cell, long lever arm
ACC+TOF	→	TOP+ARICH (Better K/p separation)
ECL:		waveform sampling
KLM: RPC	→	Scintillator+SiPM

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

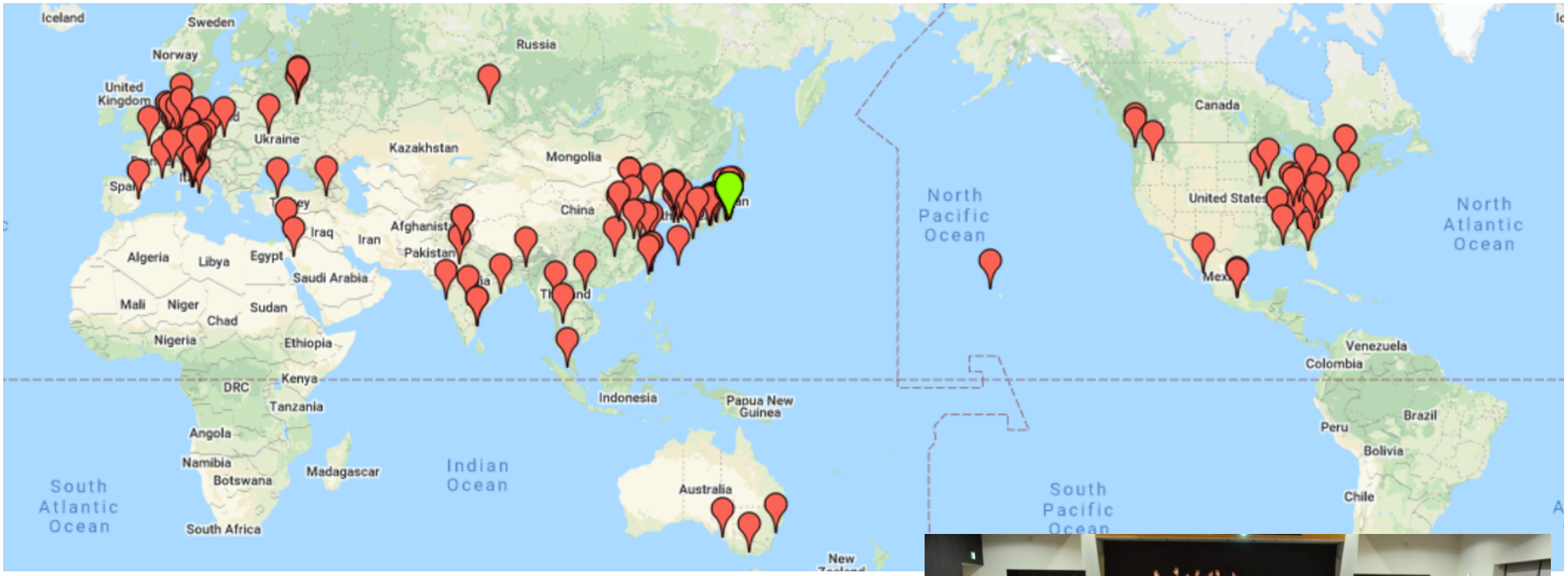
Inclusive measurements
$b \rightarrow s/d\,\gamma$ $b \rightarrow s\,l\,l$

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

International collaboration



- ~1120 active members
  - ~240/~140/~70 (Ph.D/Msc/Undergrad.) students
- 123 institutes
- 26 countries/regions

First Belle II Physics Publications

Combined analysis of Belle and Belle II data to determine the CKM angle φ3 using B+→D0(K0Sh+h−)h+ decays
Submitted to JHEP
First Belle / Belle II combined analysis on UT gamma angle

Precise Measurement of the D0 and D+ Lifetimes at Belle II,
Phys. Rev. Lett. 127, 211801 (2021)
Most precise measurement of D0 and D+

Search for B+→K+ν ν Decays Using an Inclusive Tagging Method at Belle II
Phys. Rev. Lett. 127, 181802 (2021)
b → s transition – probe of physics beyond SM (like B → K l+ l-)

Search for Axionlike Particles Produced in e+e− Collisions at Belle II
Phys. Rev. Lett. 125, 161806 (2020)
Dark sector search at e+ e- machine

Search for an Invisibly Decaying Z′ Boson at Belle II in e+e−→μ+μ−(e±μ∓) Plus Missing Energy Final States
Phys. Rev. Lett. 124, 141801 (2020)
First Belle II physics paper. M. Campajola PhD dissertation

+ many conference contributions with physics measurements assessing the experiment readiness/ performances in doing real physics analysis

Anagrafica INFN 2021

TOTALE: 5.95 FTE

Guglielmo De Nardo	90%
Alberto Aloisio	30%
Fabio Ambrosino	10%
Marcello Campajola	100%
Francesco Di Capua	30%
Raffaele Giordano	50%

Mario Merola	85%
Marco Mirra	40%
Guido Russo	70%*
Antonio Ordine	20%
Silvio Pardi	70%*
+ Giovanni Gaudino new PhD	

*percentuali su altre sigle di progetti con attività riconducibili a Belle II sono state incluse

Calorimetro elettromagnetico

Mantenimento e operations del sottosistema (De Nardo, Aloisio, Campajola, Di Capua, Giordano, Merola, Mirra)

Sistema di monitoraggio temperatura e umidità (Aloisio, Di Capua, Giordano)

Studio background di fascio

Dosimetria con film radiocromici (installati calorimetro e vertice) sviluppo e installazione sistema di lettura on-line (Di Capua)

Studio rad-hardness di FPGA installati sulla beam-line e su detector (Giordano)

Calcolo

Attività di produzione di simulazioni MC (data center ReCaS/Ibisco)

Coordinamento dei data center italiani (Pardi)

Fisica

Analisi dati di processi leptonici del B e del dark sector (De Nardo, Merola, Campajola, Gaudino)

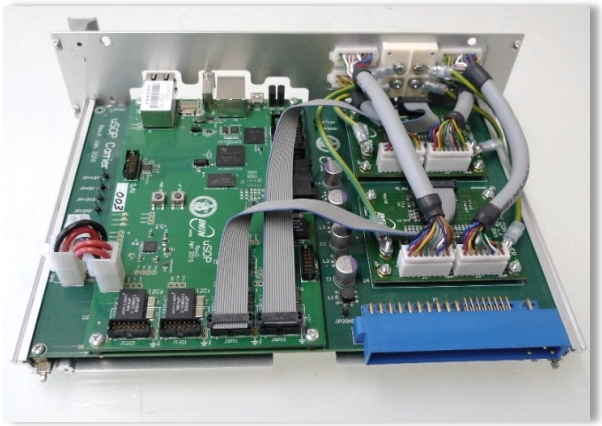
Misura della produzione di coppie di mesoni B (De Nardo, Merola)

Studio delle performance ricostruzione fotoni e π^0 (Gaudino, Mirra)

HIGHLIGHTS ATTIVITÀ NAPOLI

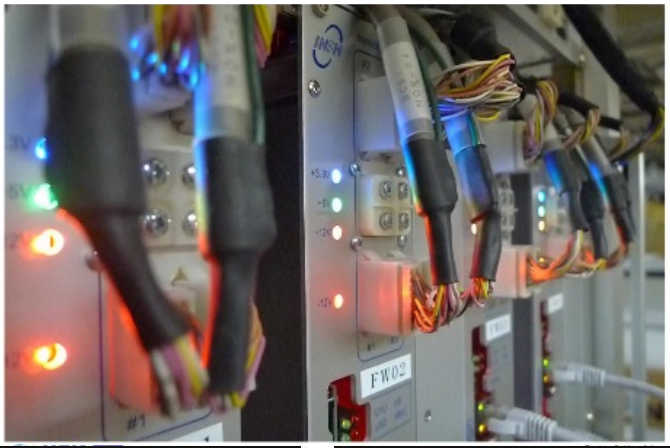
ECL endcaps temperature and humidity monitoring

A. Aloisio, F. Di Capua, R. Giordano

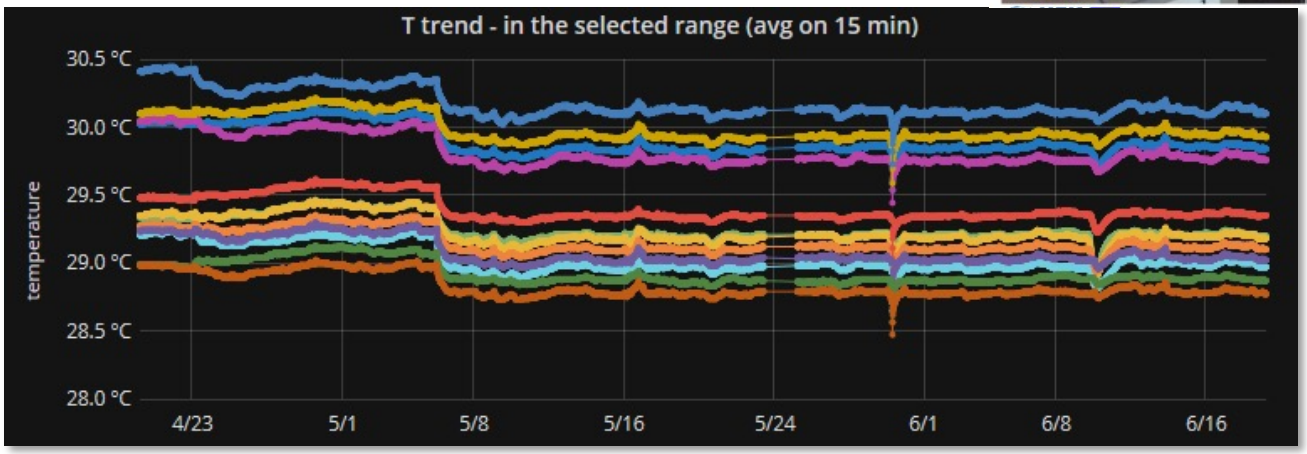


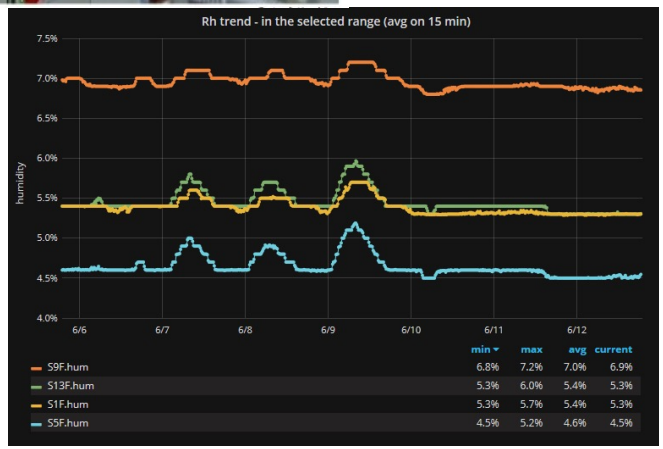
uSOP is a single board computer based on ARM processors, developed in Napoli

A monitoring system based on uSOP has been installed and is currently acquiring temperature
and humidity from sensors on the ECL endcaps



The system is fully integrated with the Belle II slow control



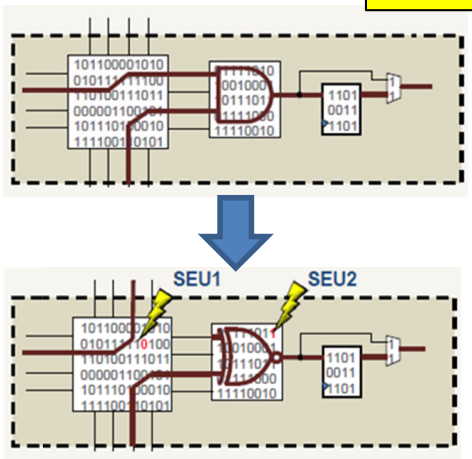


Hardware activities

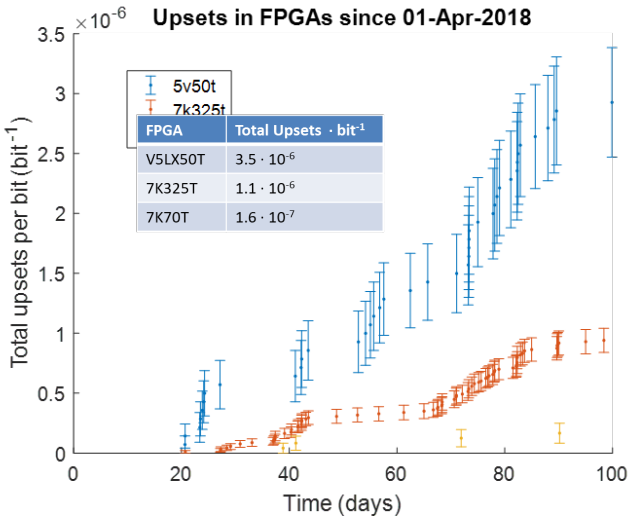
FPGA radiation tolerance

R. Giordano

- Kintex-7 and Virtex-5 FPGAs installed and tested for radiation effects
- Development of a FPGA based self reparing circuit



Phase2

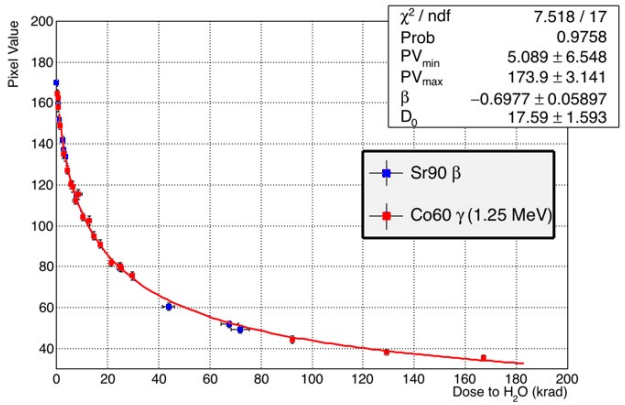


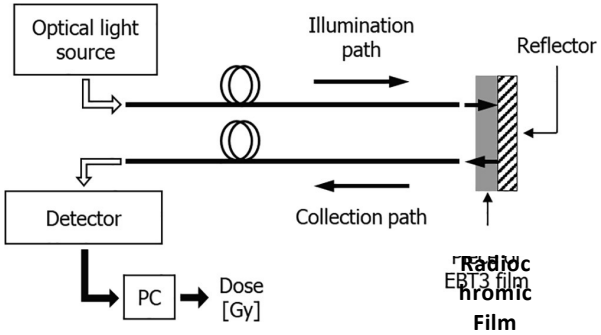
Radiadion dose measurements

F. Di Capua

- Integral dose measured with radio-chromic films
- Films response calibrated at known doses
- Installation of on-line readout system in 2022

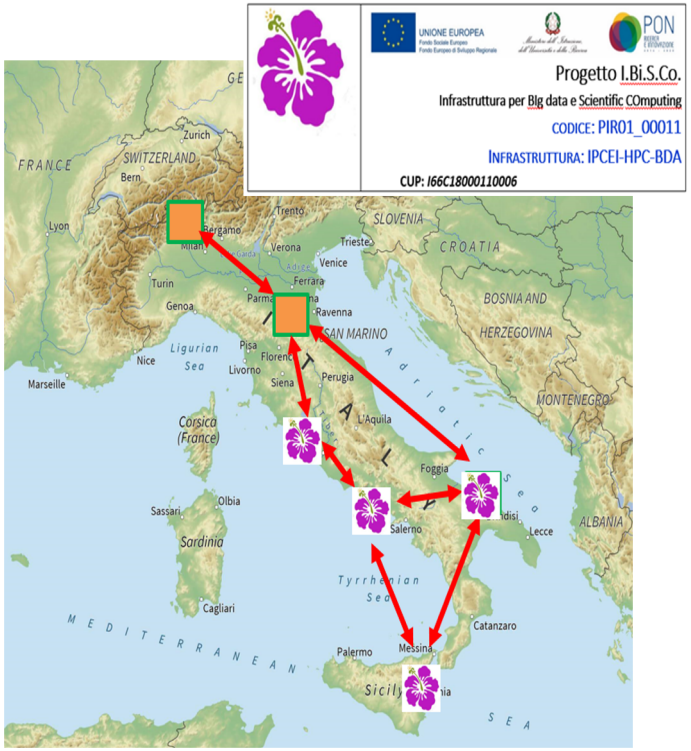
Film calibration to electron and gamma





Computing

G. Russo, S. Pardi



Silvio Pardi Coordinatore italiano del Computing e "Infrastructure coordinator" per la collaborazone

Risorse di Calcolo

Napoli fornisce oltre 2000 Core tra risorse INFN ed UNINA e 400TB di spazio disco. Tra I siti più grandi della collaborazione.

IBISCO Project

Finanziamento del PON IBISCO. Già acquisiti oltre 6.000 cores per High Troughput Computing e 10 PB di spazio disco di cui 1PB già disponibile per Belle II.

Numerose attività di R&D in Corso coordinate da Napoli.

- New protocols for data access/data management (HTTP/SRMless storge)
- Data Federation
- Caching System
- Network packet Marking
- Accesso to Federate Cloud Resource by EGI

B counting

G. De Nardo, M. Merola

B-counting strategy

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%)

From Mario Talk at Belle II meetings

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

Number of selected hadronic events in on-peak data

Estimated number of non-BB events in on-peak data

Efficiency of hadronic selection for BB events

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

Ratio of measured luminosities

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

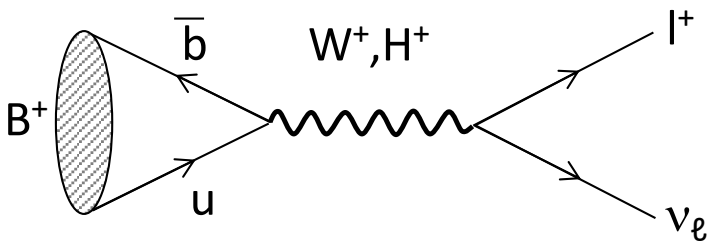
Efficiencies and cross sections of non-BB processes in on-peak and off-peak (primed quantities) data.

Responsibility of Napoli and Perugia group

Aiming at the publication of the method in 2022

Leptonic decays

G. De Nardo, G. Gaudino, M. Merola



Very clean theoretically, hard experimentally

SM is helicity suppressed

Sensitive to NP contribution (for ex: Charged Higgs)

Belle II may test LFU

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

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

$$r_H = (1 - \tan^2\beta \frac{m_B^2}{m_H^2})^2 \quad \textit{in 2HDM type II}$$

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

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

$$R^{\tau\pi} = \frac{\Gamma(B \to \tau\nu)}{\Gamma(B \to \pi l\nu)}$$

Mode	SM BR	Current meas.	Belle II 5 ab-1	Belle II 50 ab-1
τν	10^{-4}	20% uncertainty	15%	6%
μν	10^{-6}	40% uncertainty*	20%	7%
eν	10^{-11}	Beyond reach	-	-

From sensitivity study we published in The Belle II Physics Book

* PRL 121 031801 2.4σ excess [2.9,10.7]×10^{-7} at 90% C.L.

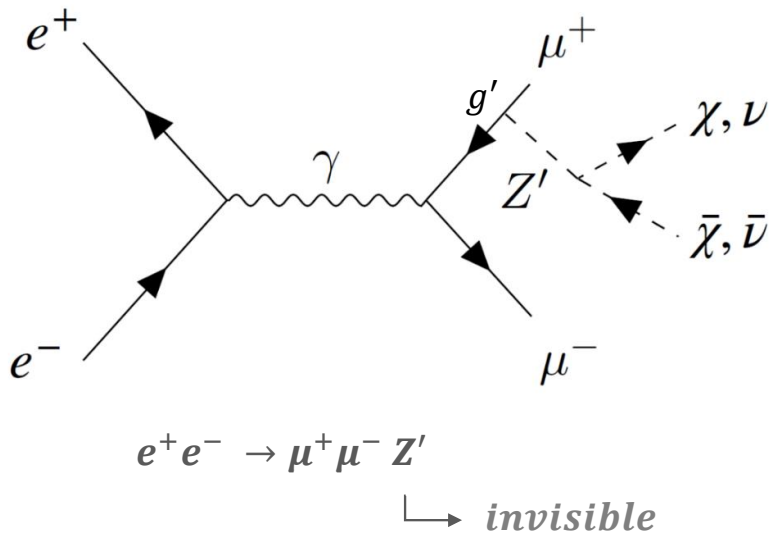
Aiming at public Belle II result in late 2022

talk from Giovanni Gaudino later today

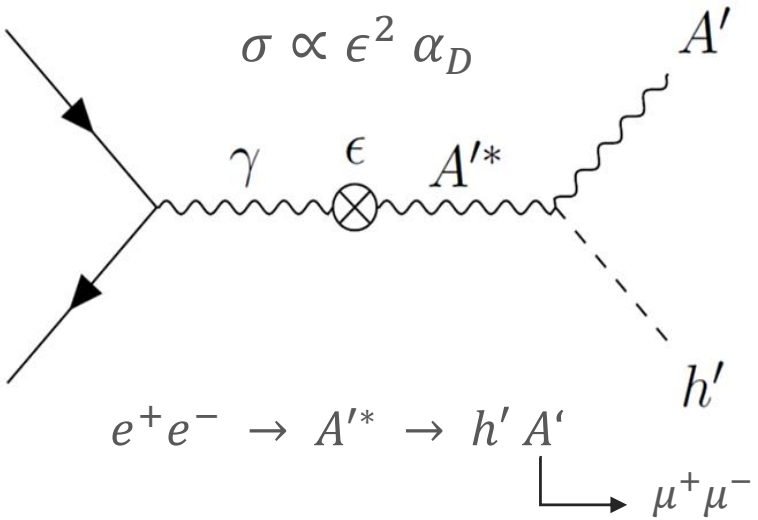
Dark sector searches

M. Campajola

Z' decays to invisible



Dark Higgs-strahlung



- Low multiplicity e+ e- collision products effectively exploitable to search for dark sector portal searches
- Search of Z' decays to invisible already published in 2020
- Dark Higgsstraluung on the way to be published in early 2022
- Already working on the update of the Z' search

talk from Marcello Campajola later today