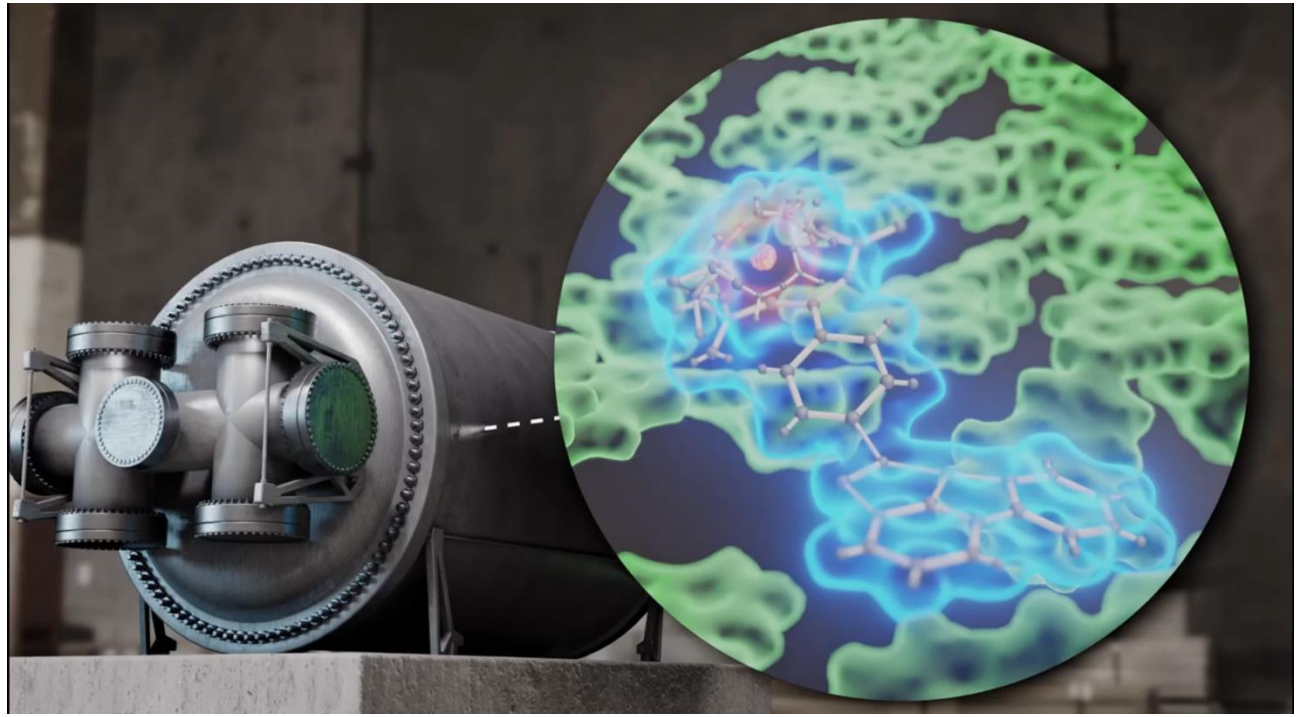
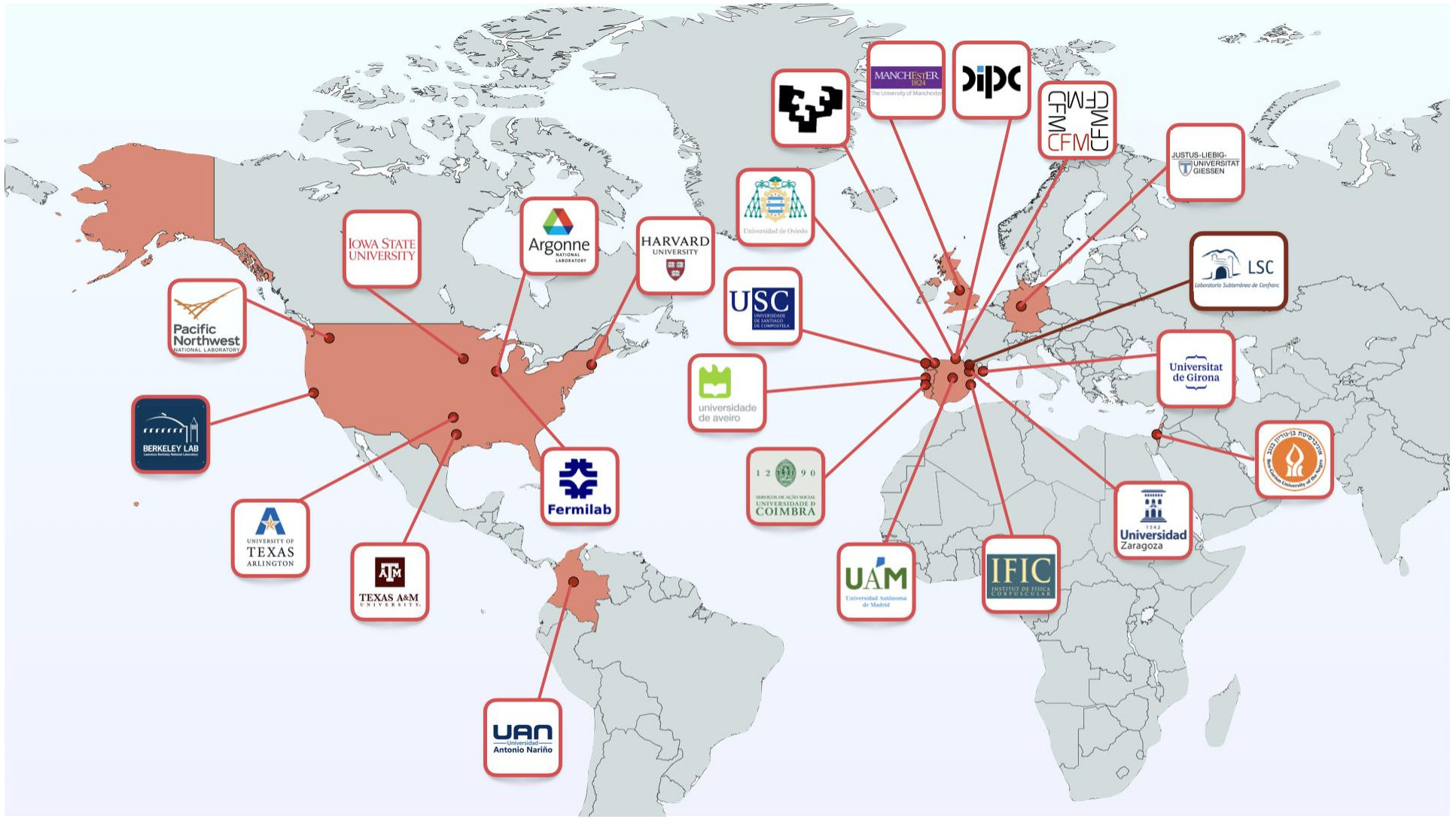
Searching the Grail: A background free $\beta\beta0\nu$ experiment using Ba^{2+} tagging in a High-Pressure Xenon Chamber



Iván Rivilla and on behalf of NEXT

NEXT · CFM Materials Physics Center Centro de Física de Materiales · Universidad del País Vasco · Euskal Herriko Unibertsitatea · LSC Laboratorio Subterráneo Canfranc · ikerbasque Basque Foundation for Science · DIPC


MANCHESTER
1824
The University of Manchester
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IOWA STATE
UNIVERSITY
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Universitat
de Girona
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CORPUSCULAR
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Universidad
Zaragoza
UAN
Universidad
Antonio Nariño


Bahía De La Concha
Bahia de la Concha
Funicular Monte Igueldo
Cánopy Donostia & Aventura
Busparking
Restaurante Alaia
Hotel Leku Eder
Igeldo Pasealekua
Lasarmendi Bidea
Ezeiza
Playa de Ondarreta
Hotel La Caleria
Loretopexa
La Perla Bar Restaurante
Palacio Miramar
Parking OTA Palacio Miramar
Paseo Marítimo de San Sebastián
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Hotel Codina
Reno Plazatxoa
Olaran
Hotel Avenida
Hotel NH Collection San Sebastián Aranzazu
Ondarreta Beach Hotel
Mirador Duque de Baena
Cines Antiguo Berri
Escuela Técnica Superior de...
Talent House
Barceló Costa Vasca
Kursi Hostel
Facultad de Economía y Empresa UPV/EHU
Abaxando
José María Sert Plaza
Parking Ondarreta
Polideportivo Municipal Bentaberri
Polideportivo Municipal Pío Baroja
Colegio Mayor AYETE Ikastetxe Nagusia
Dirección Gen... Tráfico De Guipúz...
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Autocaravanas, área de servicio y aparcamiento
Universidad del País Vasco Facultad de...
Facultad de ... UPV/EHU
Munto Berri Café Ba...
Bamboo Dance Aiete
Parroquia Santo Cristo Gurutzeaga de Aiete
Bera Bera
Palacio de Ayete
Parque de Ayete
GUREAK
Isidro Ansorena Kalea
Tecnun
Hotel Distrito Oeste
Carrefour Express
CIC nanoGUNE
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Bar Restaurante Arretxe
Hotel Artik San Sebastián
ARATZ
MAS QUE PAN
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MILIMARA Suites
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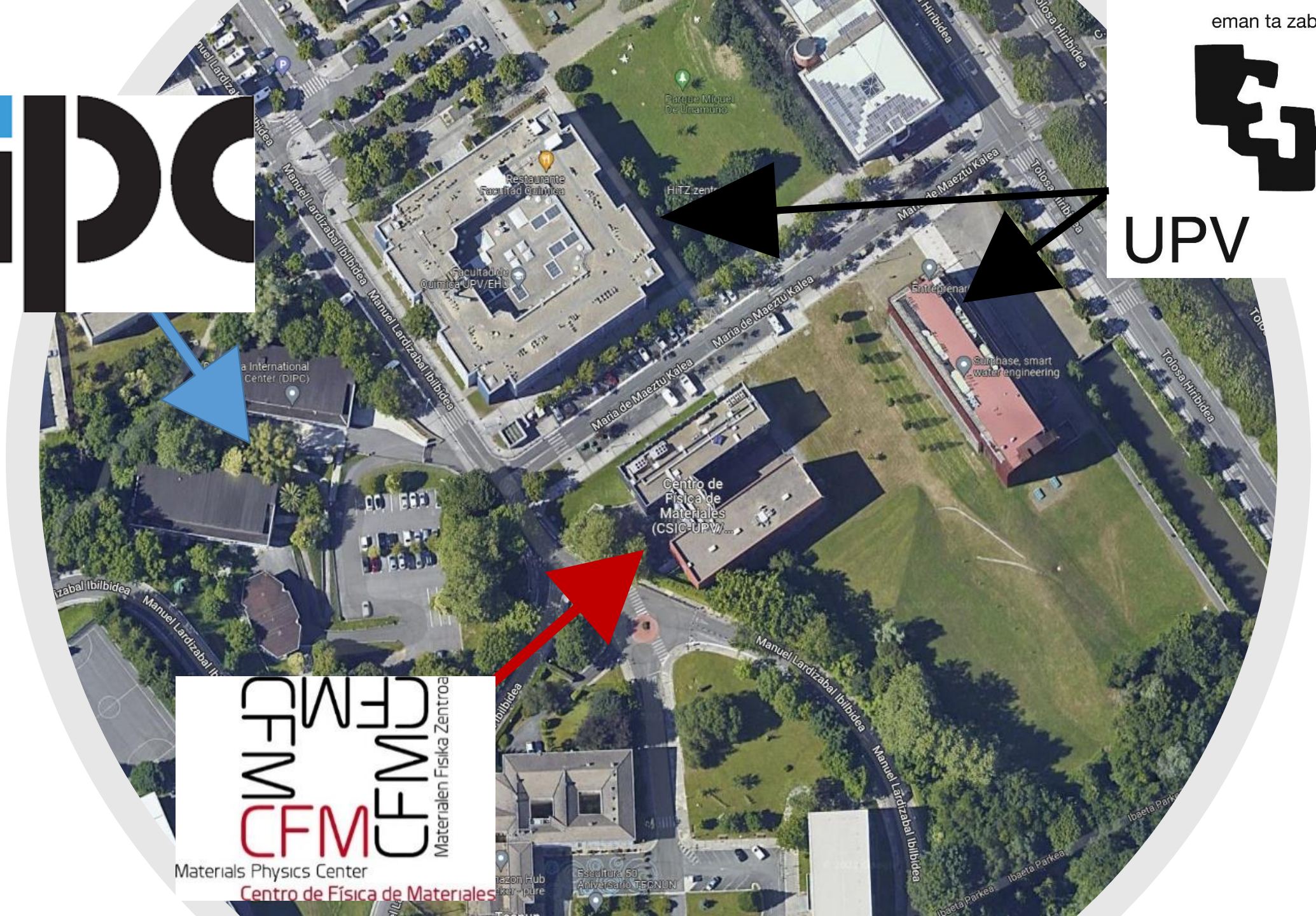
Livensa Living San Sebastián
Academia de francés Olaffance
Estación de Servicio Repsol



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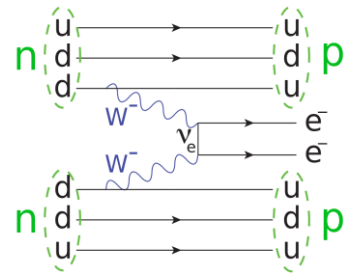
UPV EHU

CFM
Materials Physics Center
Centro de Física de Materiales
Materialen Fisika Zentroa

How to confirm experimentally if neutrino is a Majorana particle?



$\beta\beta 2\nu$

$^{Z}_{A}X \rightarrow {}^{Z+2}_{A}X + 2\,e^{-} + 2\,\bar{\nu}$

SM-allowed process
Measured in several nuclei

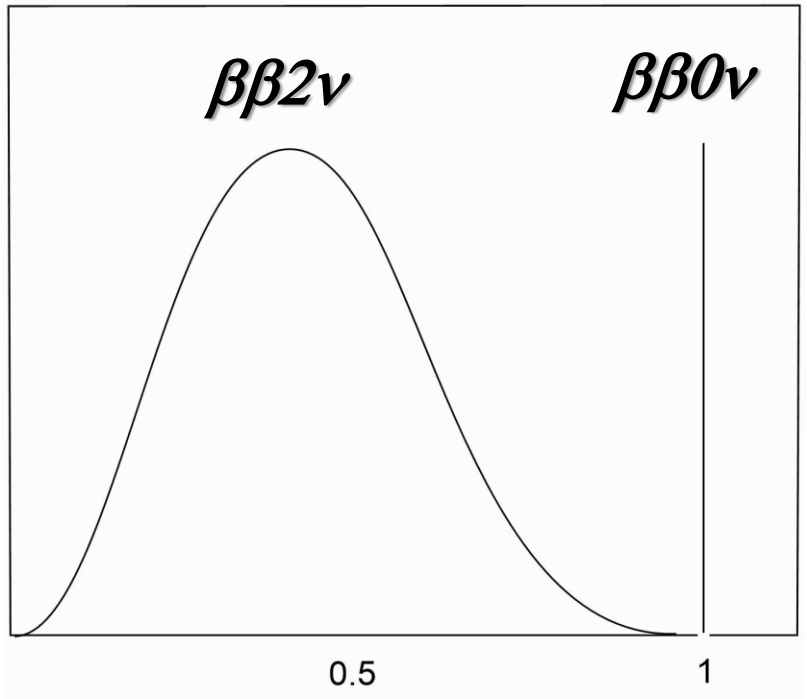
$T^{2\nu}_{1/2} \sim 10^{19} - 10^{21}\ yr$

$\beta\beta 0\nu$

$^{Z}_{A}X \rightarrow {}^{Z+2}_{A}X + 2\,e^{-}$

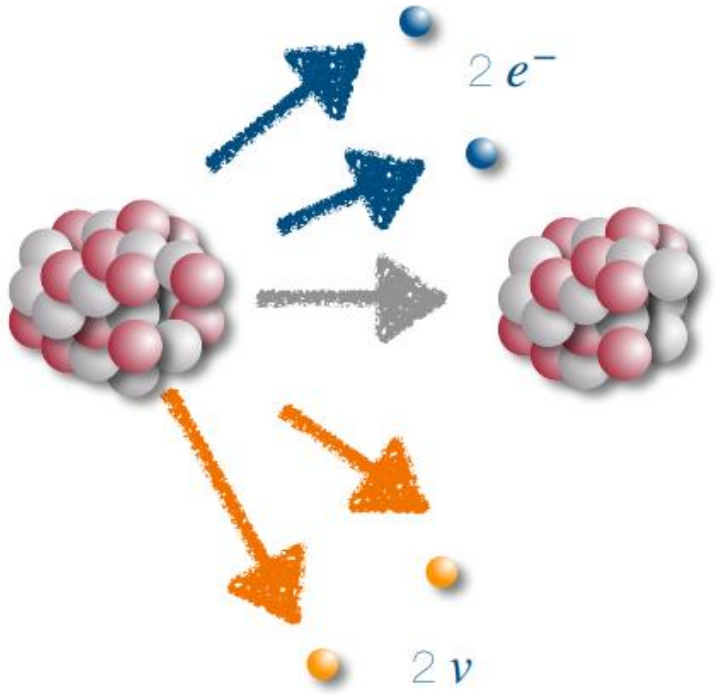
Lepton number violating process
Requires massive, Majorana neutrinos

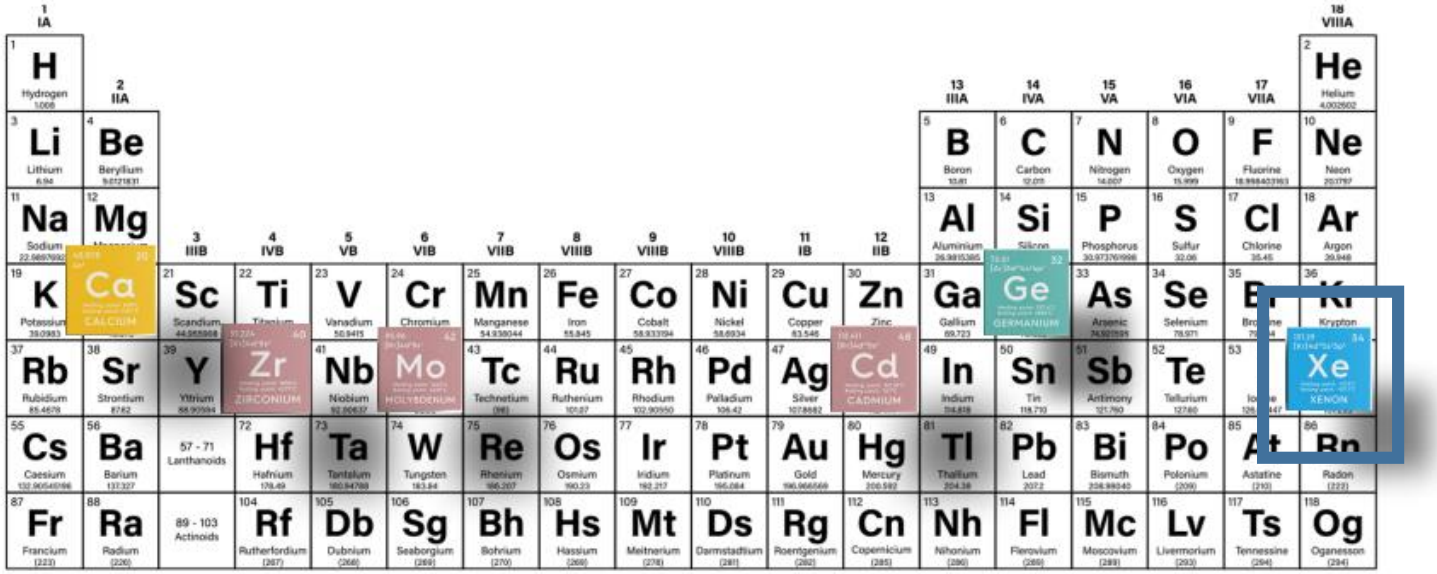
$T^{0\nu}_{1/2} > 10^{27}\ yr$

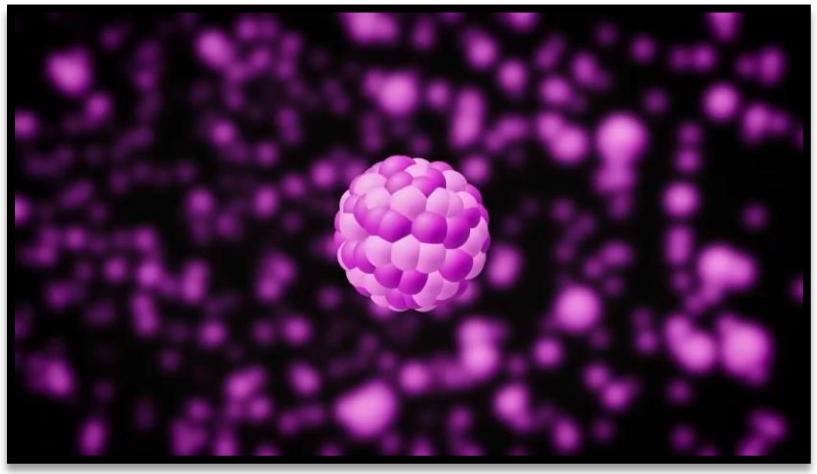


$(T_{e1} + T_{e2}) / Q_{\beta\beta}$

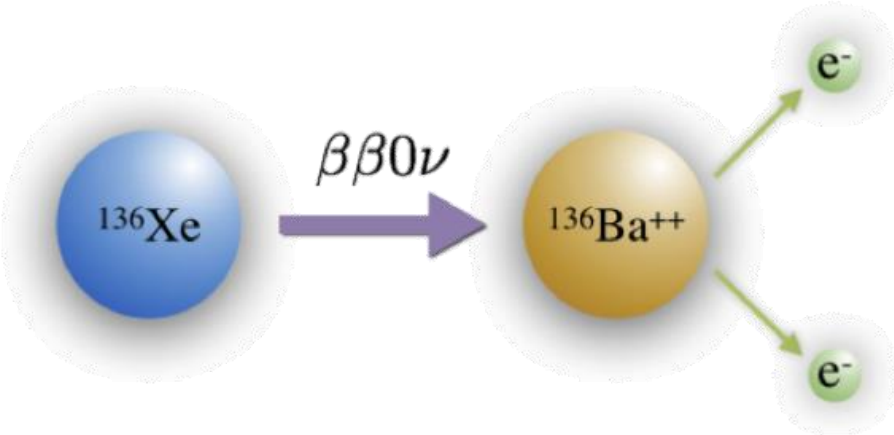
How to confirm experimentally if neutrino is a Majorana particle?



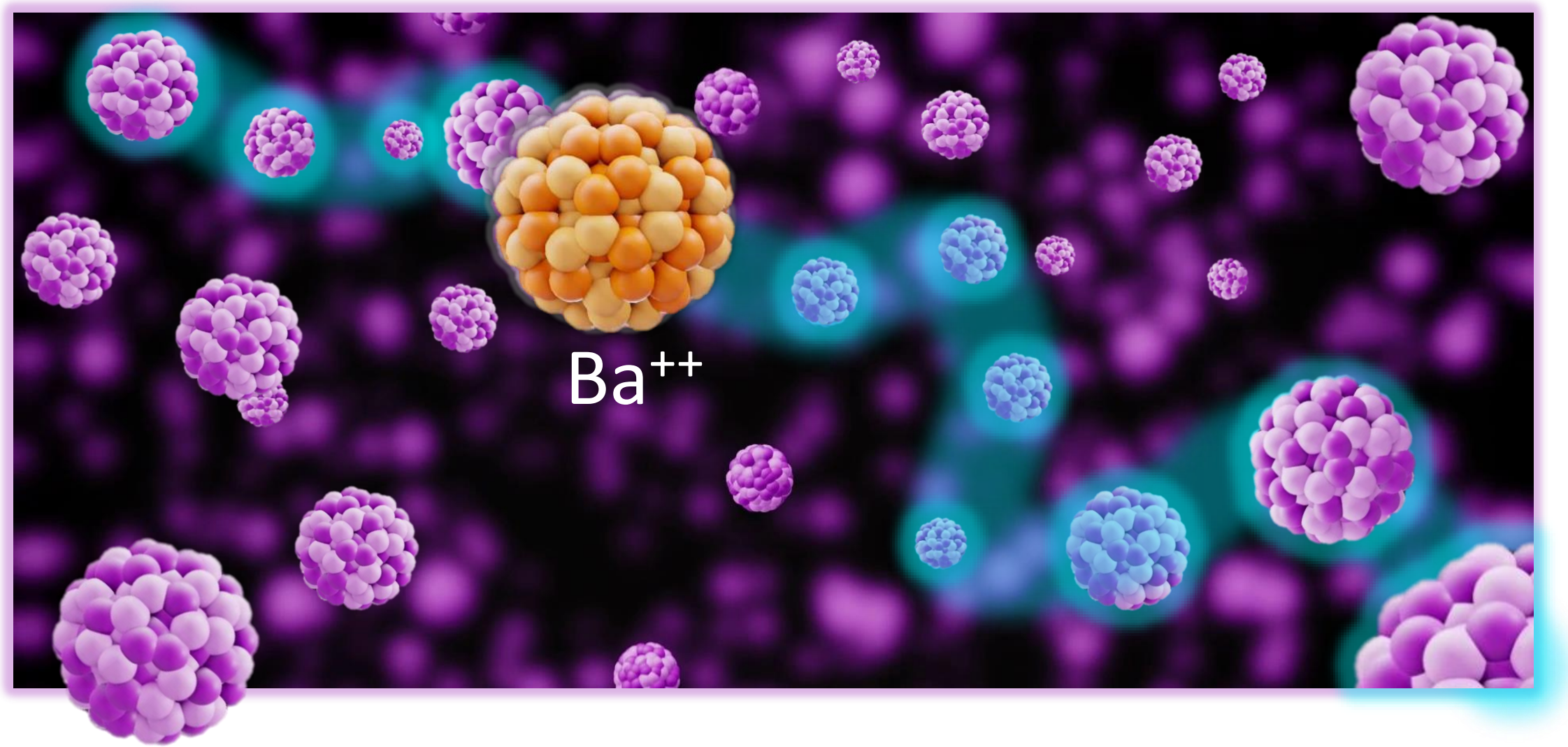




- *^{136}Xe ideal candidate*
- *Allows to build large detectors with Access to topological information.*
- The NEXT experiment can already reconstruct this track



How to confirm experimentally if neutrino is a Majorana particle?

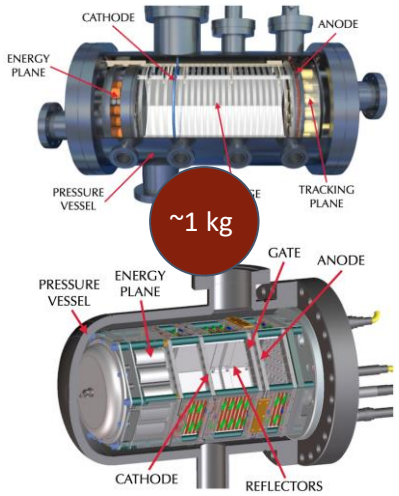


Detecting “tagging” the Ba^{++} signaling a $\beta\beta0\nu$ process has been a long sought holy grail of xenon chambers.

The NEXT Program

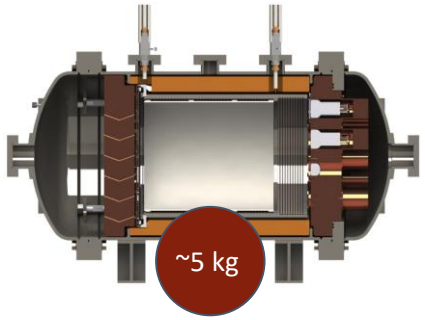
A. Usón Talk

Prototypes
2010-2014
Demonstration of detector concept

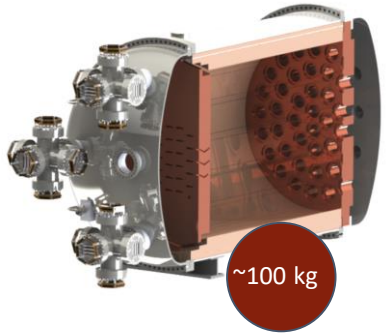


NEXT-White
2015-2021
Background model assessment

$2\nu\beta\beta$ measurement for ^{136}Xe



NEXT-100
2022-2026
Neutrinoless double beta decay search in ^{136}Xe

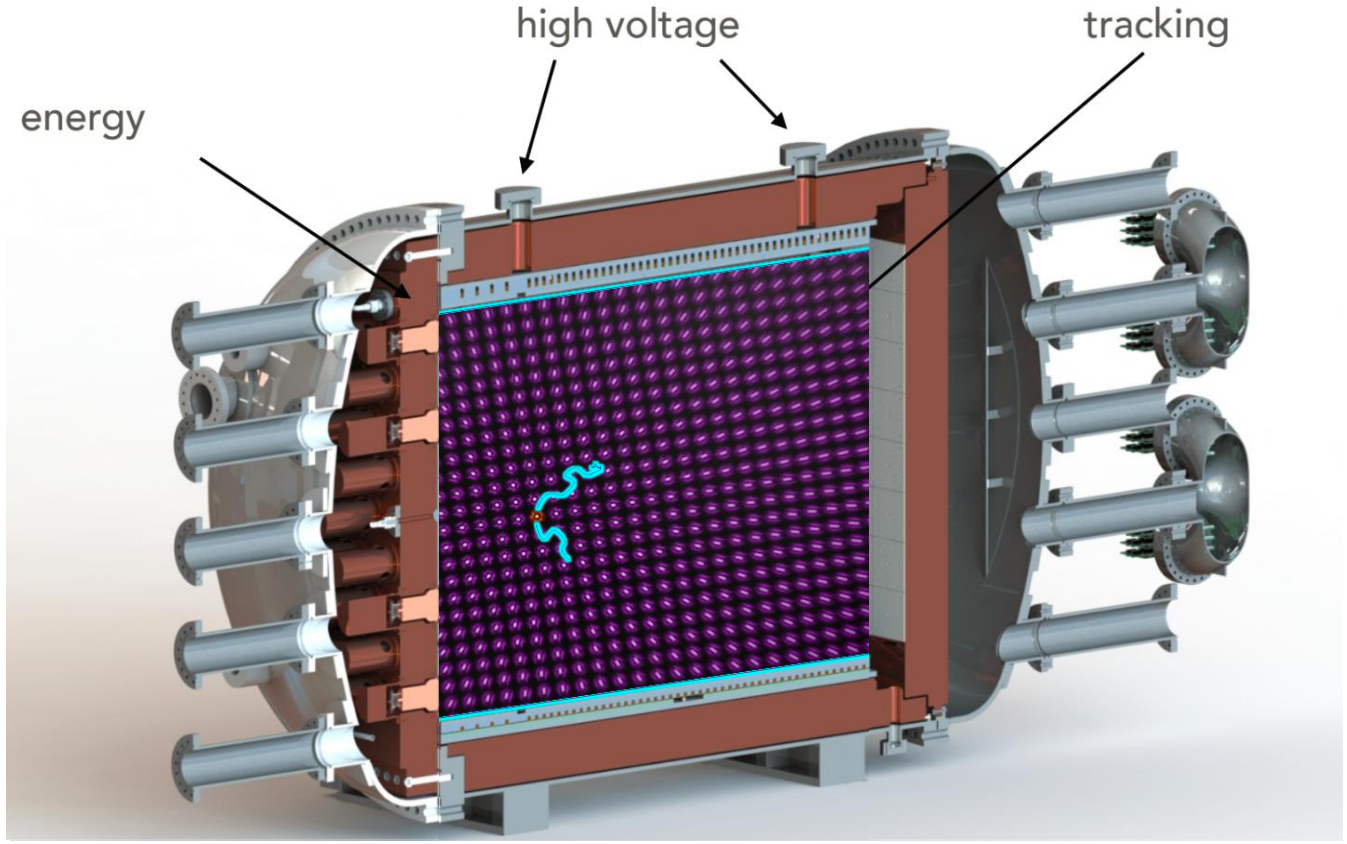


NEXT-HD
2027?
Neutrinoless double beta decay search through inverted neutrino mass ordering

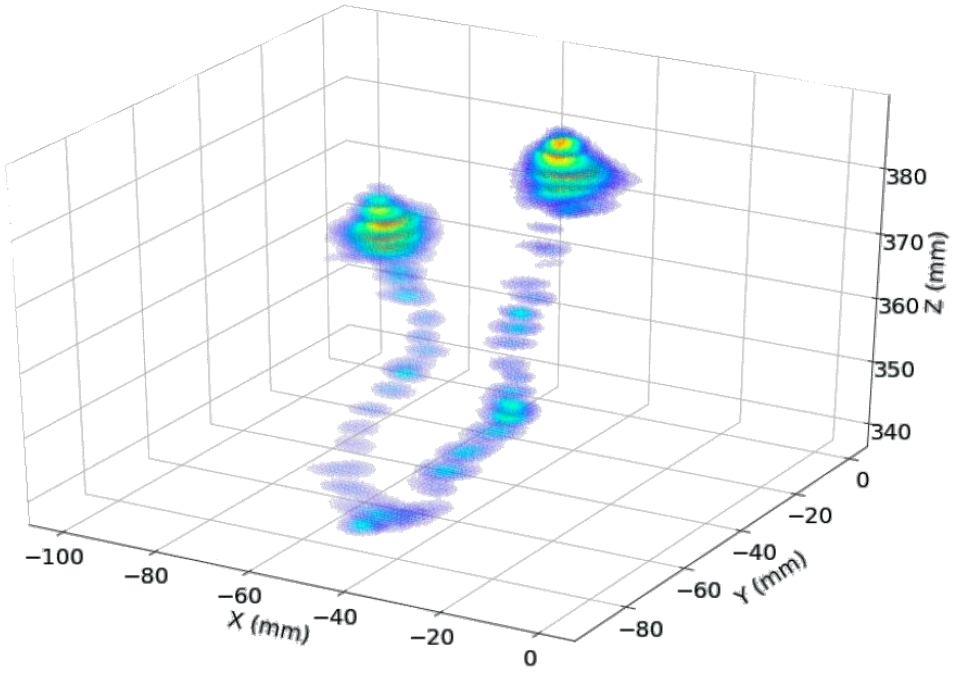
NEXT-BOLD
Barium tagging for background-free experiment

2009 2014 2015 2021 2022 2026 2027

NEXT detectors capabilities



$\beta\beta 0\nu$ in high-pressure ^{136}Xe gas

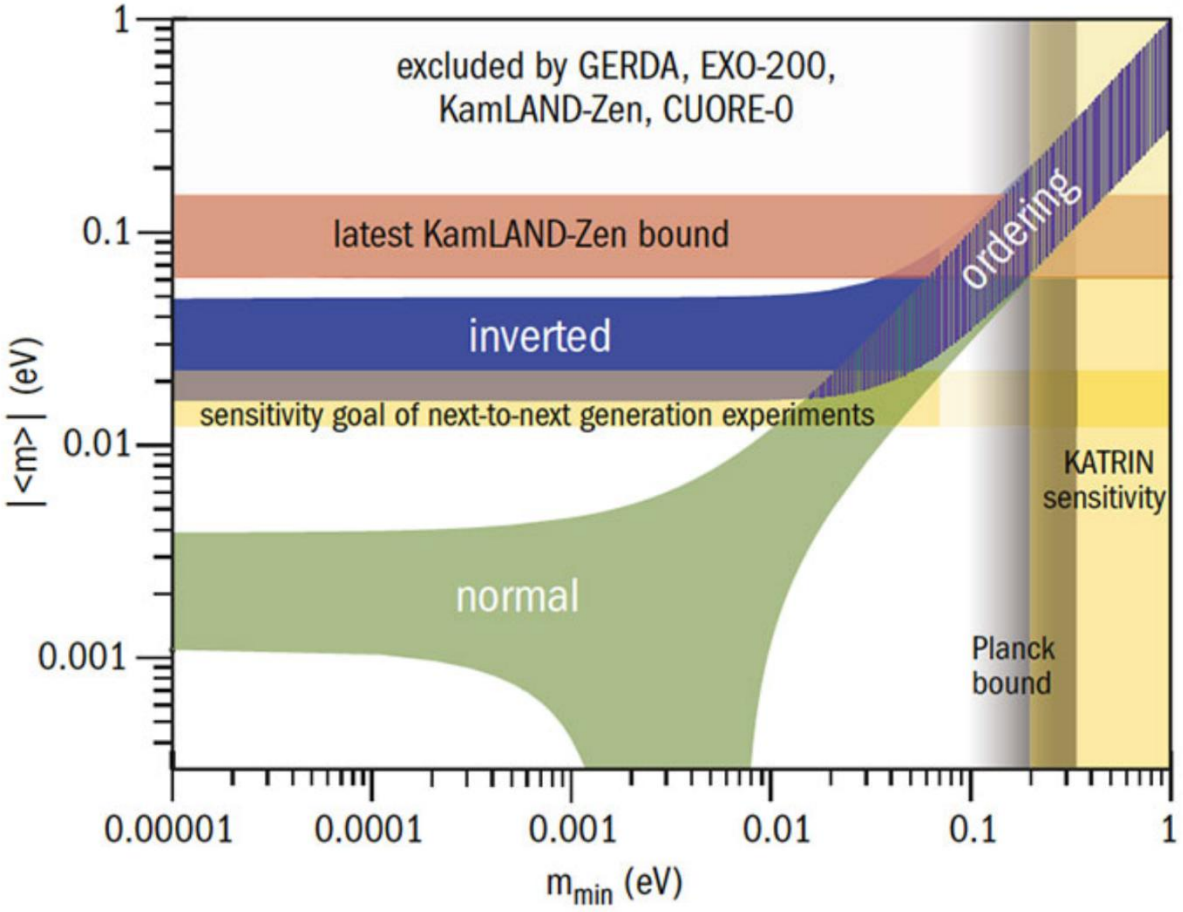


ββ2ν candidate at 2 MeV, showing 2 energy blobs at the extremes.

Energy resolution better than 1% FWHM at $Q_{\beta\beta}$.

Detecting "tagging" the Ba^{++} signaling a ββ0ν process has been a long sought holy grail of xenon chambers.

The NEXT thing:

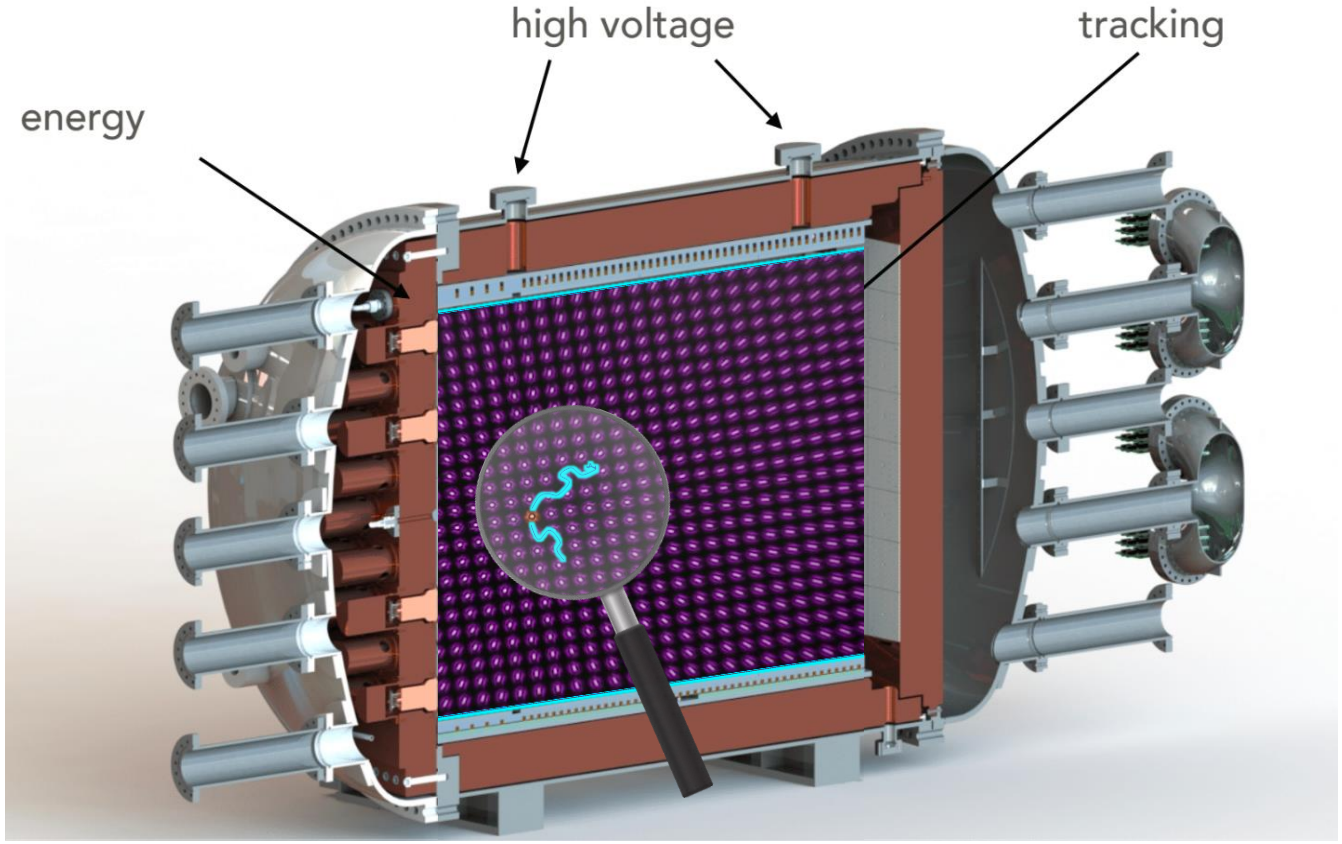


Current generation detectors “touching” inverse hierarchy región.
Objective for the next generation is to cover this region.

Lifetimes ~ $10^{27\text{-}28}$ years

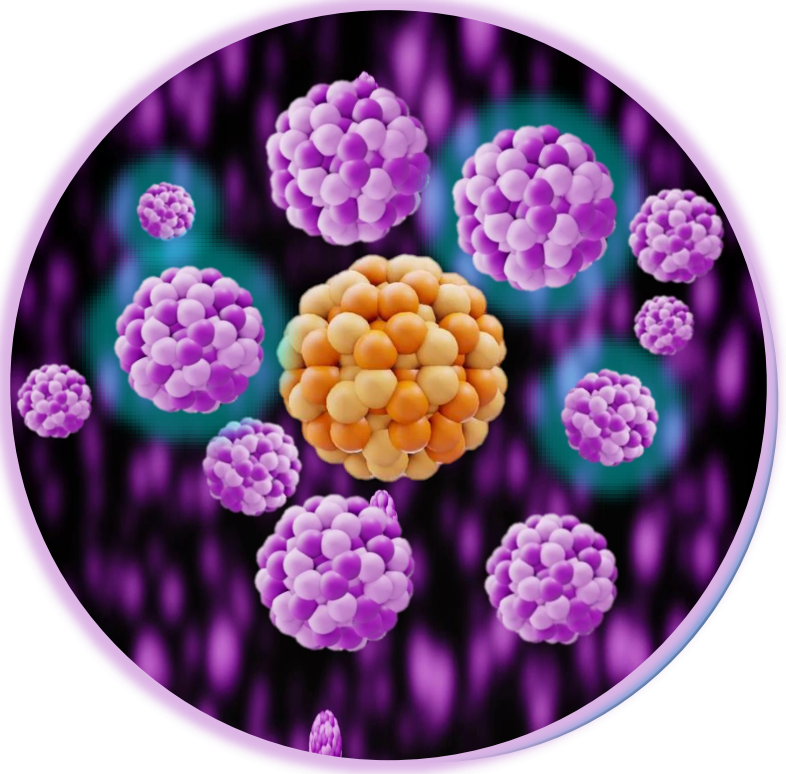
This implies almost background free detectors at the *ca*.Tonne-scale

How to get there with xenon gaseous detectors:



$\beta\beta 0\nu$ in high-pressure ^{136}Xe gas

Ba^{++}



Detecting "tagging" the Ba^{++} signaling a ββ0ν process has been a long sought holy grail of xenon chambers.

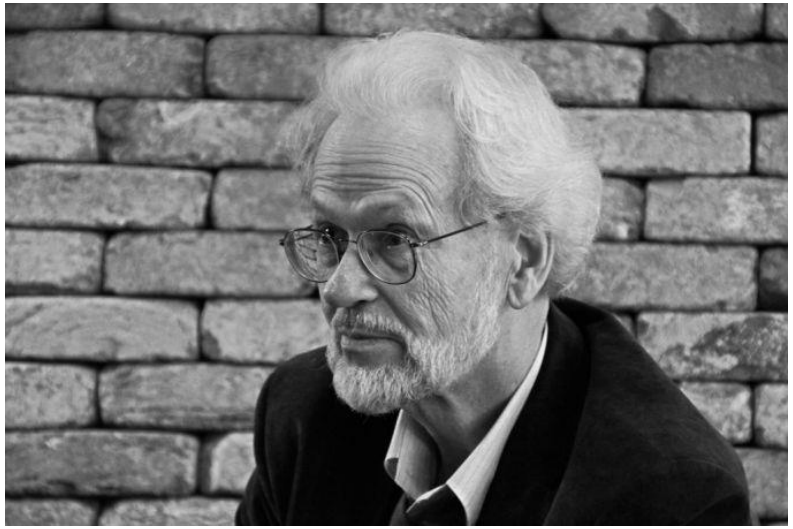
Detecting the barium daughter in ^{136}Xe 0-νββ decay using single-molecule fluorescence imaging techniques

David R. Nygren

Department of Physics, University of Texas at Arlington
Box 19059, Arlington, TX 76015

nygren@uta.edu

Abstract. Single-molecule fluorescent imaging may provide an avenue to efficiently detect the Ba^{++} daughter atom in the decay $^{136}Xe \rightarrow Ba + 2e^{-}$, and, unambiguously associate the birth point in space within the electron trajectories of the decay event. Chelation of doubly-charged alkaline earth elements such as calcium and barium by certain precursor molecules converts the resulting complex from a non-fluorescent to a fluorescent state. Repeated photo-excitation of a single fluorescent complex reveals both presence and location with high precision. This technique, widespread now in biochemistry, biophysics and biology, may permit a similar discriminating response in a large high-pressure xenon gas TPC for the Ba^{++} ion from xenon double-beta decay. The TPC measures the event time and energy of the two nascent electrons, as well as topology and position in 3-D from their trajectories in the gas. Measurement of the 2-D location of the molecular ion after arrival at the cathode plane permits an association of ion with the event. Demonstration of an efficient, highly specific detection of the barium daughter would provide a long-sought pathway to a background-free result in the search for this decay mode, of central importance for determining the nature of the neutrino.



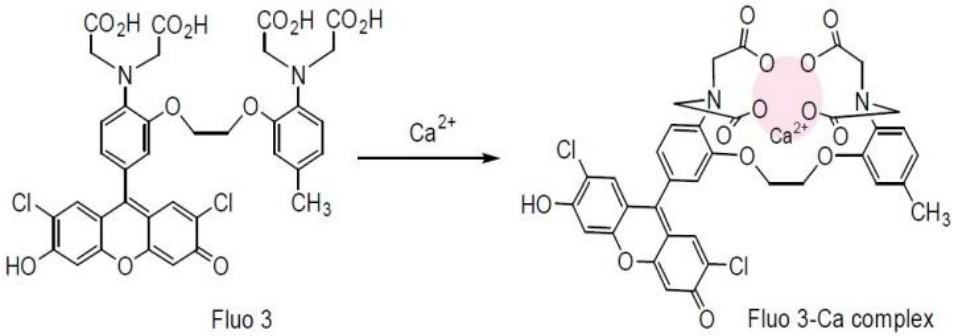


Figure 1. The skeletal formula for Fluo-3 is shown before and after complex formation. The conformal change that Fluo-3 undergoes in chelation with Ca^{++} creates a fluorescent complex. In that state, the fluorescent response increases by a factor of 60 - >100 in the cellular environment. *Image source*: Dojindo Molecular Industries, Inc.

David R Nygren 2015 *J. Phys.: Conf. Ser.* **650** 012002

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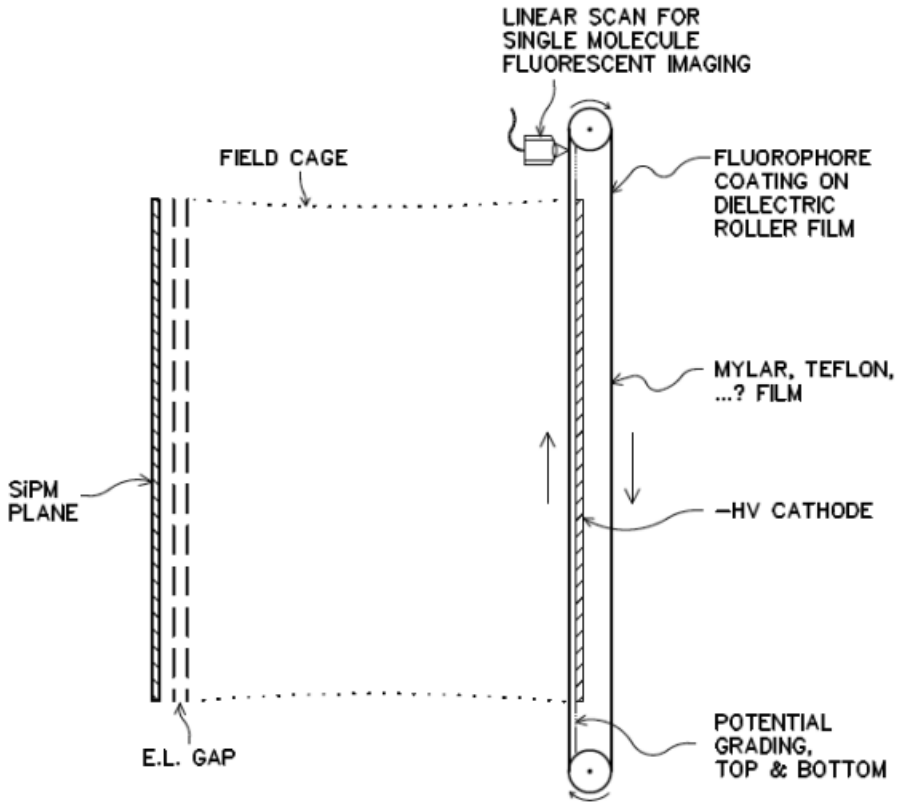


HIGH PRESSURE XENON GAS ELECTROLUMINESCENT TPC
WITH SINGLE MOLECULE FLUORESCENT IMAGING OF BARIUM DAUGHTER

David R Nygren 2015 *J. Phys.: Conf. Ser.* **650** 012002

Demonstration of Single-Barium-Ion Sensitivity for Neutrinoless Double-Beta Decay Using Single-Molecule Fluorescence Imaging

A. D. McDonald,[1,†] B. J. P. Jones,[1,‡] D. R. Nygren,[1,§] C. Adams,[2] V. Álvarez,[3] C. D. R. Azevedo,[4] J. M. Benlloch-Rodríguez,[3] F. I. G. M. Borges,[5] A. Botas,[3] S. Cárcel,[3] J. V. Carrión,[3] S. Cebrián,[6] C. A. N. Conde,[5] J. Díaz,[3] M. Diesburg,[7] J. Escada,[5] R. Esteve,[8] R. Felkai,[3] L. M. P. Fernandes,[9] P. Ferrario,[3] A. L. Ferreira,[4] E. D. C. Freitas,[9] A. Goldschmidt,[10] J. J. Gómez-Cadenas,[3,§] D. González-Díaz,[11] R. M. Gutiérrez,[12] R. Guenette,[2] K. Hafidi,[13] J. Hauptman,[14] C. A. O. Henriques,[9] A. I. Hernandez,[12] J. A. Hernando Morata,[11] V. Herrero,[8] S. Johnston,[15] L. Labarga,[16] A. Laing,[3] P. Lebrun,[7] I. Liubarsky,[3] N. López-March,[1,3] M. Losada,[12] J. Martín-Albo,[2] G. Martínez-Lema,[11] A. Martínez,[3] F. Monrabal,[1] C. M. B. Monteiro,[9] F. J. Mora,[8] L. M. Moutinho,[4] J. Muñoz Vidal,[3] M. Musti,[3] M. Nebot-Guinot,[3] P. Novella,[3] B. Palmeiro,[3] A. Para,[7] J. Pérez,[3] M. Querol,[8] J. Repond,[15] J. Renner,[3] S. Riordan,[15] L. Ripoll,[17] J. Rodríguez,[3] L. Rogers,[1] F. P. Santos,[5] J. M. F. dos Santos,[9] A. Simón,[3] C. Sofka,[3,‖] M. Sorel,[3] T. Stiegler,[18] J. F. Toledo,[8] J. Torrent,[3] Z. Tsamalaidze,[19] J. F. C. A. Veloso,[4] R. Webb,[18] J. T. White,[18,*] and N. Yahlali[3]

(NEXT Collaboration)

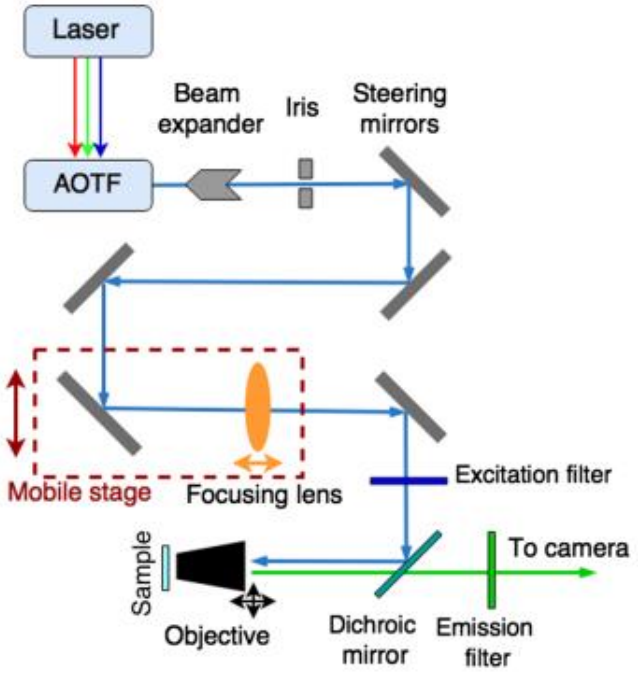


FIG. 2. A schematic view of the TIRF system.

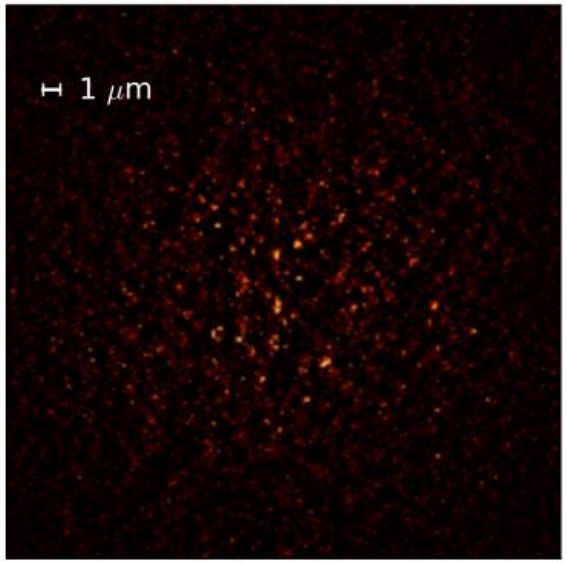


FIG. 3. A sample image from the EM-CCD in one of the barium-spiked samples showing both near-surface (bright) and deeper (dim) fluorescent molecules.

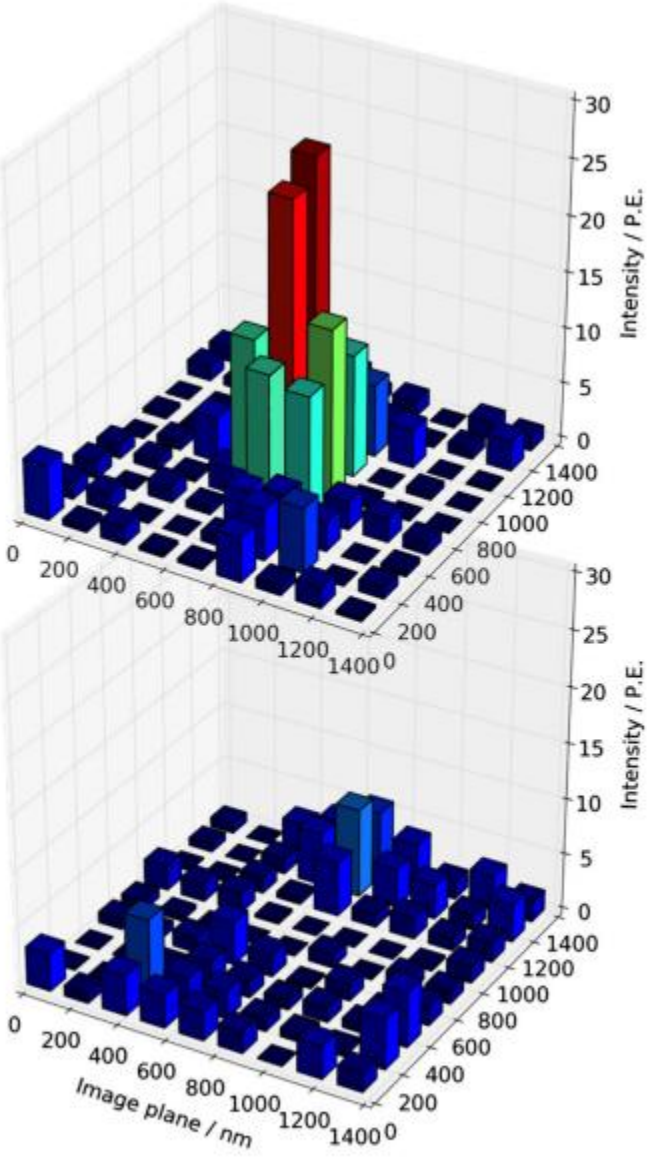
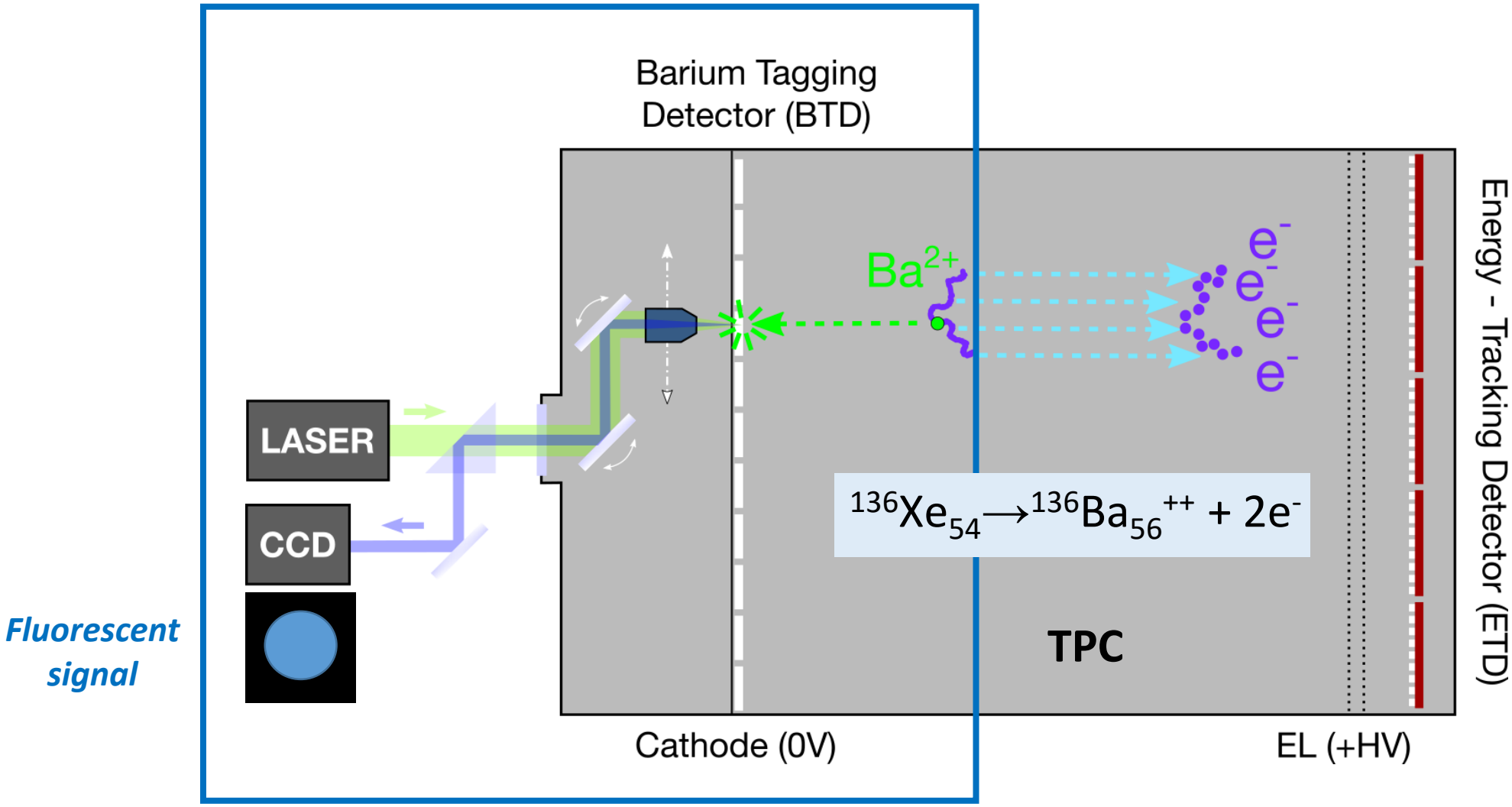


FIG. 1. A single Ba^{++} candidate. A fixed region of the CCD camera is shown with a 0.5 s exposure before (top) and after (bottom) the photobleaching transition.

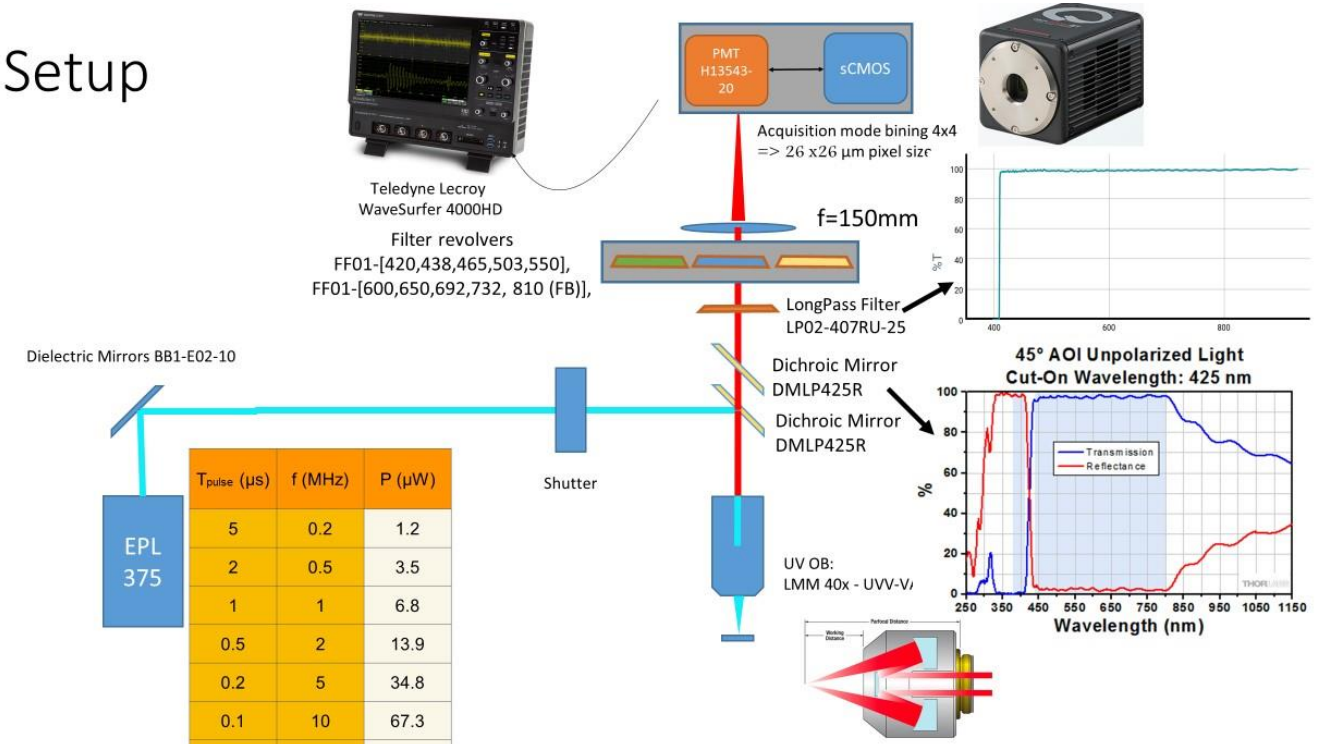
Phys. Rev. Lett. 120, 132504 – Published 26 March 2018

BOLD/SABAT: The basic scheme

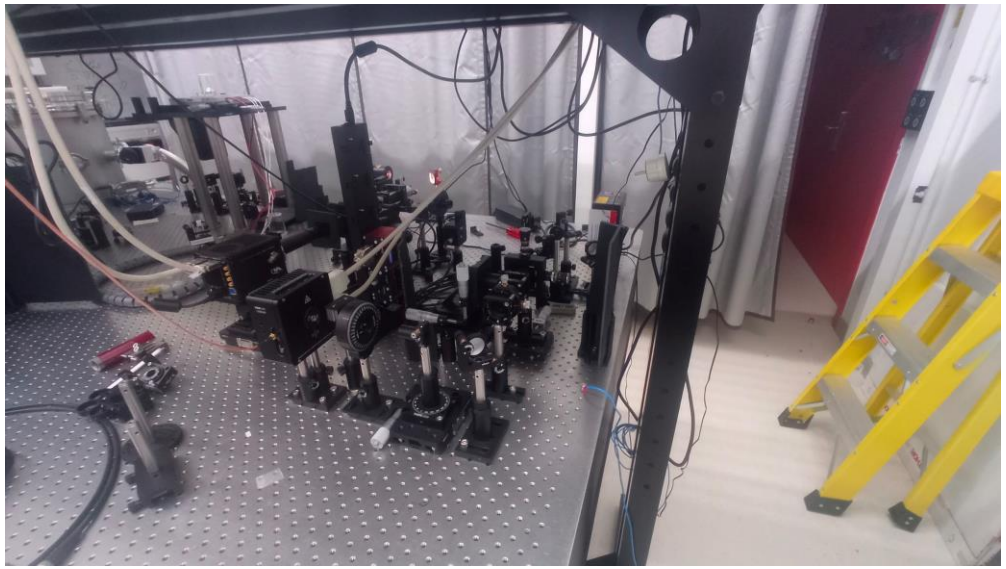


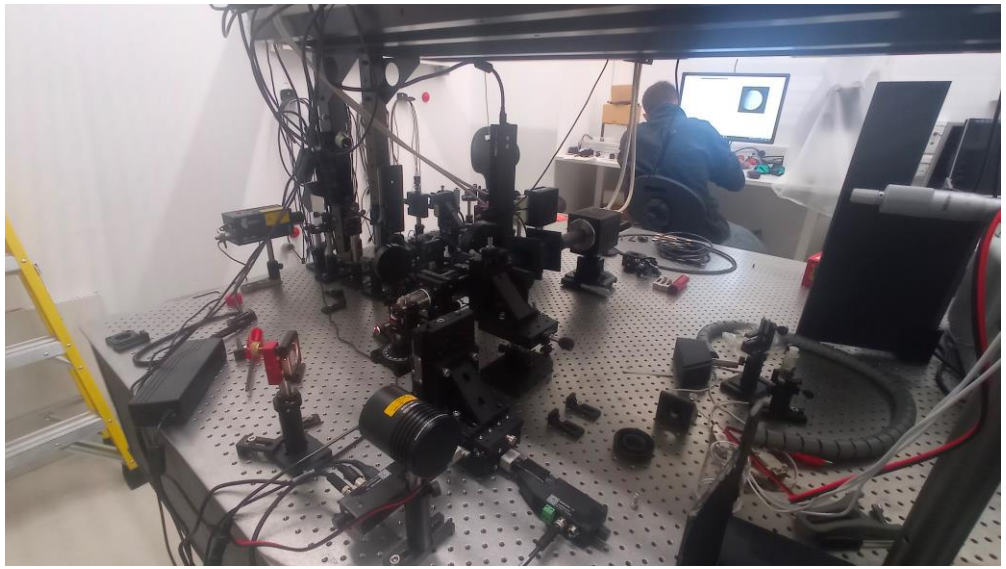
BOLD/SABAT: The basic scheme

Setup

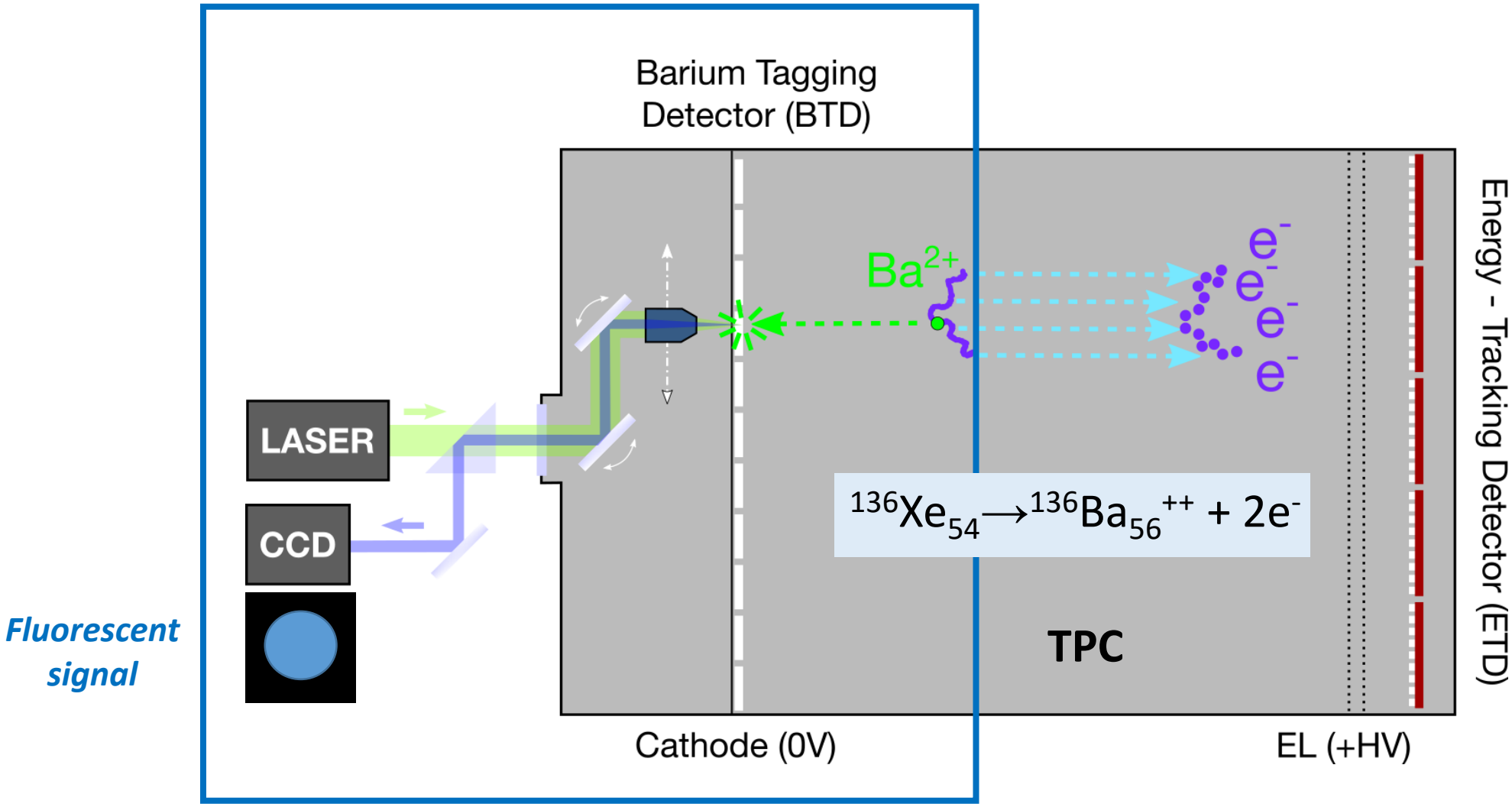


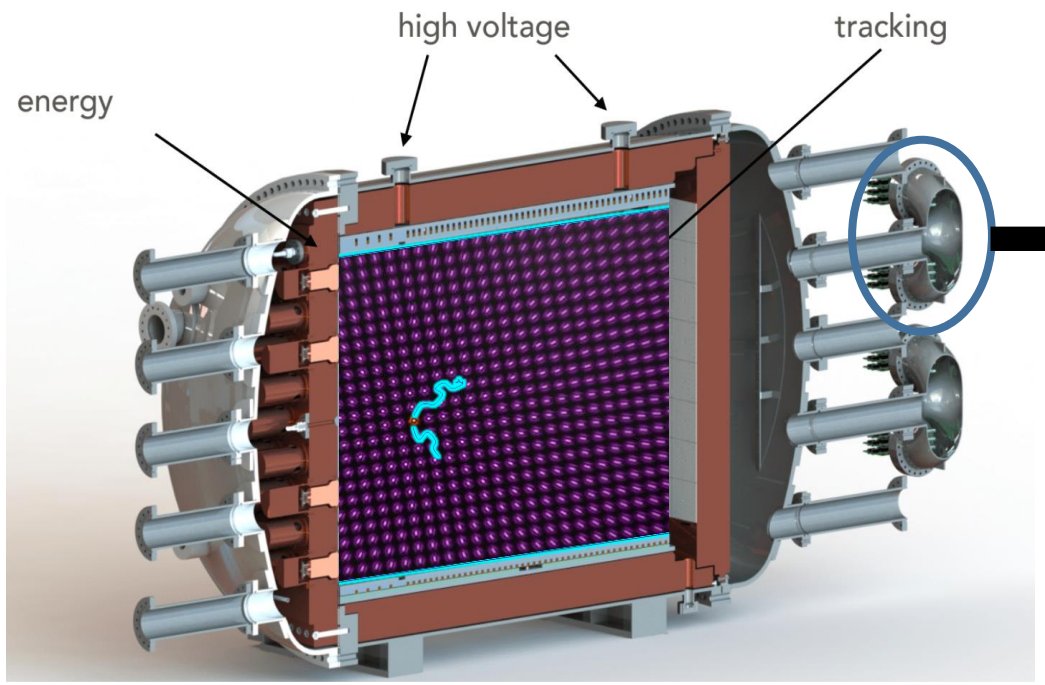
T_{pulse} (µs)	f (MHz)	P (µW)
5	0.2	1.2
2	0.5	3.5
1	1	6.8
0.5	2	13.9
0.2	5	34.8
0.1	10	67.3
0.05	20	137.5

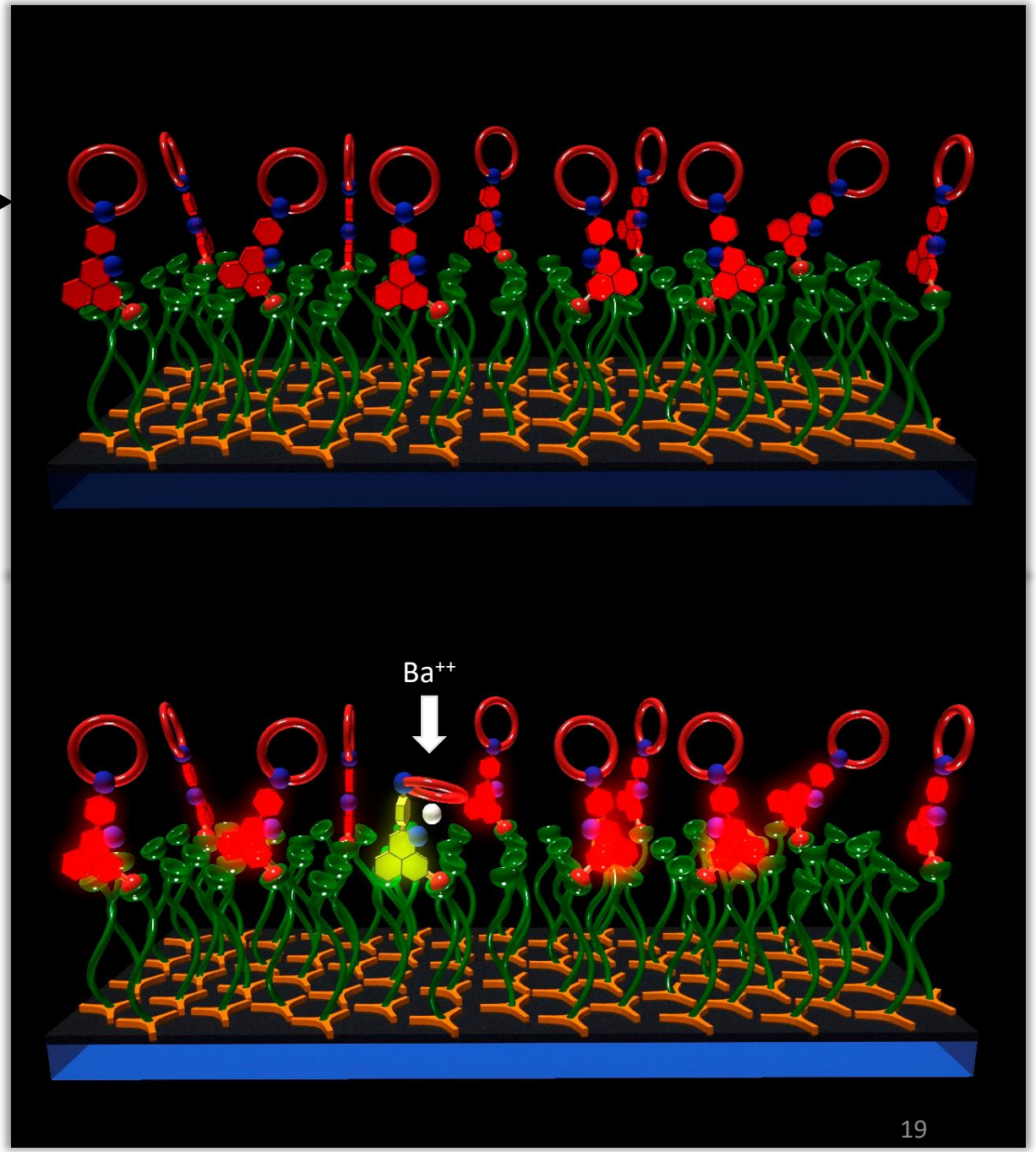


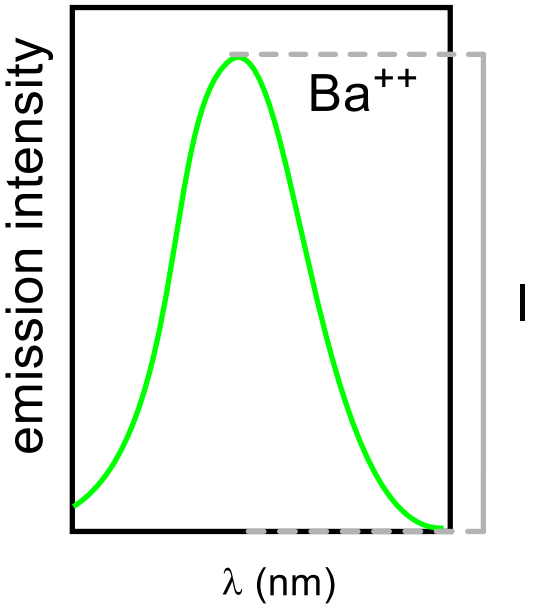


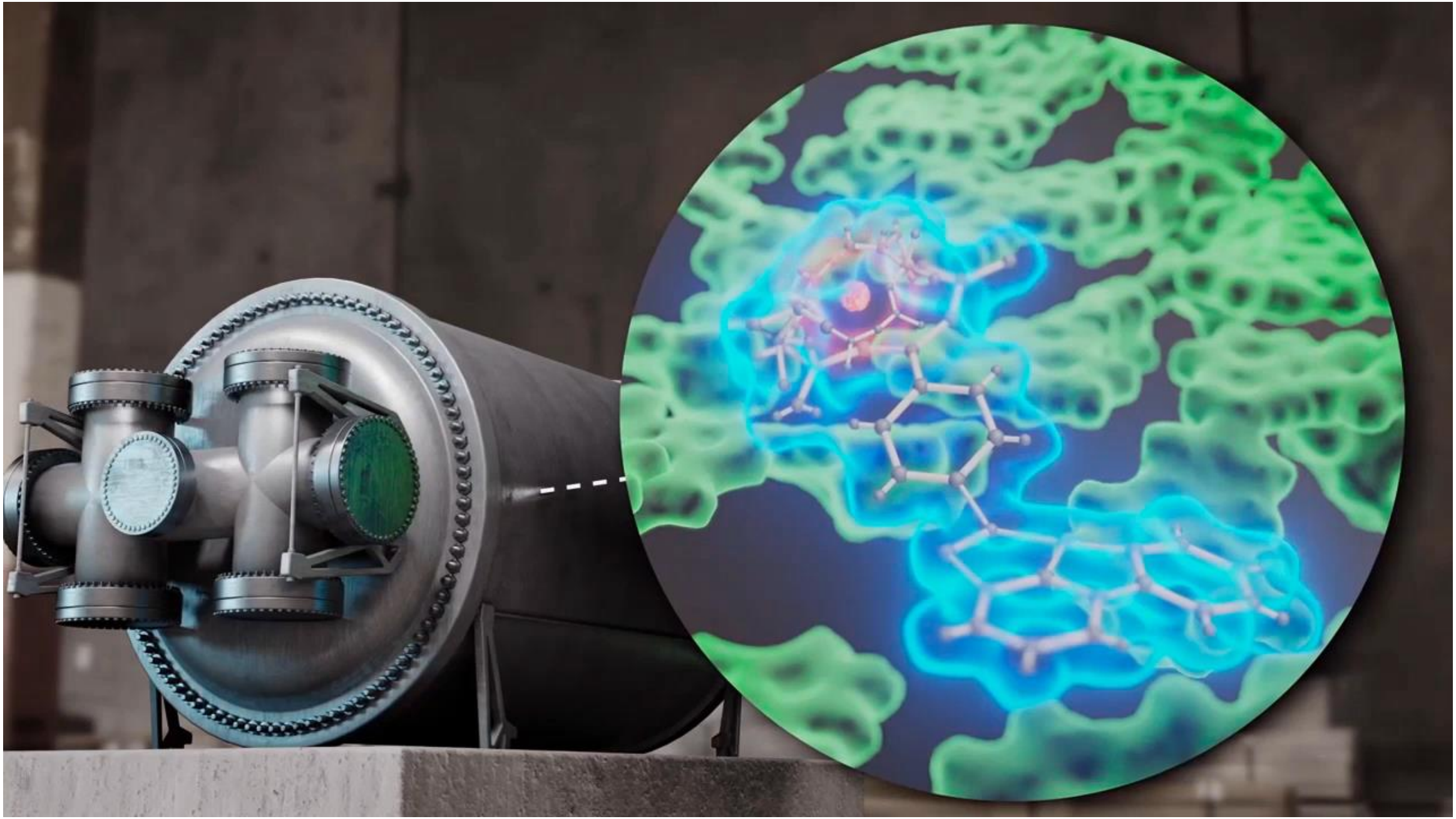
BOLD/SABAT: The basic scheme




high voltage
tracking
energy


Ba++


emission intensity
Ba++
I
λ (nm)



FMIs (Fluorescent Monocolor Indicators) and FBIs (Fluorescent Bicolor Indicators)

- Dry phase
- Selectivity (Ba2+)
- Background free
- $10^{27\text{-}28}$ years

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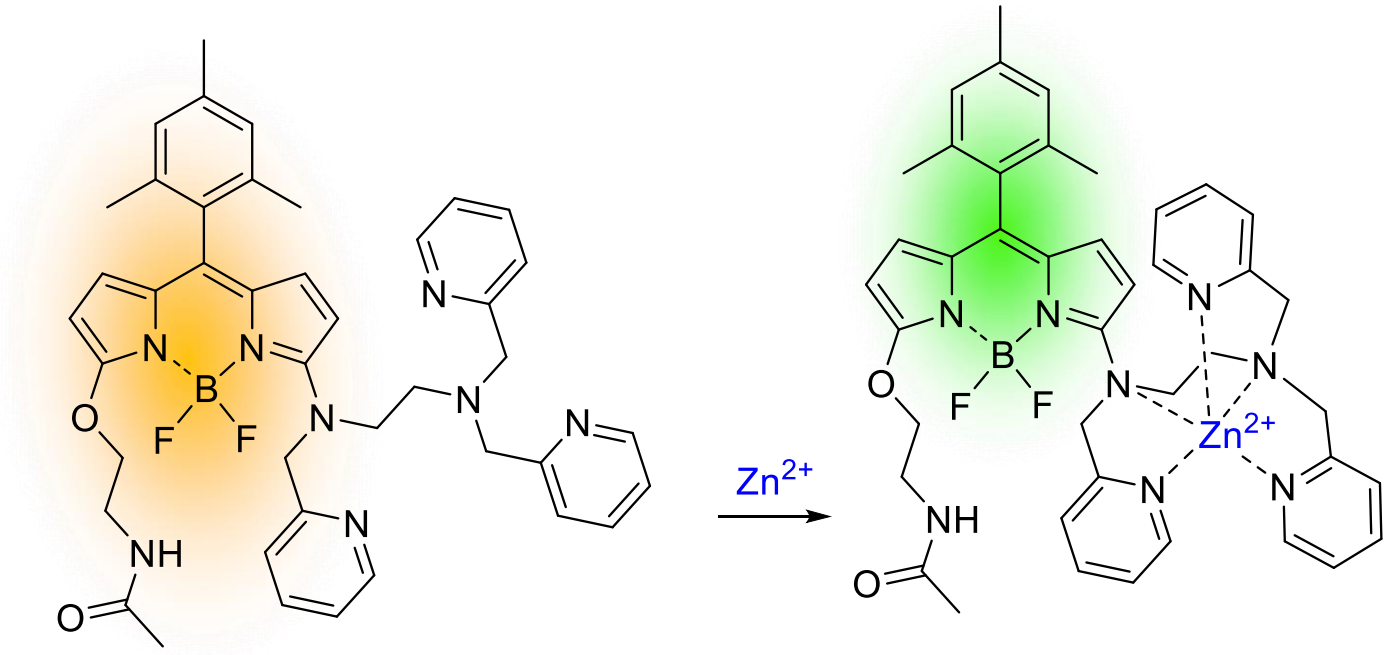

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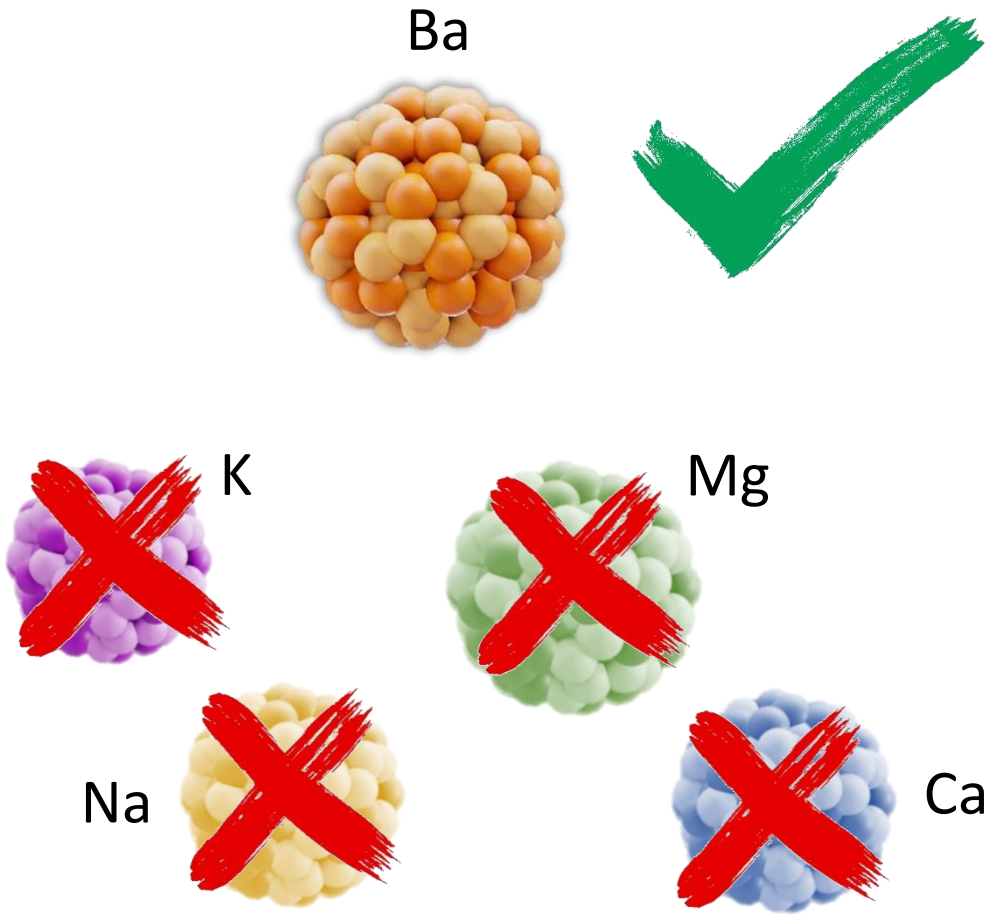
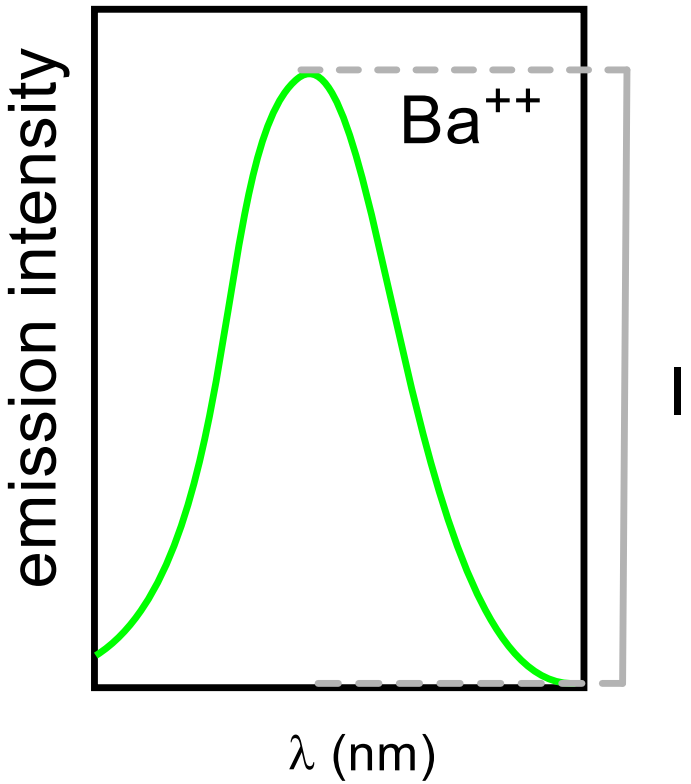
- Background free
- $10^{27\text{-}28}$ years



FMIs (Fluorescent Monocolor Indicators) and FBIs (Fluorescent Bicolor Indicators)

- Dry phase
- Selectivity (Ba2+)
- Background free
- $10^{27\text{-}28}$ years



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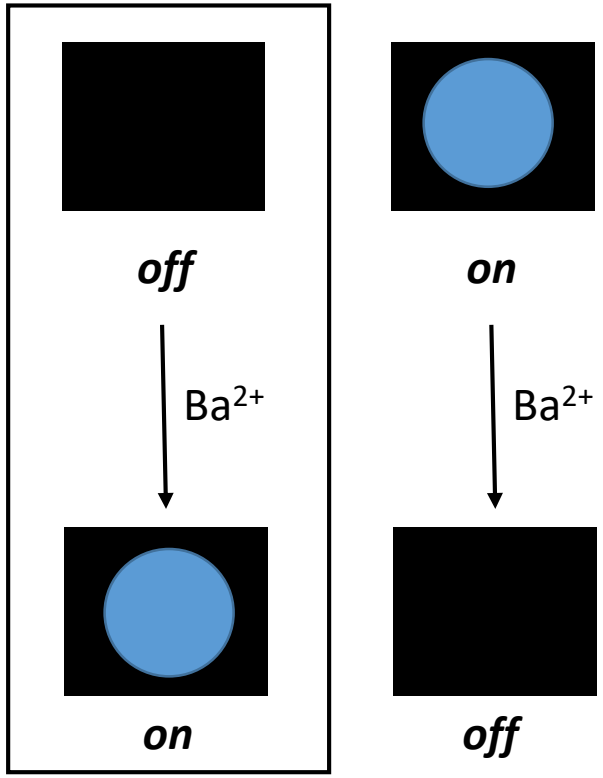
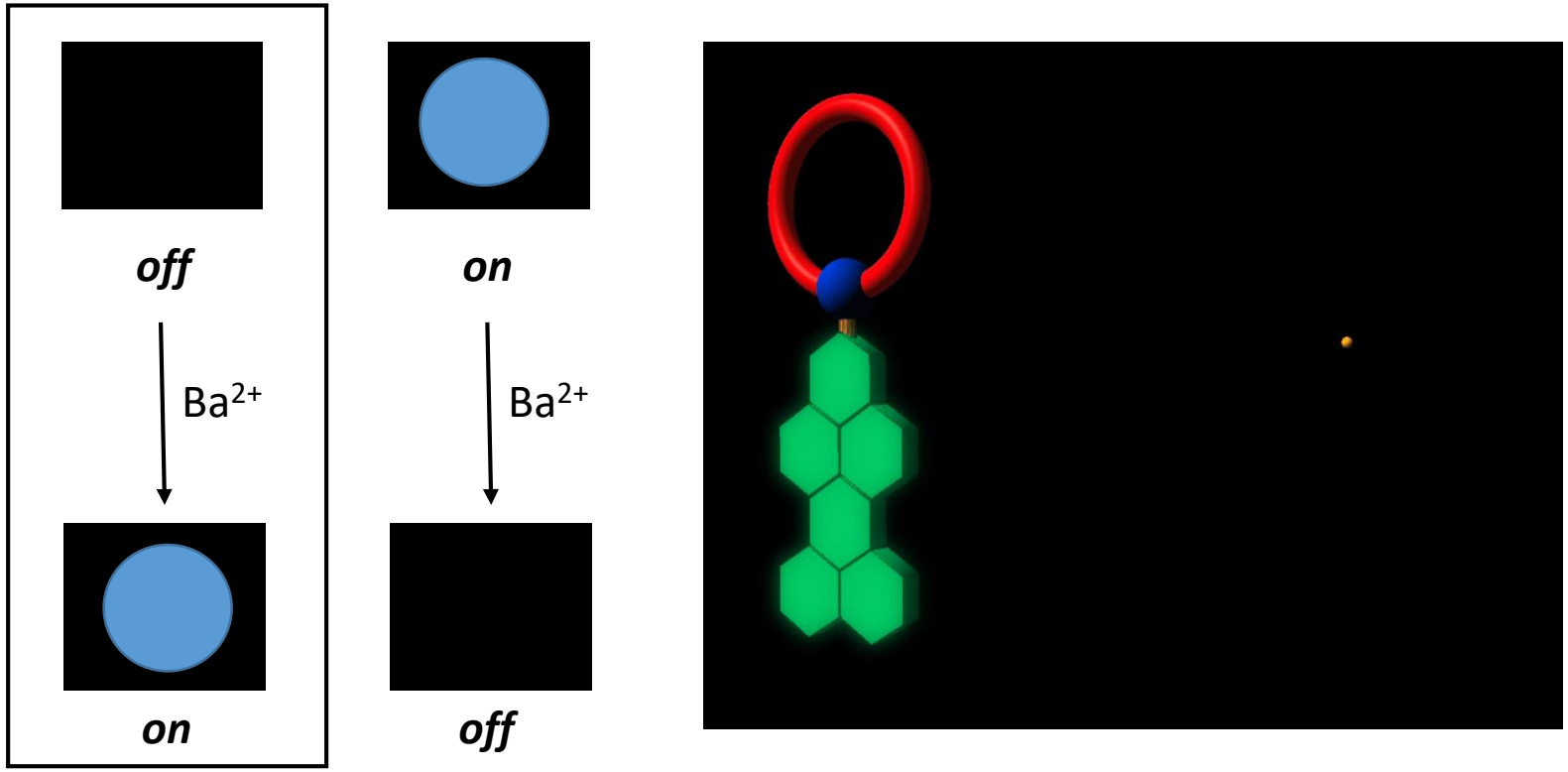


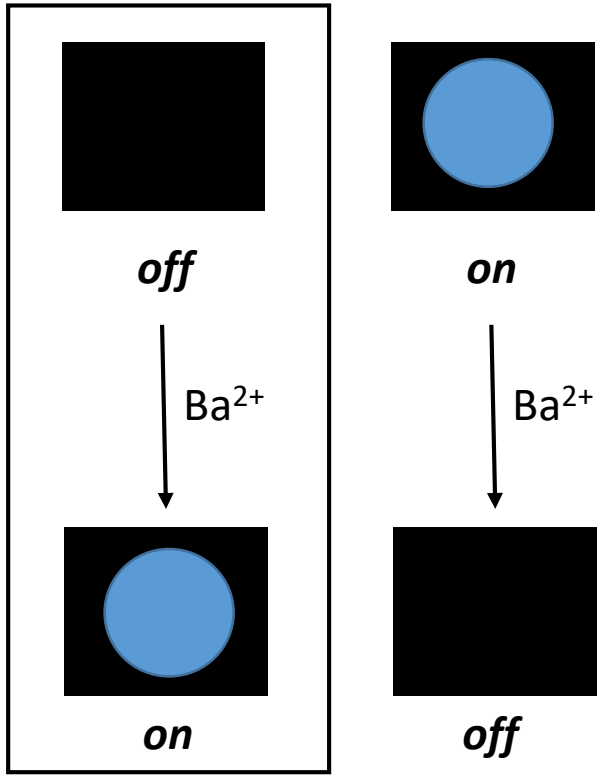
FMIs

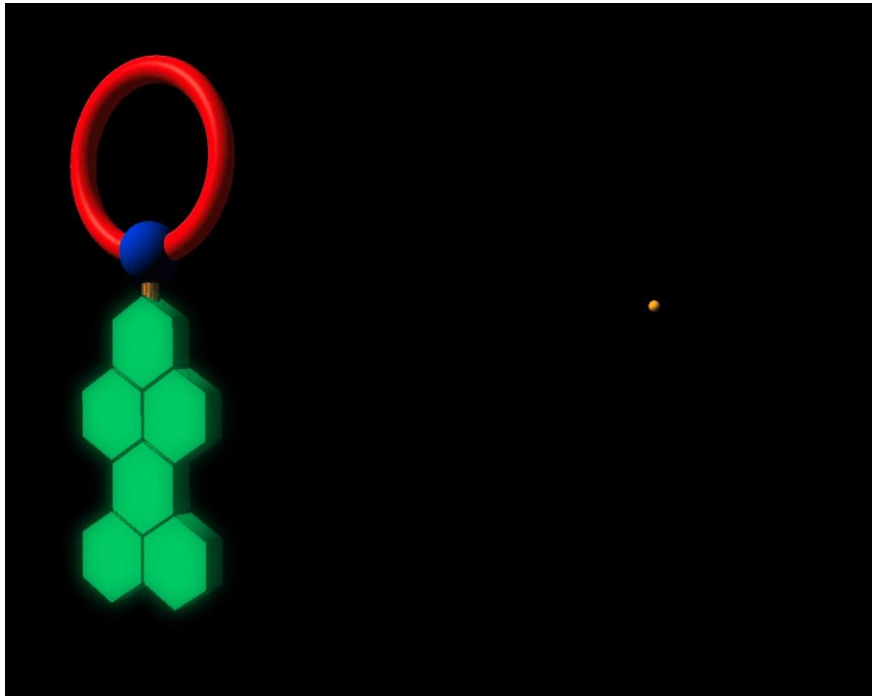
FMIs (Fluorescent Monocolor Indicators) and FBIs (Fluorescent Bicolor Indicators)

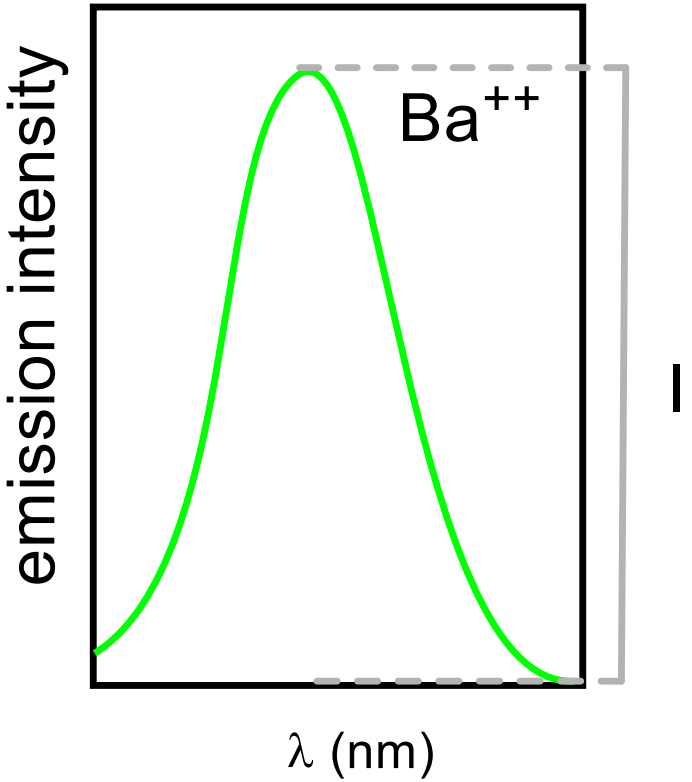


FMIs

FMIs (Fluorescent Monocolor Indicators) and FBIs (Fluorescent Bicolor Indicators)







FMIs

FMIs (Fluorescent Monocolor Indicators) and FBIs (Fluorescent Bicolor Indicators)

Demonstration of Selective Single-Barium Ion Detection with Dry Diazacrown Ether Naphthalimide Turn-on Chemosensors

Pawan Thapa,* Nicholas K. Byrnes,* Alena A. Denisenko, James X. Mao, Austin D. McDonald, Charleston A. Newhouse, Thanh T. Vuong, Katherine Woodruff, Kwangho Nam, David R. Nygren, Benjamin J. P. Jones,* and Frank W. Foss, Jr.*

Cite This: *ACS Sens.* 2021, 6, 192–202 Read Online

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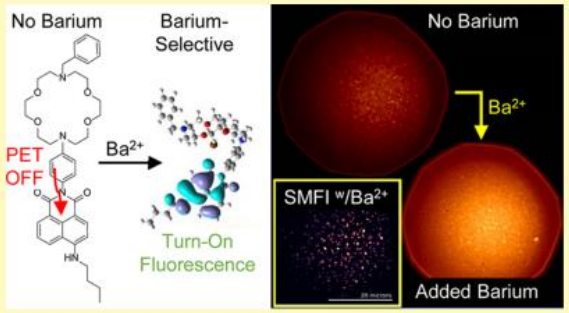
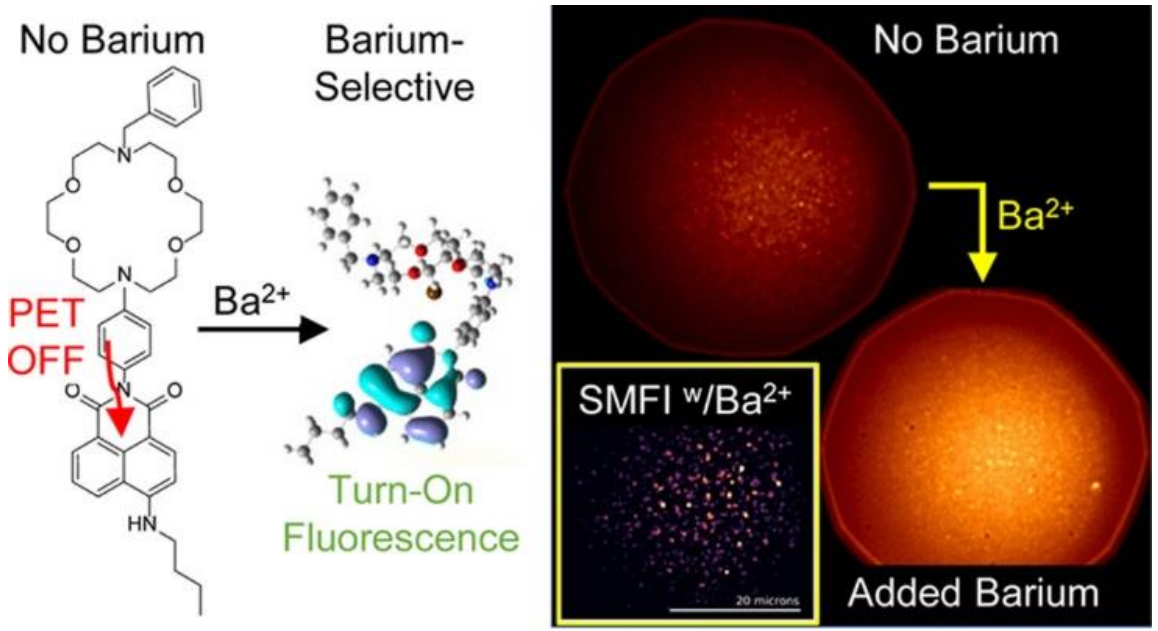
ABSTRACT: Single-molecule fluorescence imaging (SMFI) of gas-phase ions has been proposed for "barium tagging," a burgeoning area of research in particle physics to detect individual barium daughter ions. This has potential to significantly enhance the sensitivity of searches for neutrinoless double-beta decay ($0\nu\beta\beta$) that is obscured by background radiation events. The chemistry required to make such sensitive detection of Ba^{2+} by SMFI in dry Xe gas at solid interfaces has implications for solid-phase detection methods but has not been demonstrated. Here, we synthesized simple, robust, and effective Ba^{2+}-selective chemosensors capable of function within ultrapure high-pressure ^{136}Xe gas. Turn-on fluorescent naphthalimide-(di)azacrown ether chemosensors were Ba^{2+}-selective and achieved SMFI in a polyacrylamide matrix. Fluorescence and NMR experiments supported a photoinduced electron transfer mechanism for turn-on sensing. Ba^{2+} selectivity was achieved with computational calculations correctly predicting the fluorescence responses of sensors to barium, mercury, and potassium ions. With these molecules, dry-phase single-Ba^{2+} ion imaging with turn-on fluorescence was realized using an oil-free microscopy technique for the first time—a significant advance toward single-Ba^{2+} ion detection within large volumes of ^{136}Xe, plausibly enabling a background-independent technique to search for the hypothetical process of $0\nu\beta\beta$.



KEYWORDS: *barium tagging, barium sensor, turn-on fluorescence, PET chemosensor, single-molecule imaging*



ACS Sensors **2021** *6* (1), 192-202

FMIs (Fluorescent Monocolor Indicators) and FBIs (Fluorescent Bicolor Indicators)

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Pawan Thapa,* Nicholas K. Byrnes,* Alena A. Denisenko, James X. Mao, Austin D. McDonald, Charleston A. Newhouse, Thanh T. Vuong, Katherine Woodruff, Kwangho Nam, David R. Nygren, Benjamin J. P. Jones,* and Frank W. Foss, Jr.*

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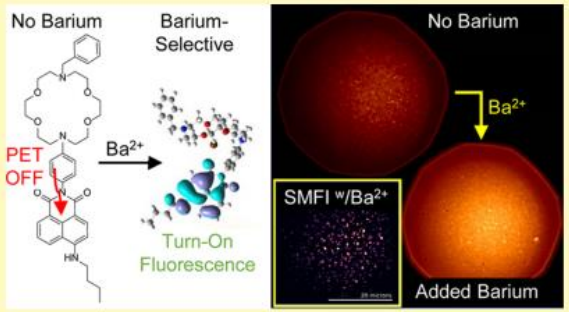

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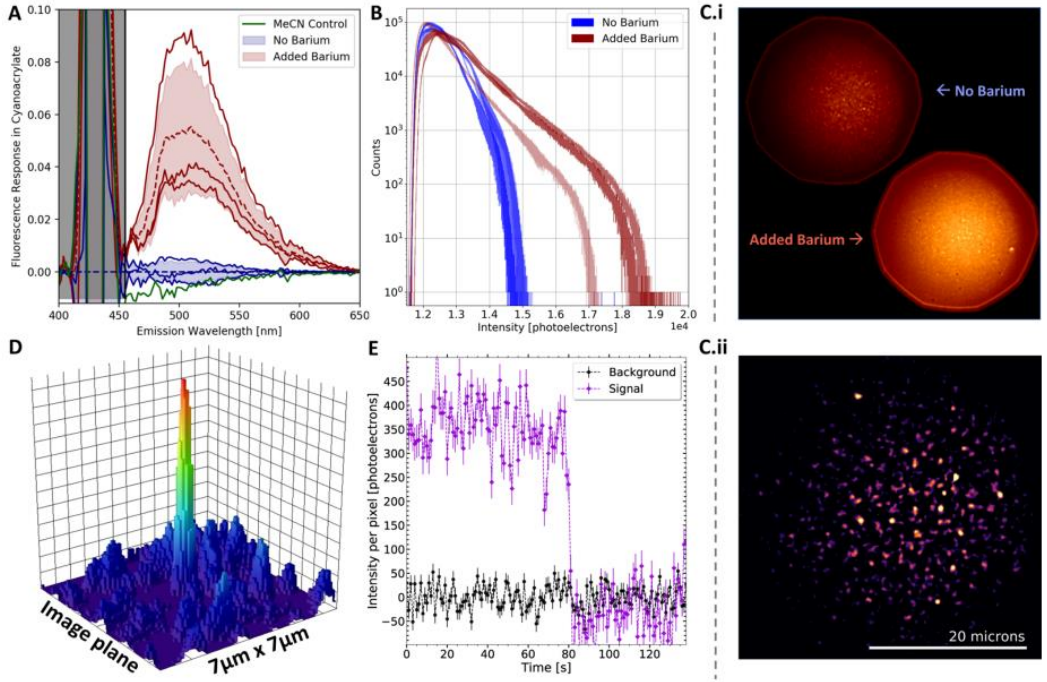
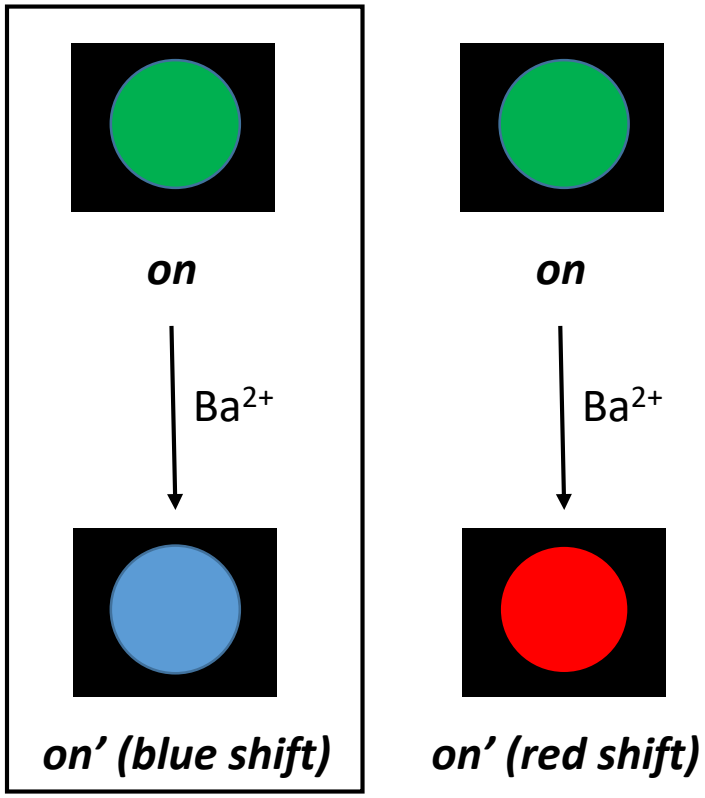


Figure 7. Solid-matrix measurements of barium-sensing fluorophore **1D**. (A) Bulk spectrophotometry in a dried cyanoacrylate matrix; (B) raw pixel histogram of three **1D**-coated slides imaged at the single-molecule level; (C) single-molecule level microscopy images of the **1D** layer with and without Ba^{2+} (i) and with Ba^{2+} after background removal (ii); (D) specific single reconstructed barium-chelated **1D** molecule; and (E) barium-chelated **1D** molecule fluorescence time trajectory showing a single-step photobleaching characteristic of SMFI detection.

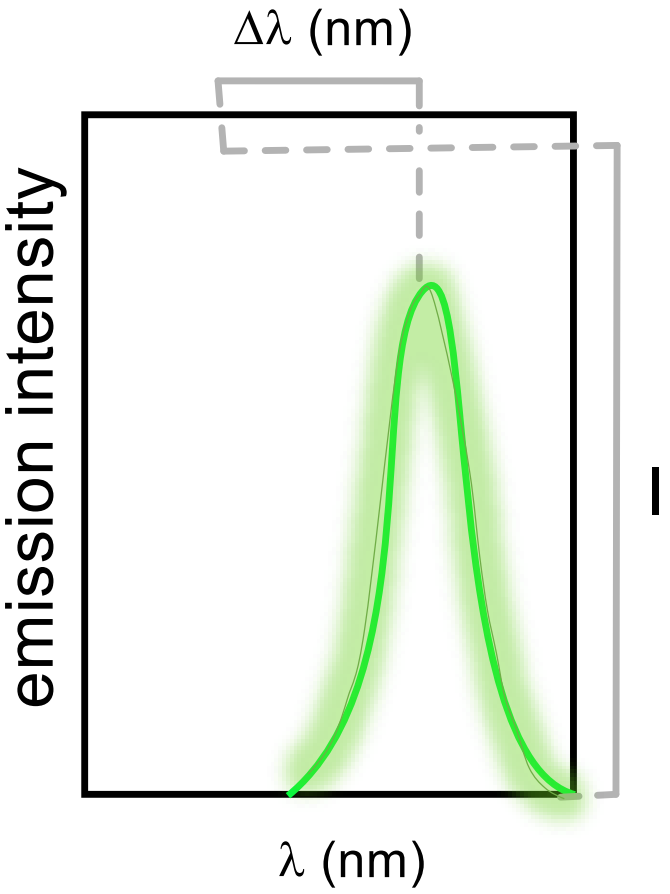
ACS Sensors **2021** *6* (1), 192-202

FMIs (Fluorescent Monocolor Indicators) and FBIs (Fluorescent Bicolor Indicators)



FBIs

FMIs (Fluorescent Monocolor Indicators) and FBIs (Fluorescent Bicolor Indicators)



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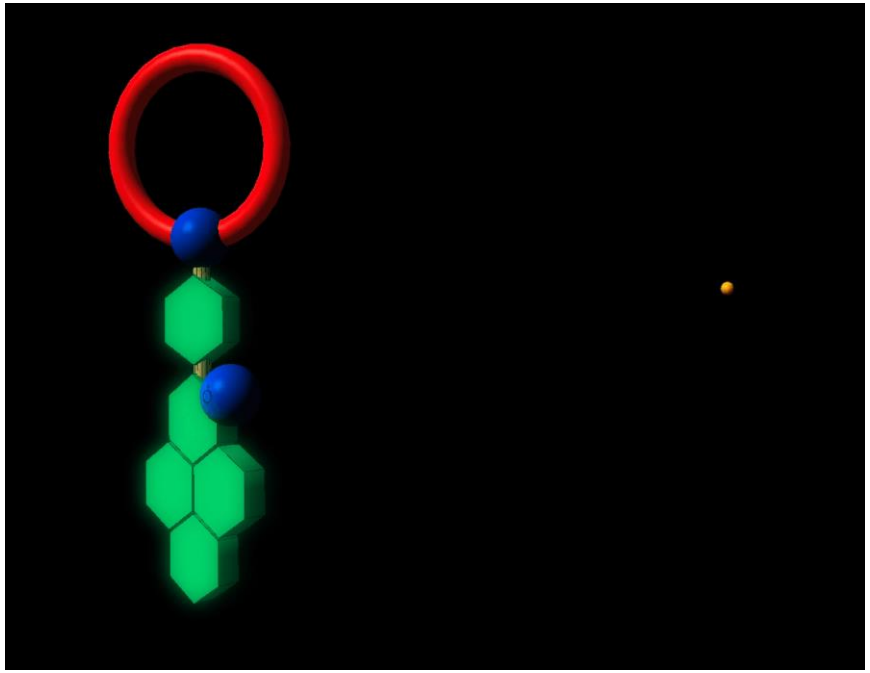

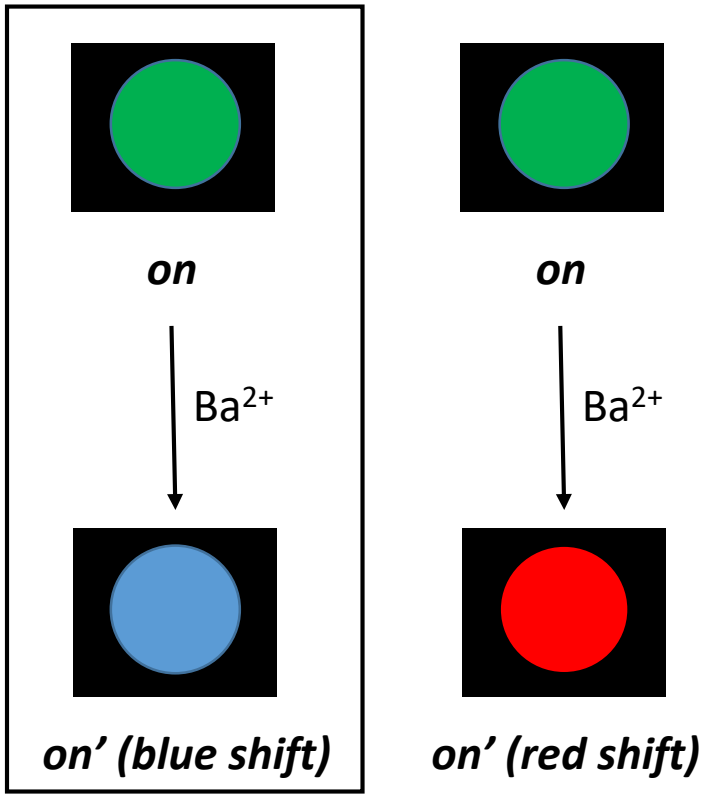

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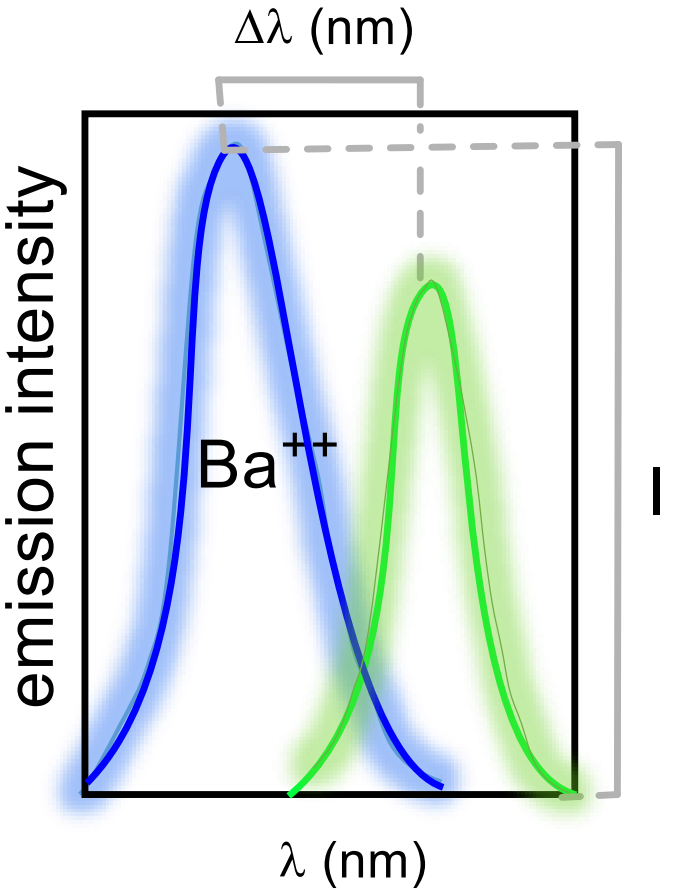

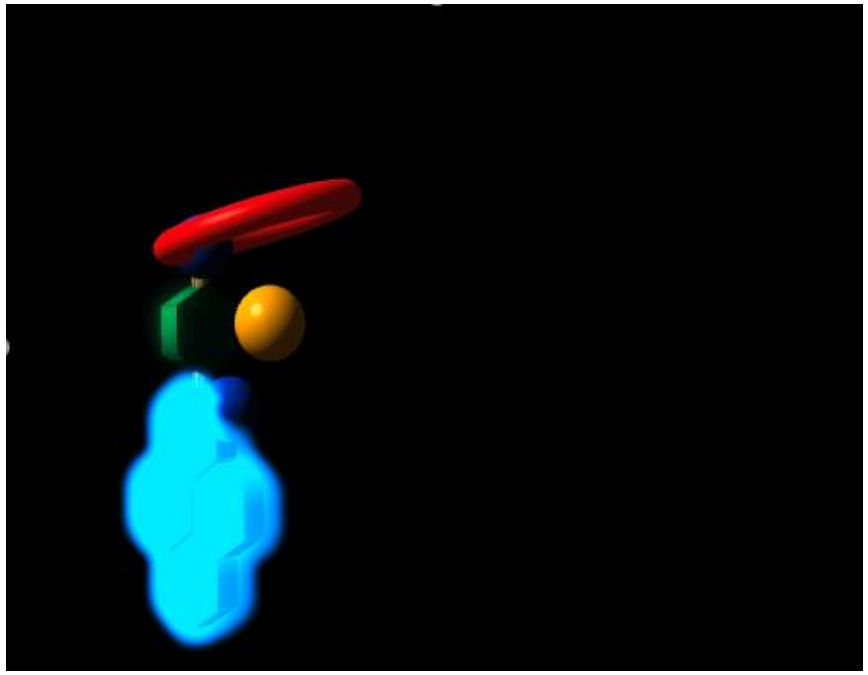

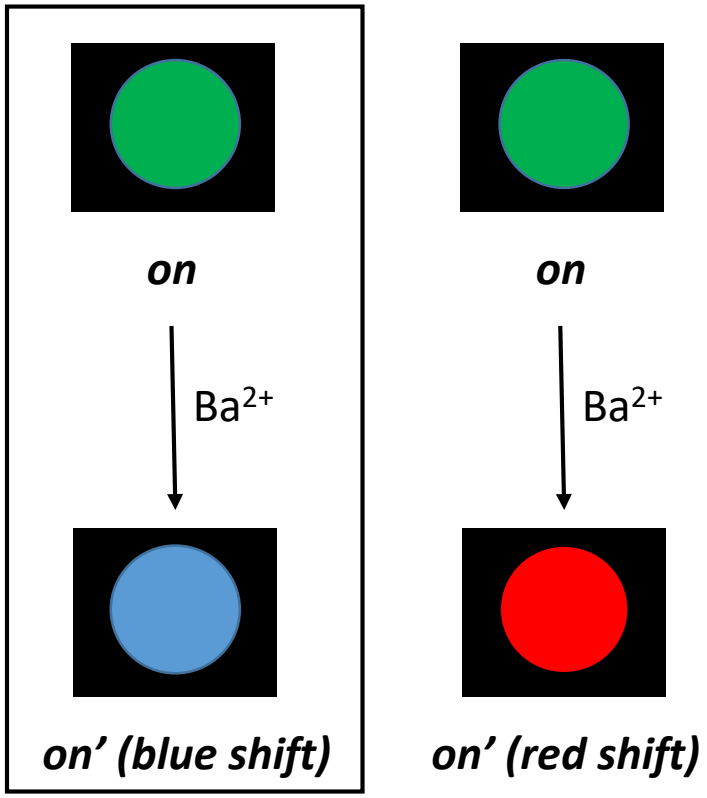

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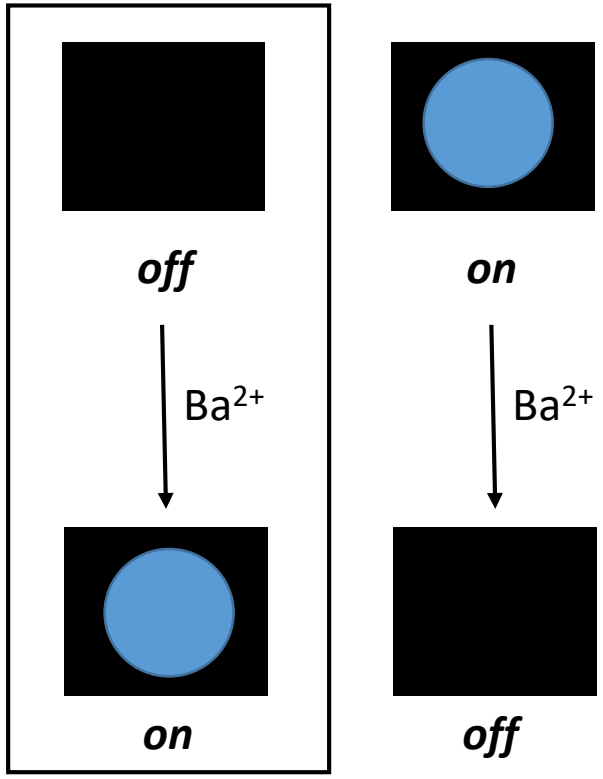
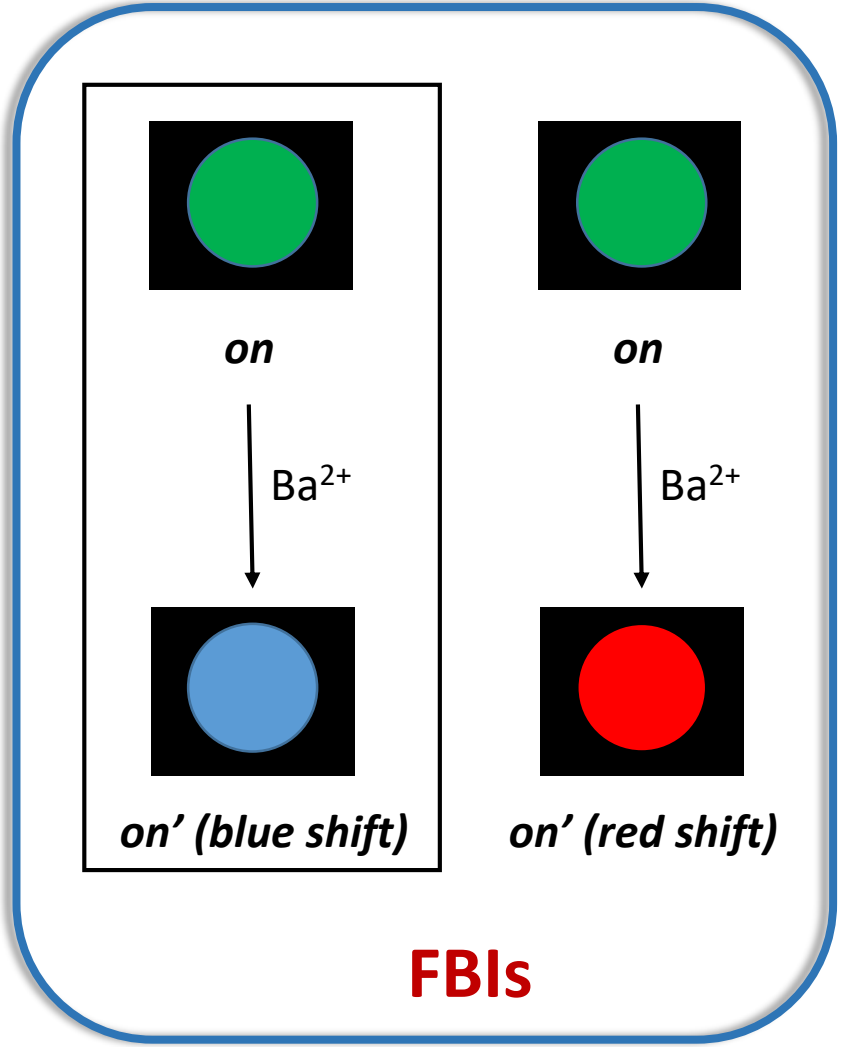
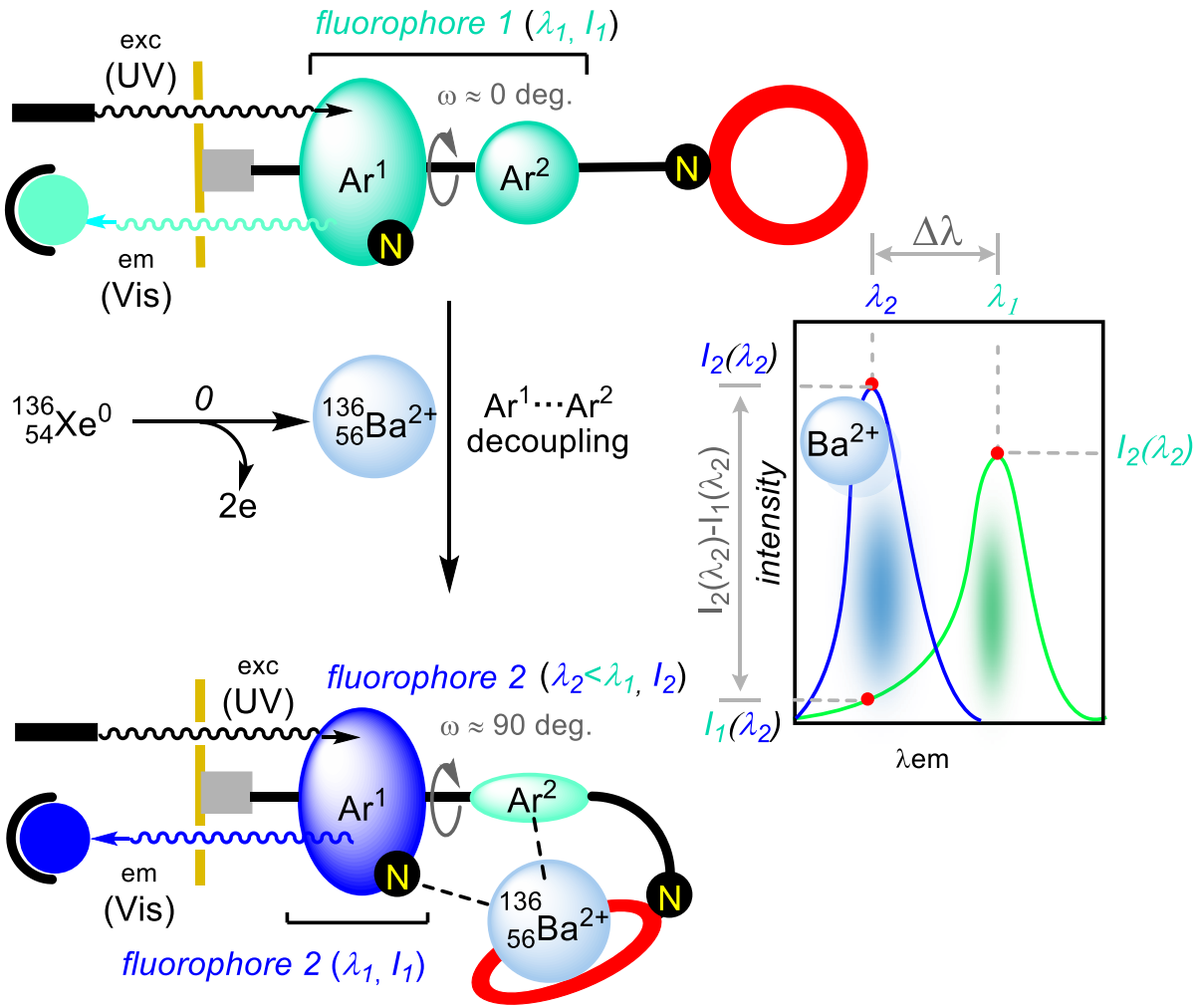


FMIs



FBIs

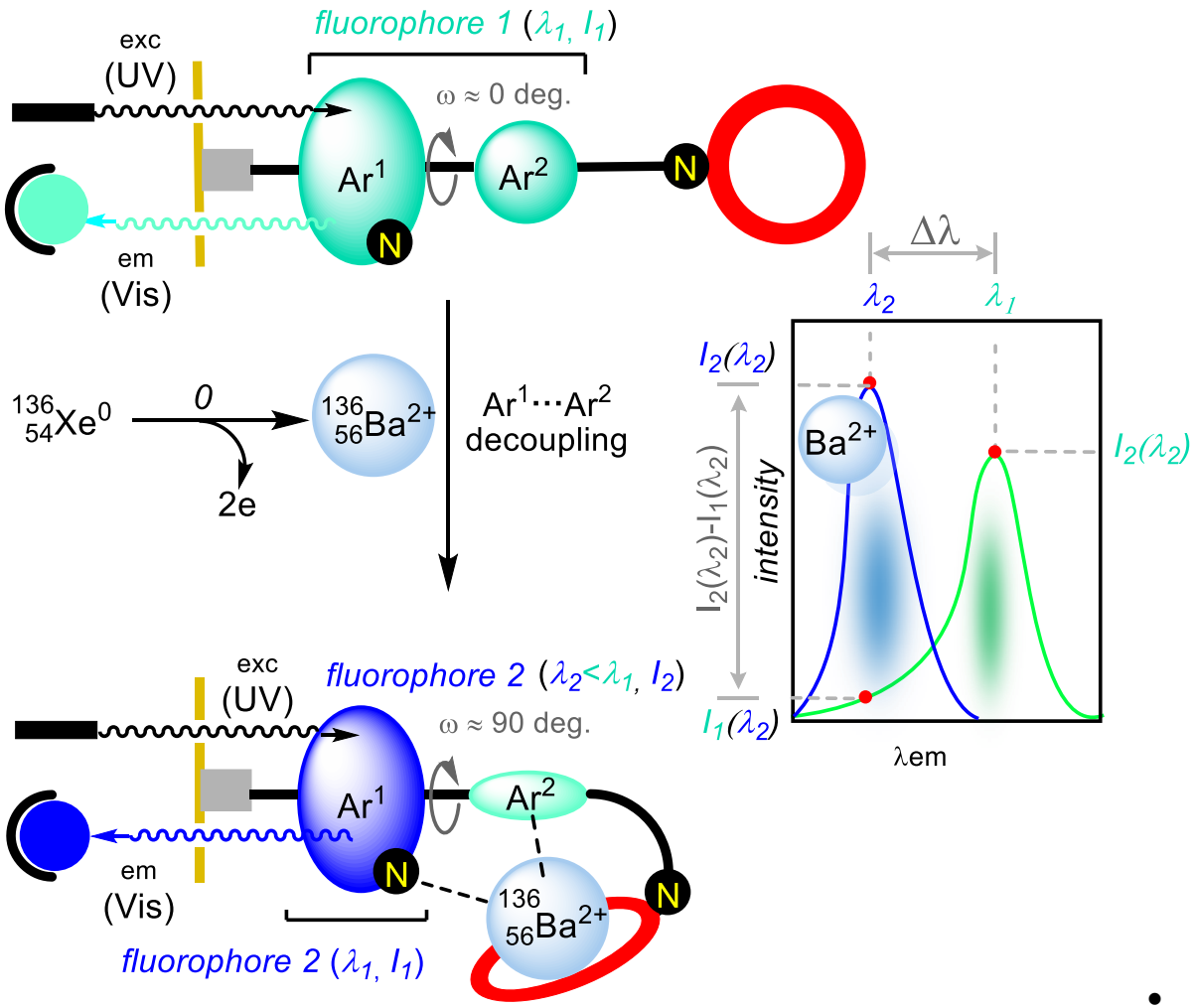
1st generation FBIs: Two Fluorophores in One Molecule

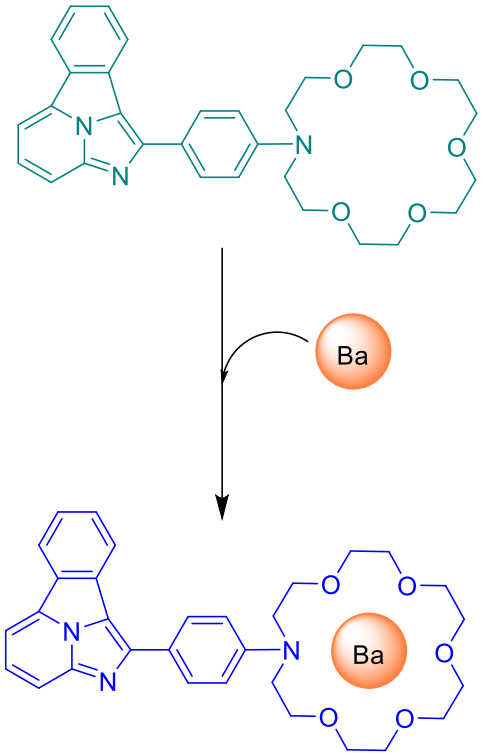


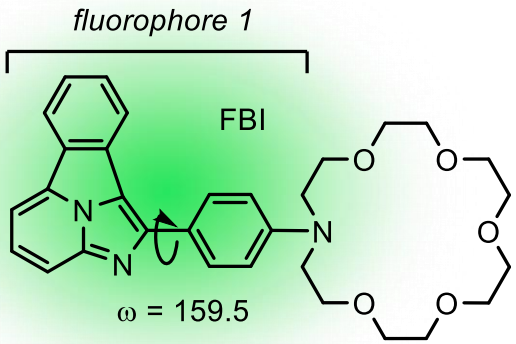
- Two fluorophores (Ph or Hetero-Aromatic-Cyclic system) in one molecule
- Crown Ether (Chelating agent)
- Two responses depending on the coordinator state of the sensor

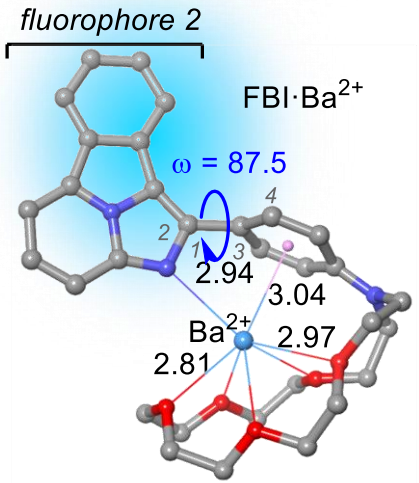
Phys. Chem. Chem. Phys. **23,** 15440–15457 (2021)

1st generation FBIs: Two Fluorophores in One Molecule



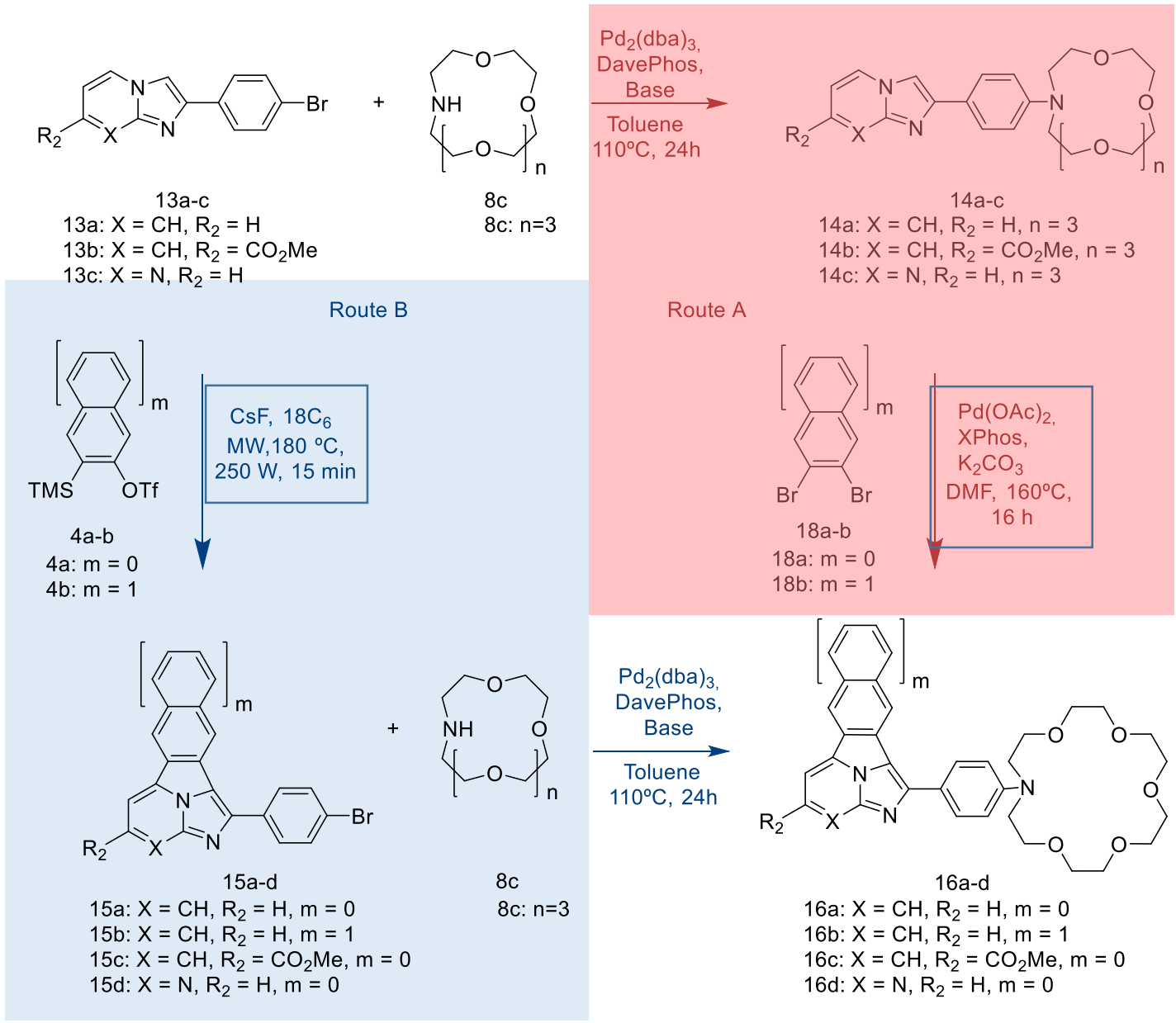






- Green (free)---Blue (Ba^{++})

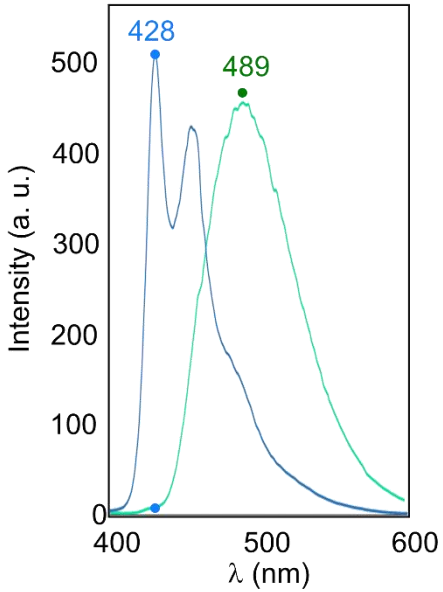
Phys. Chem. Chem. Phys. **23,** 15440–15457 (2021)

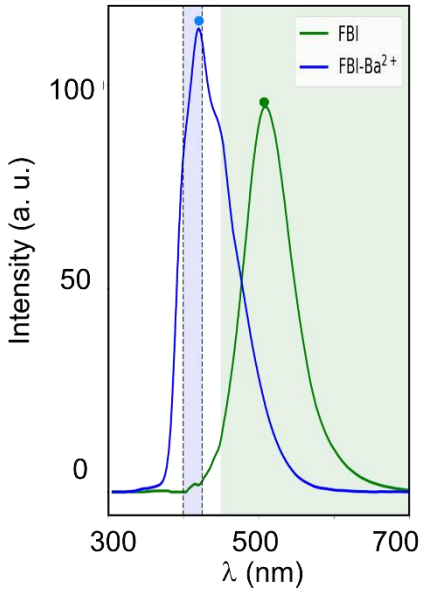


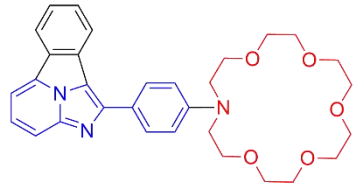
- C-C or C-N coupling reactions
- High order 8+2 cycloadditions reactions
- Library of sensors or candidates

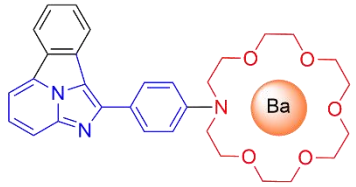
Nature **583,** 48–54 (2020)

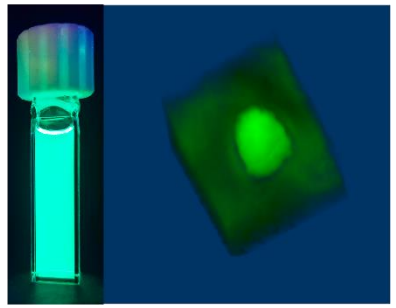
- Different responses in solution/dry phase
- Filter
- Background-free signal!!!

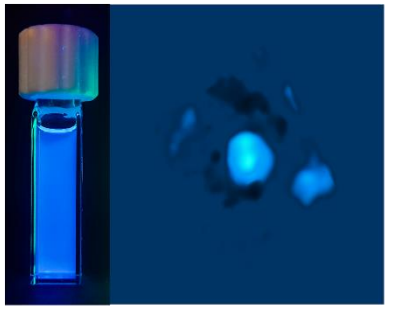












Nature **583,** 48–54 (2020)

Article

Fluorescent bicolour sensor for low-background neutrinoless double β decay experiments

https://doi.org/10.1038/s41586-020-2431-5

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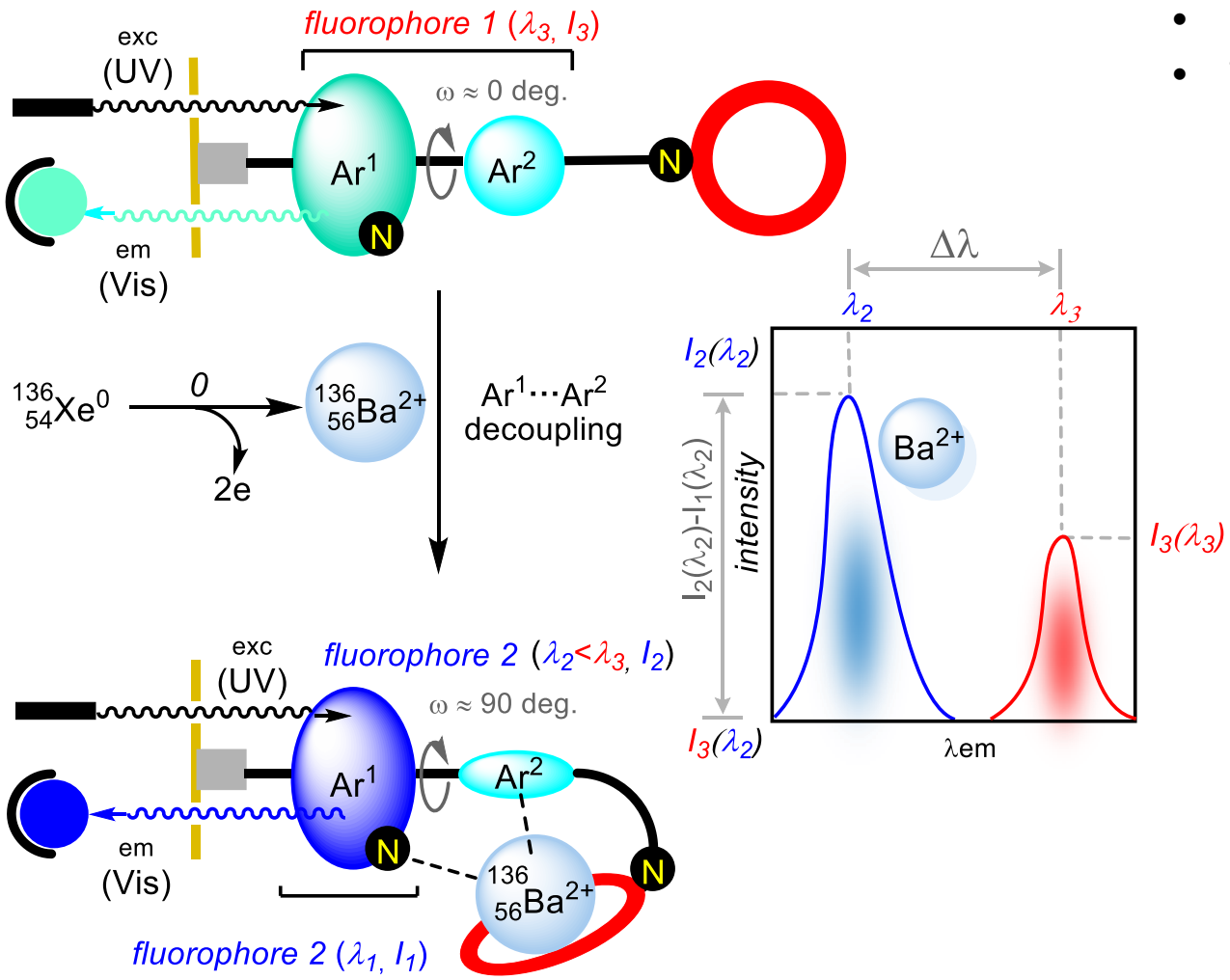
Published online: 22 June 2020

Iván Rivilla[1], Borja Aparicio[2], Juan M. Bueno[3], David Casanova[1,4], Claire Tonnelé[1], Zoraida Freixa[4,5], Pablo Herrero[1], Celia Rogero[1,6], José I. Miranda[7], Rosa M. Martínez-Ojeda[3], Francesc Monrabal[1,4], Beñat Olave[8], Thomas Schäfer[4,8], Pablo Artal[3], David Nygren[9], Fernando P. Cossío[1,2] ✉ & Juan J. Gómez-Cadenas[1,4] ✉

https://www.youtube.com/watch?v=W4_Qjd3h2PU

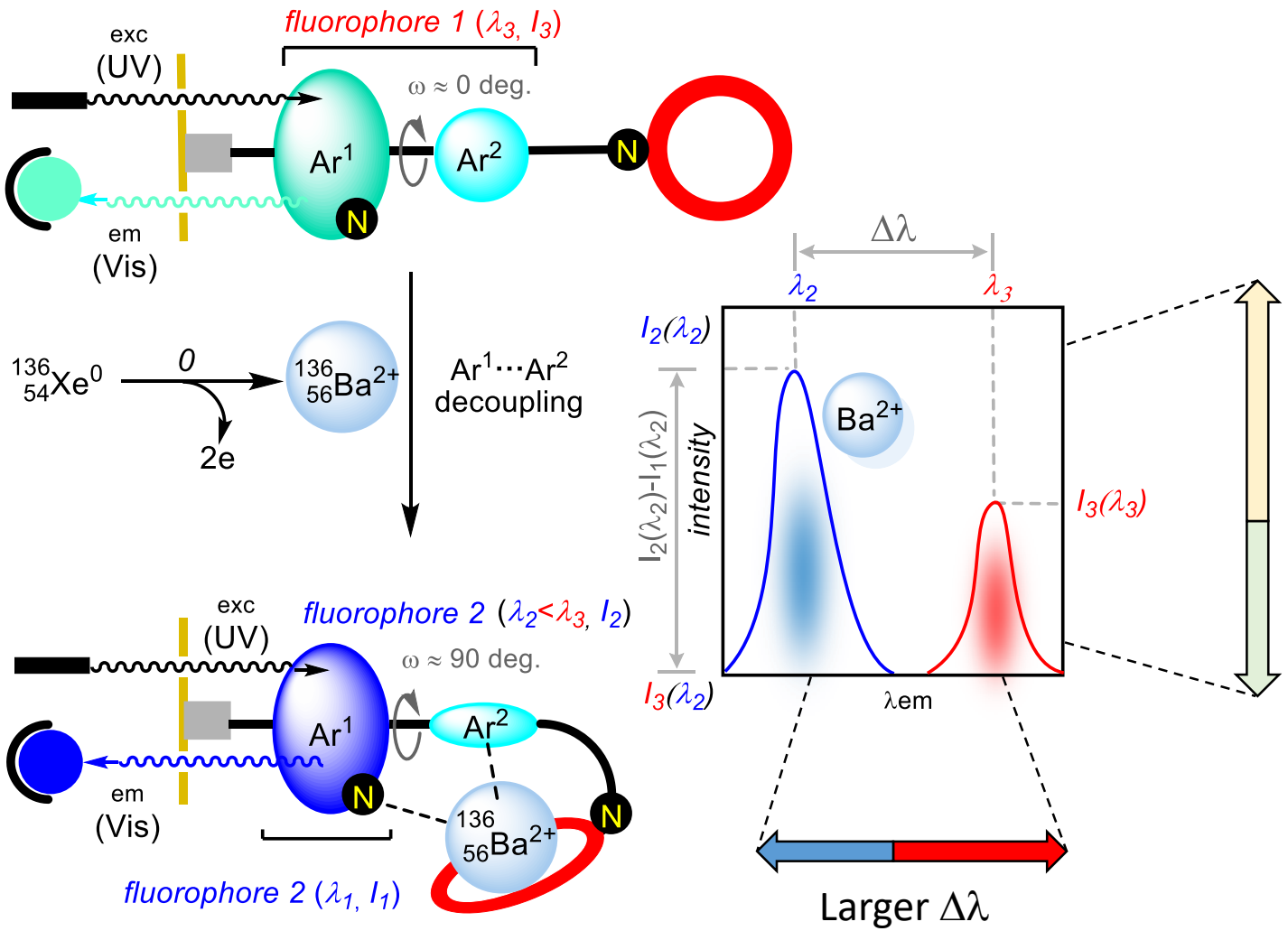
YouTube

Optimizing the photophysics of FBIs: Design Criteria for Next Generations



- *…a lot of room for further improvement!!!*
- Strict rules…NEXT/BOLD experiments
- The pipeline pharma strategy

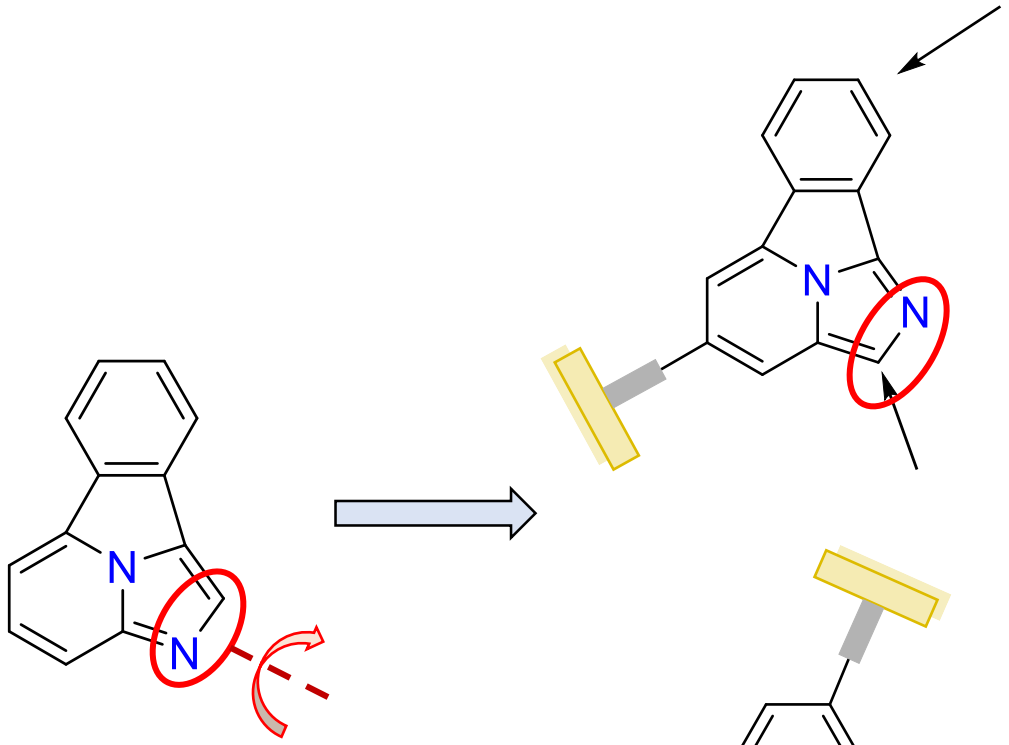
Optimizing the photophysics of FBIs: Design Criteria for Next Generations



To increase (*Neutrinoless $\beta\beta0\nu$ extremely rare event*)

- Higher brightness
- Larger discrimination factor
- Bigger binding constant

Next generation FBIs: Novel Ar^1 and Ar^2 Units

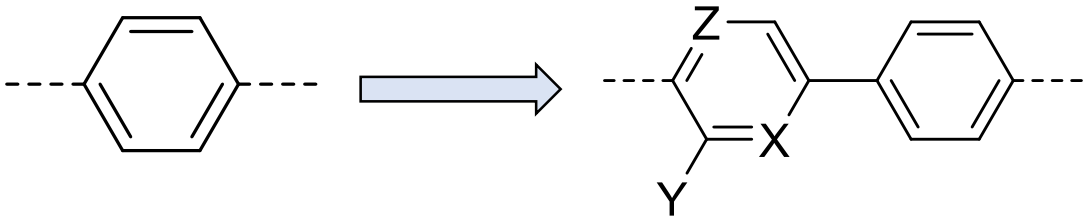


benzo[a]imidazo[5,1,2-cd]indolizine

benzo[a]imidazo[2,1,5-cd]indolizine

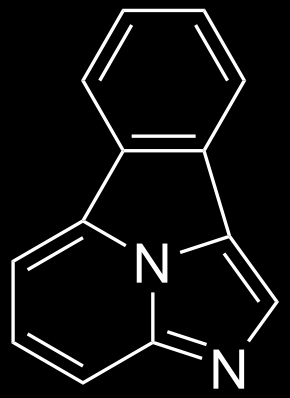
Different candidates (Design)

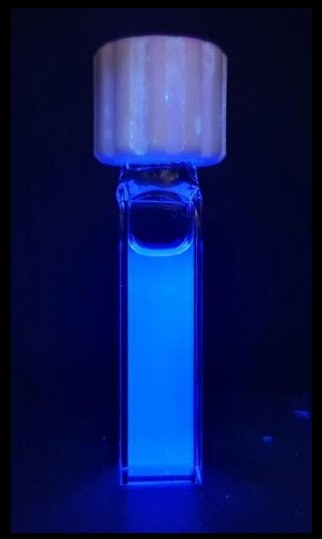
- Rotation … changing the nitrogen by carbon,
- 5,1,2 to 2,1,5
- Configurational space
- Decorate options
- Anchor to surfaces

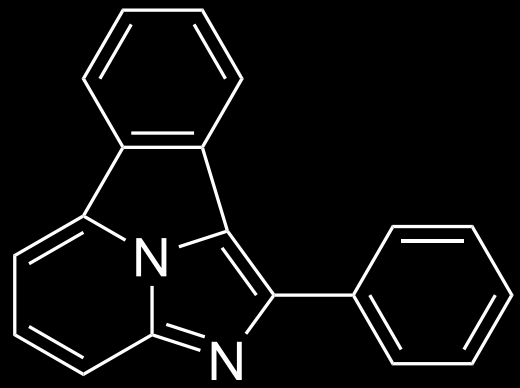


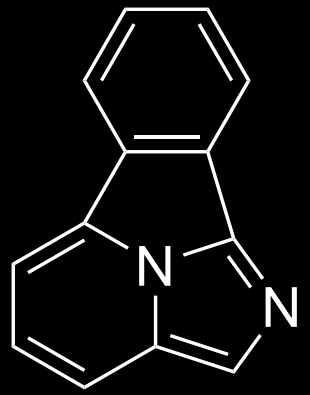
a: X=Z=CH; Y=H
b: X=N; Y=CH3; Z=CH
c: X=Z=N; Y=H

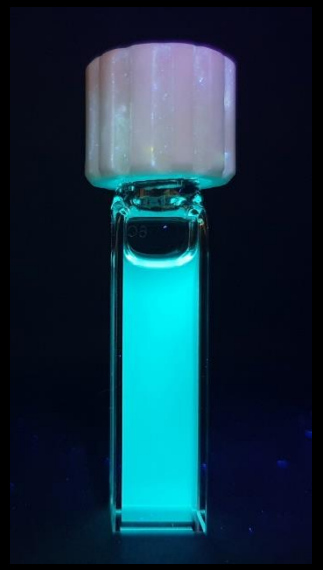
λ_{exc} = 365 nm
[ ] = $5 \cdot 10^{-5}$ M
ACN

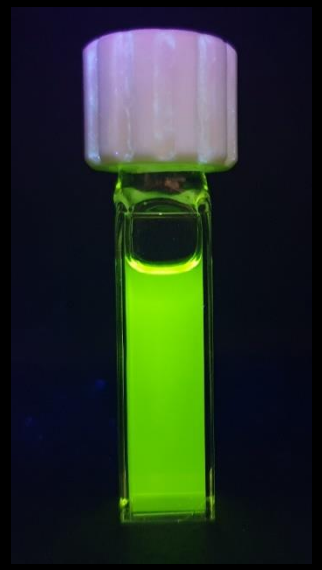


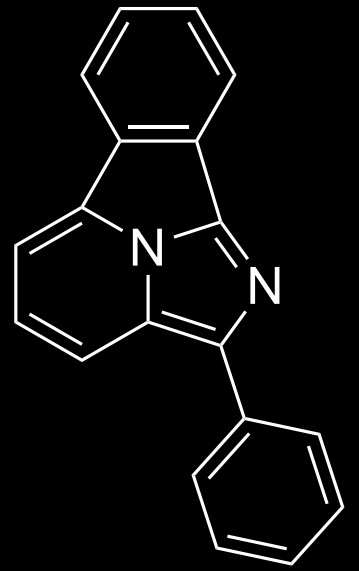




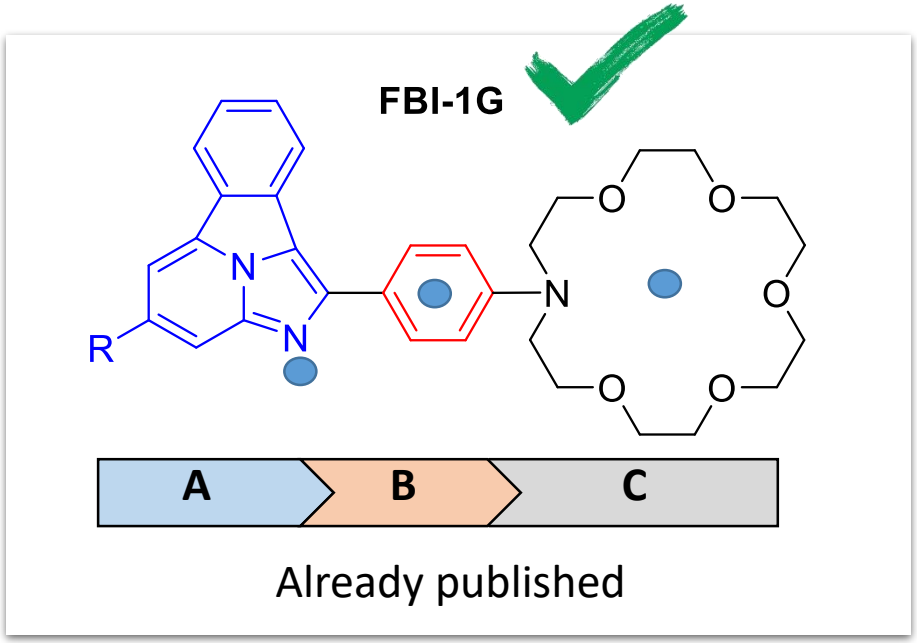








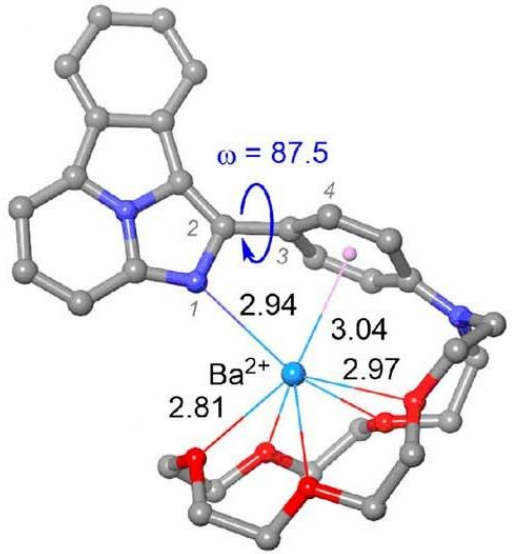
FBI Series: Four Generations



Already published

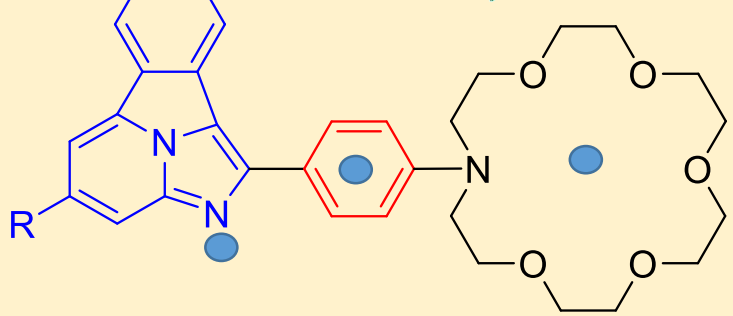
- 3 components (**A**, **B** and **C**)
- **A** Heterocycle; **B** Phenyl group and **C** Crown Ether

- Interaction with Ba++
- Center of Crown Ether
- Pi-cation-interaction-aromatic ring
- N-from heterocycle



FBI Series: Four Generations

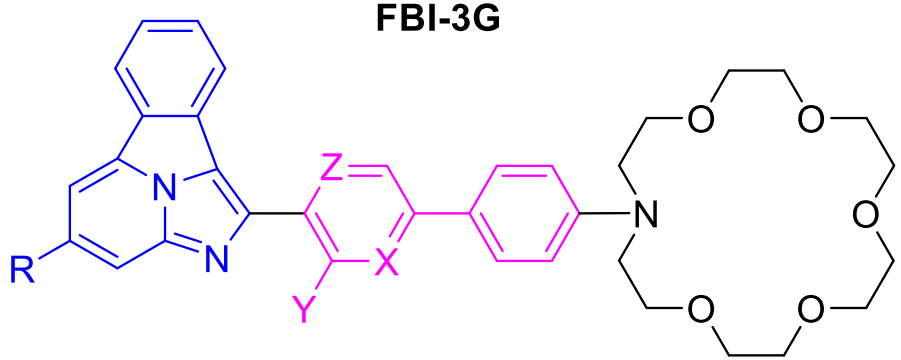
FBI-1G



A → B → C

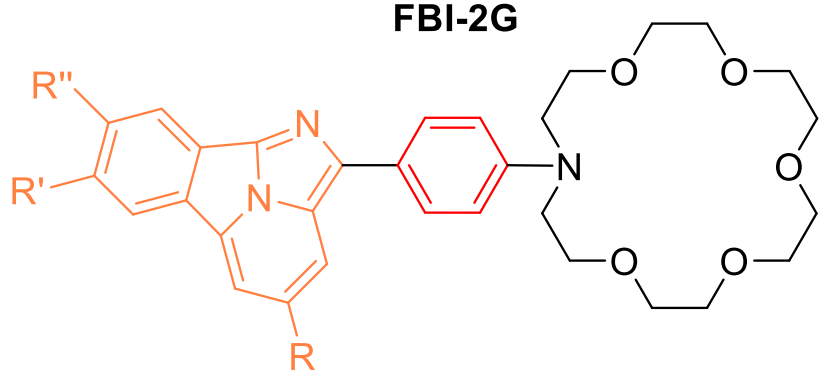
Already published

FBI-3G

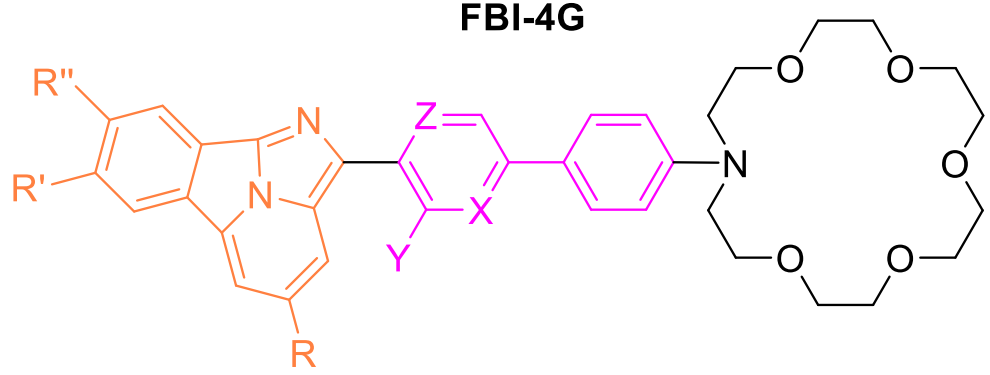


a: X=Z=CH; Y=H
b: X=N; Y=CH_3; Z=CH
c: X=Z=N; Y=H

FBI-2G



FBI-4G



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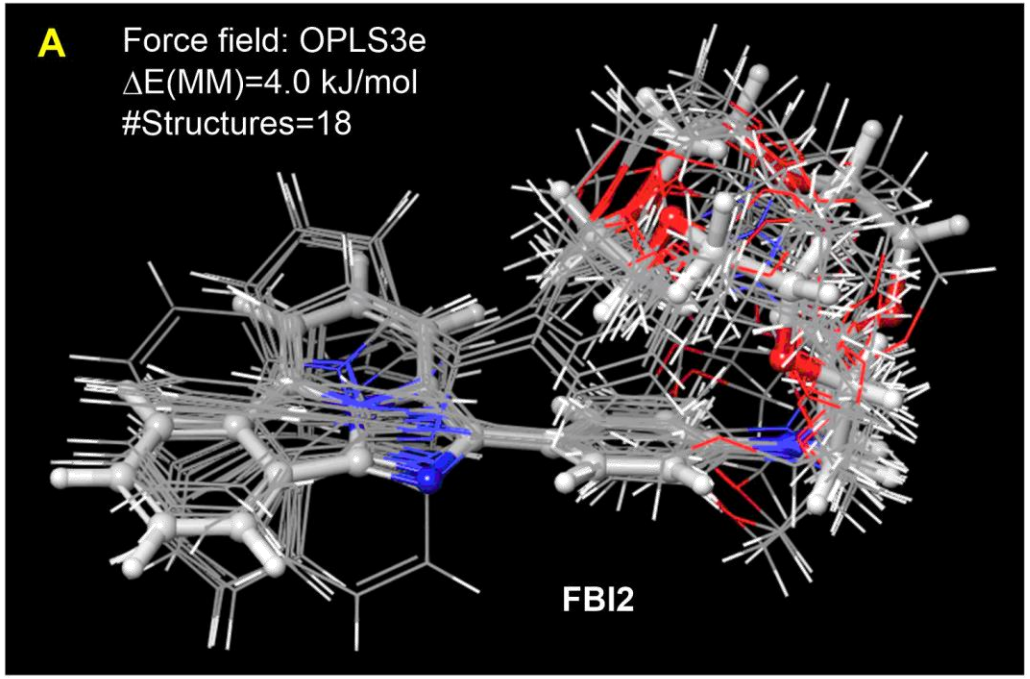

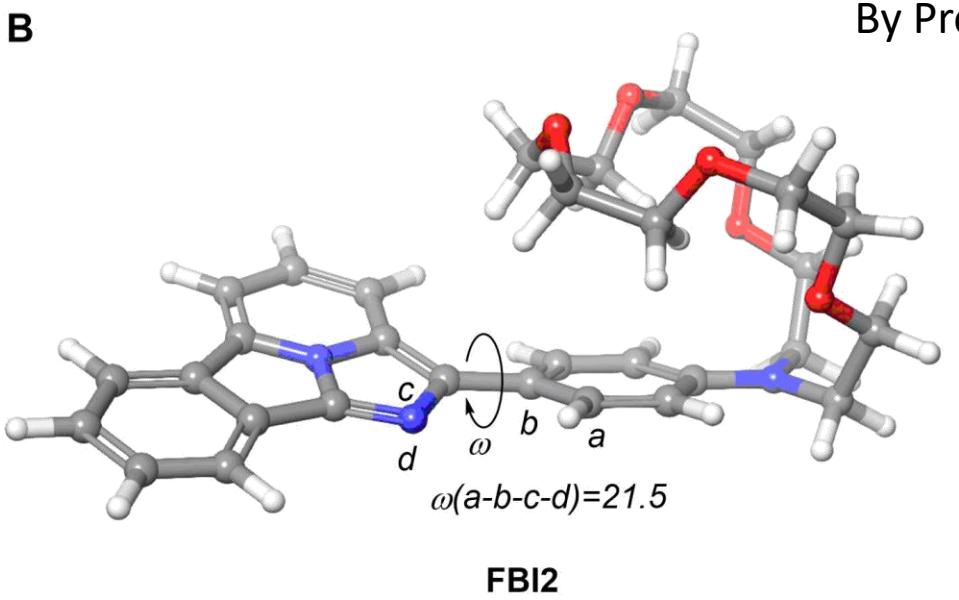

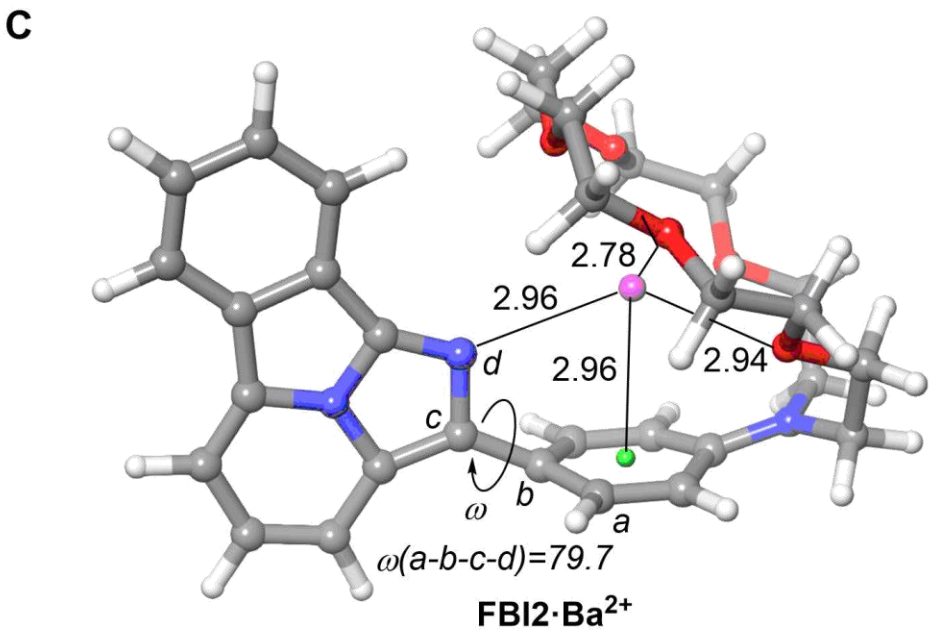

- Strong conformational flexibility
- Phenyl group coplanar with heterocycle (G1)
- Rigid conformation than G1 (Ba++)
- The pi-cation interaction is preserved
- Disconnection----color shift

$$\Delta E_b(FBI-G2) = -172.5 kcal/mol$$

$$\sum \Delta E_b(optimal) = -301.2 kcal/mol$$

$$\Delta E(deformation) = +128.71 kcal/mol$$

B3LYP-D3BJ/6 311++G(d,p)&LANL2DZ(Ba)

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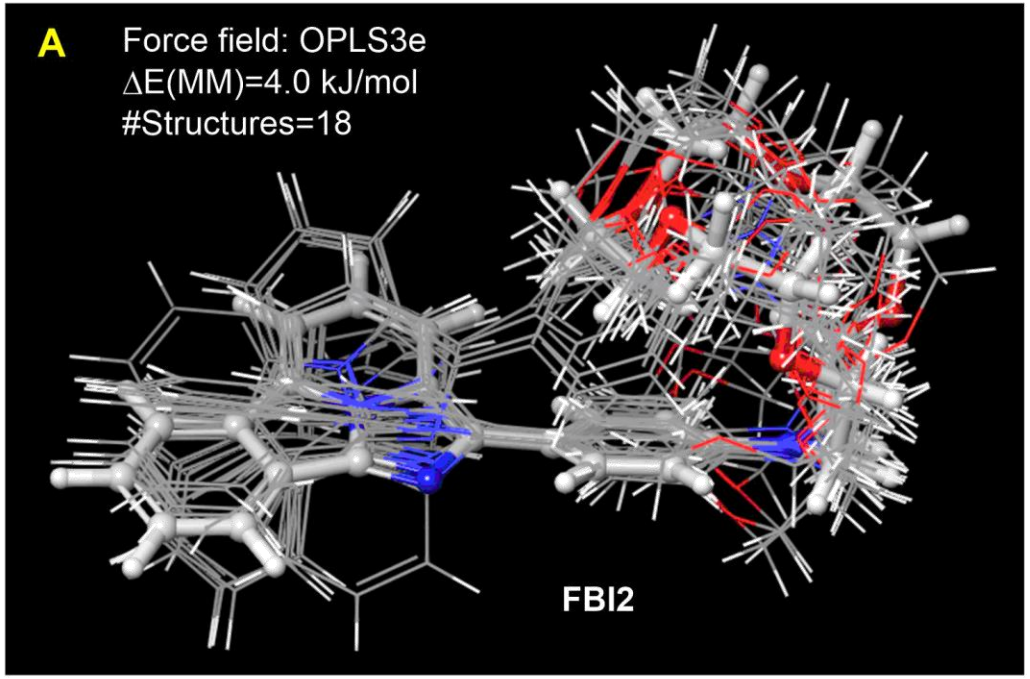
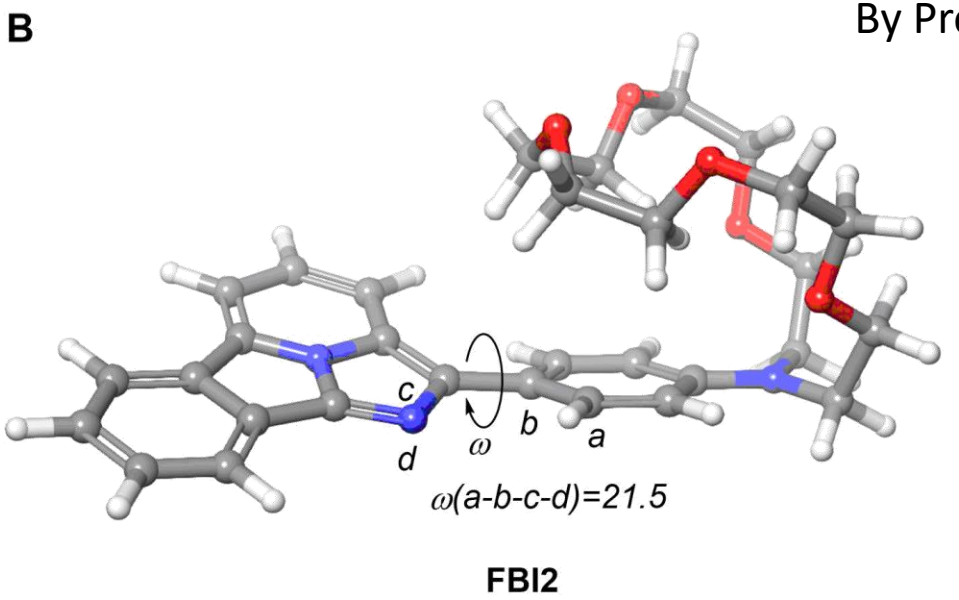
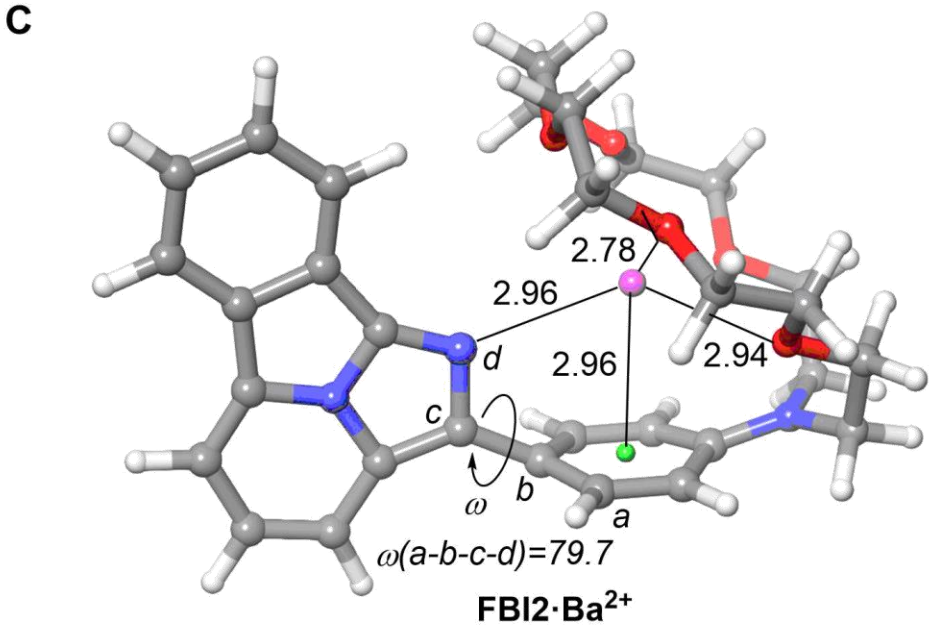
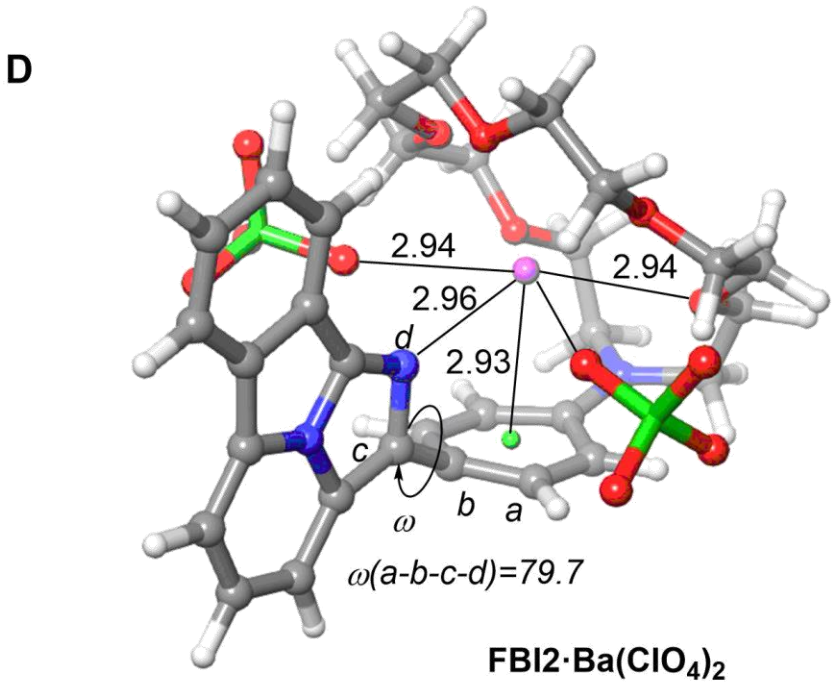






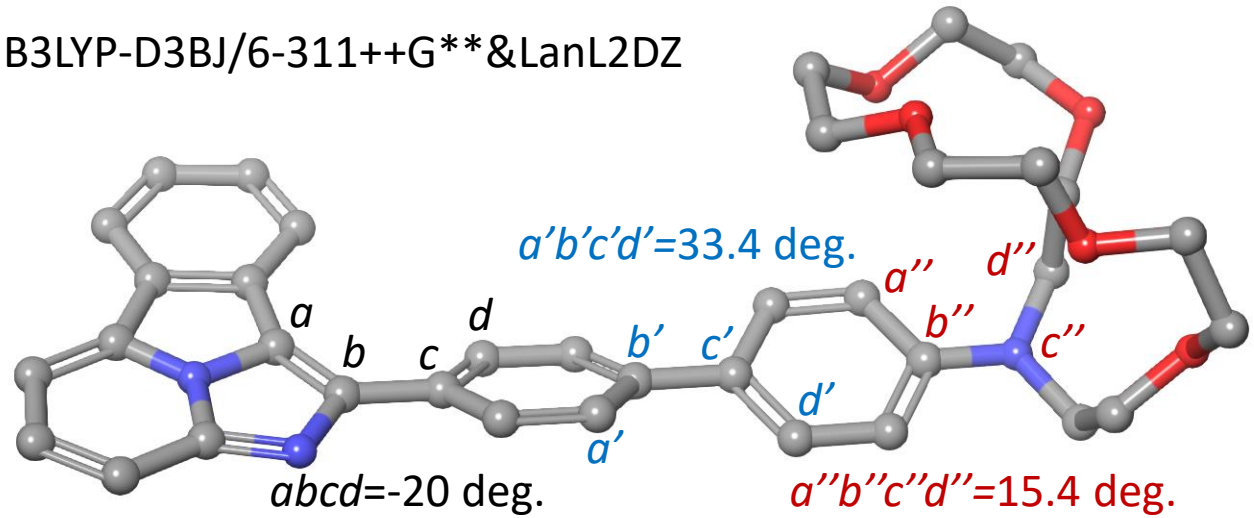


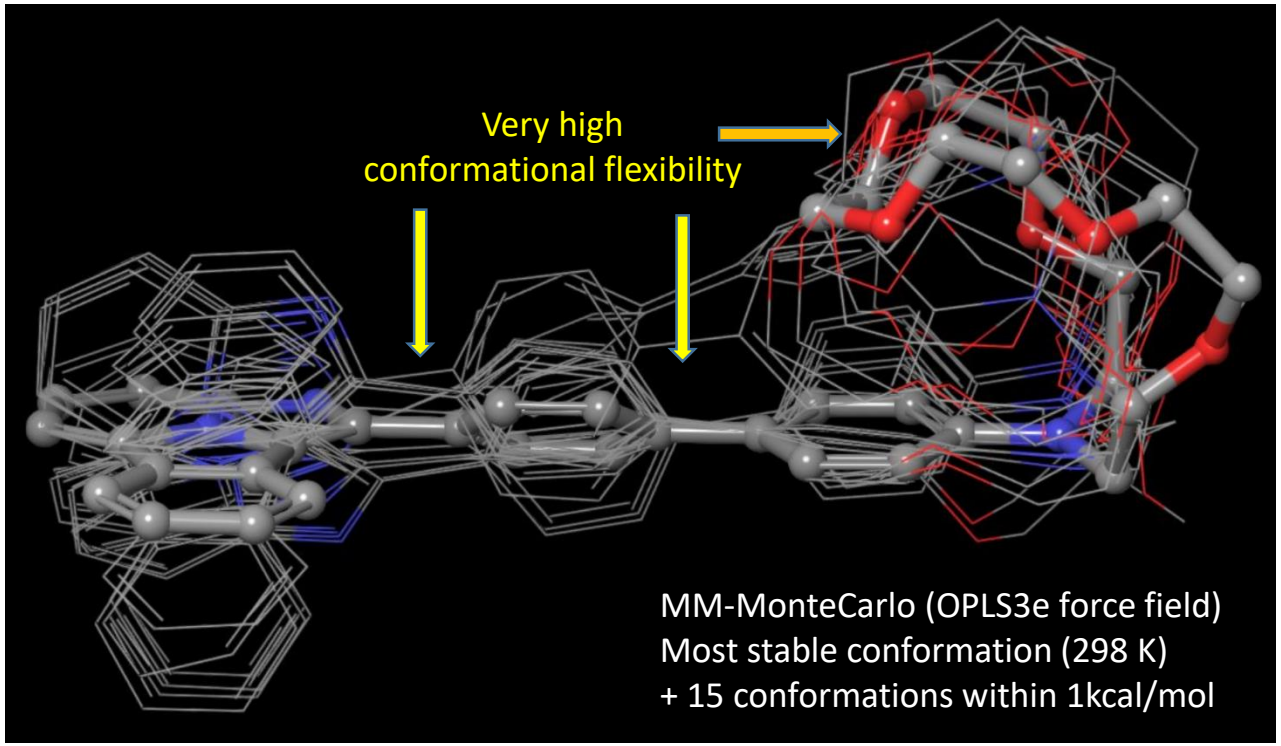
B3LYP-D3BJ/6 311++G(d,p)&LANL2DZ(Ba)

FBI-G3: The parent molecule FBI-G3a

By Prof. F Cossío

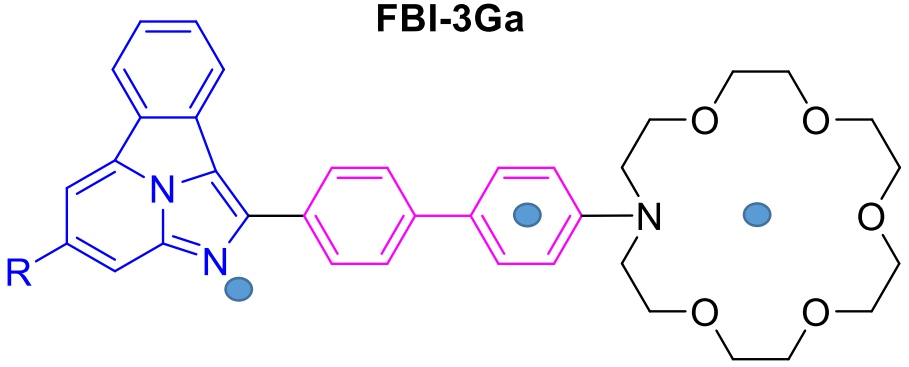
B3LYP-D3BJ/6-311++G**&LanL2DZ



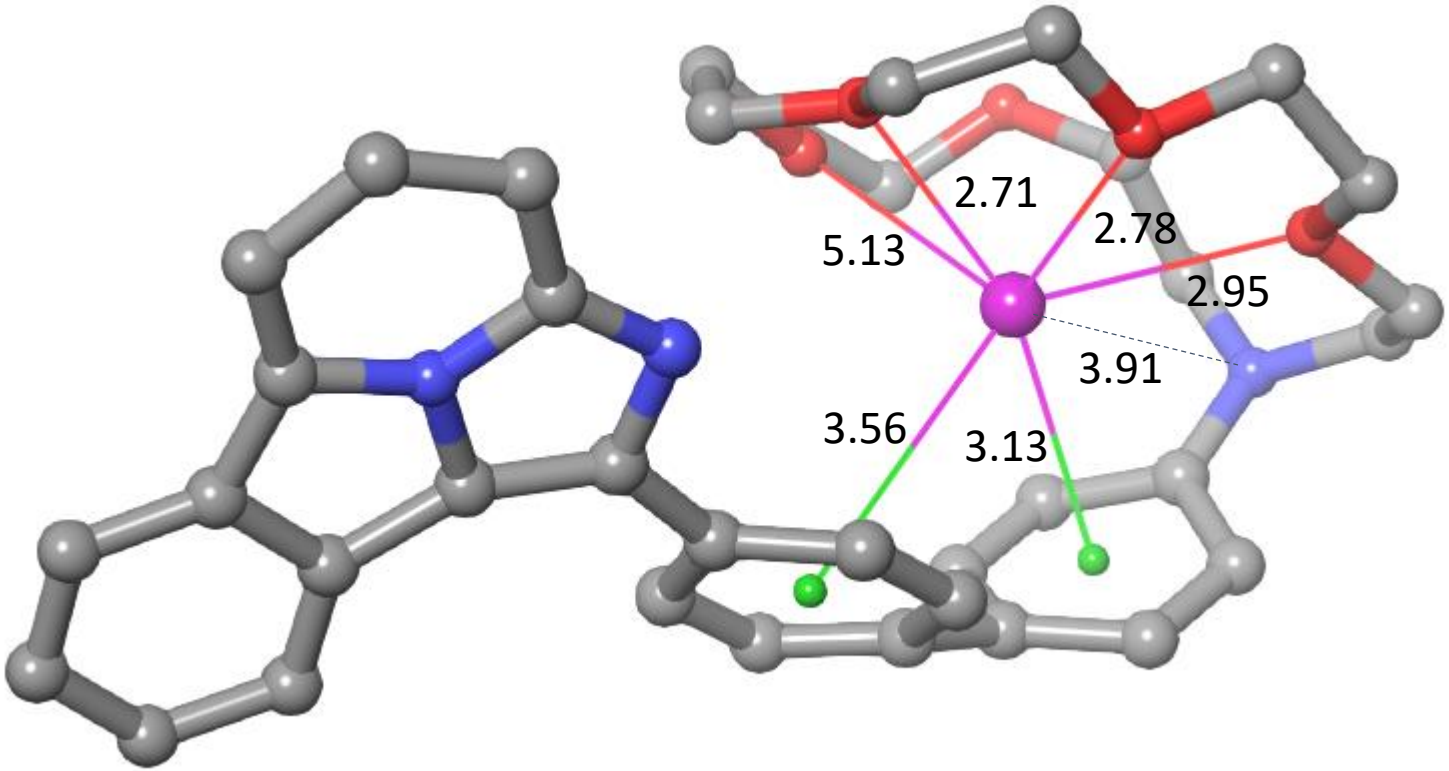


- Extended system
- High flexibility respect to G1
- Broad emission spectra

FBI-3Ga



B3LYP-D3BJ/6-311++G**&LanL2DZ

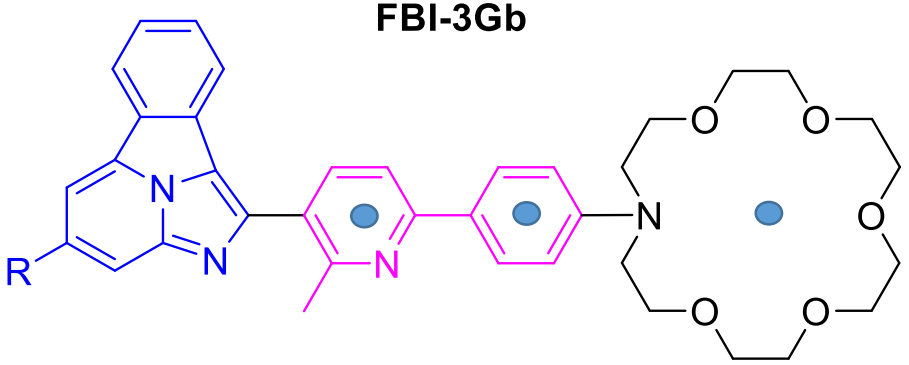


$$\Delta E_b(FBI-G3a) = -157.4 kcal/mol$$

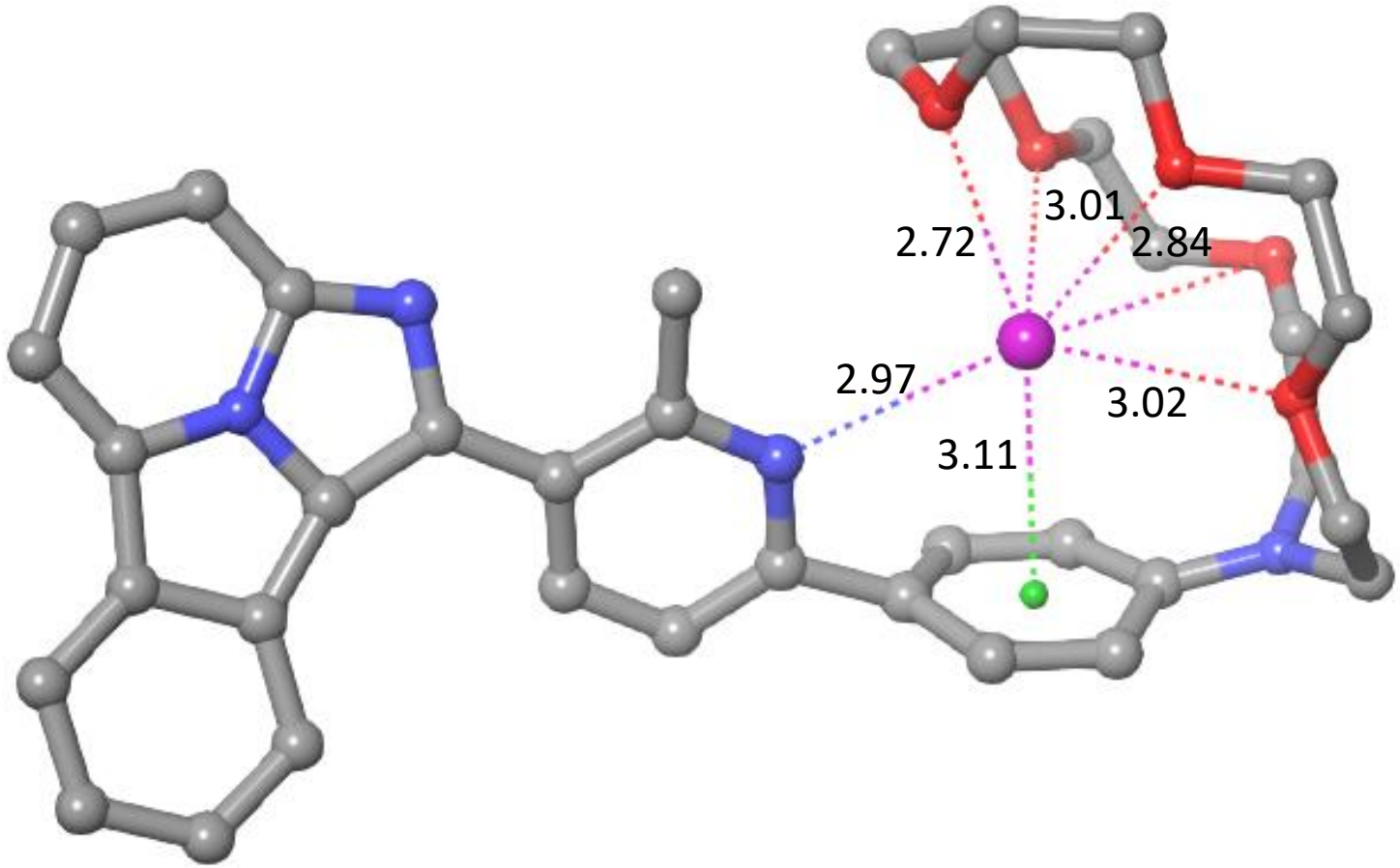
$$\sum \Delta E_b(optimal) = -315.7 kcal/mol$$

$$\Delta E(deformation) = +158.3 kcal/mol$$

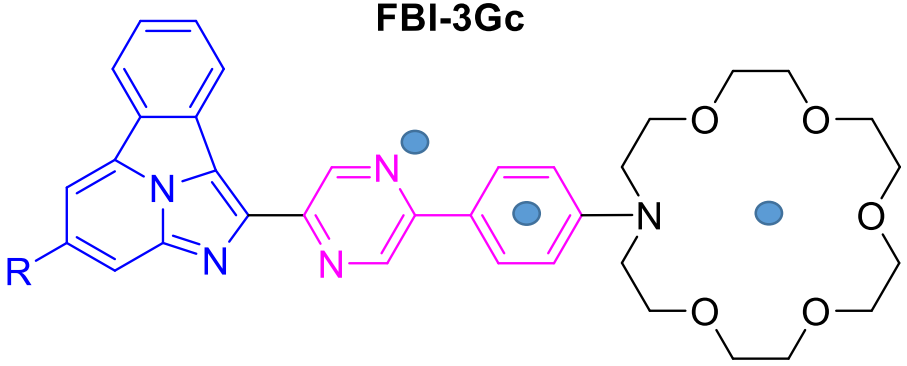
FBI-3Gb



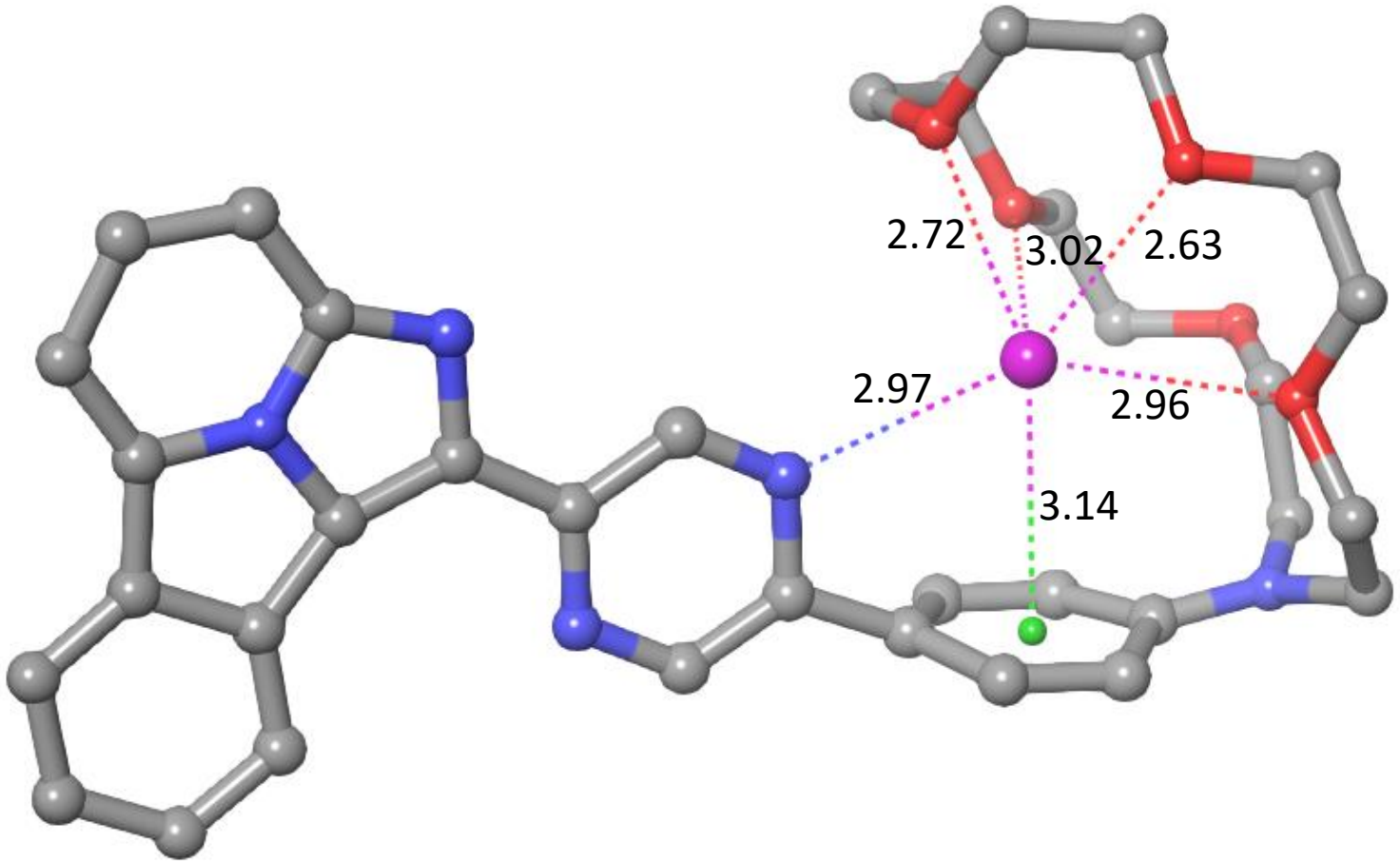
B3LYP-D3BJ/6-311++G**&LanL2DZ

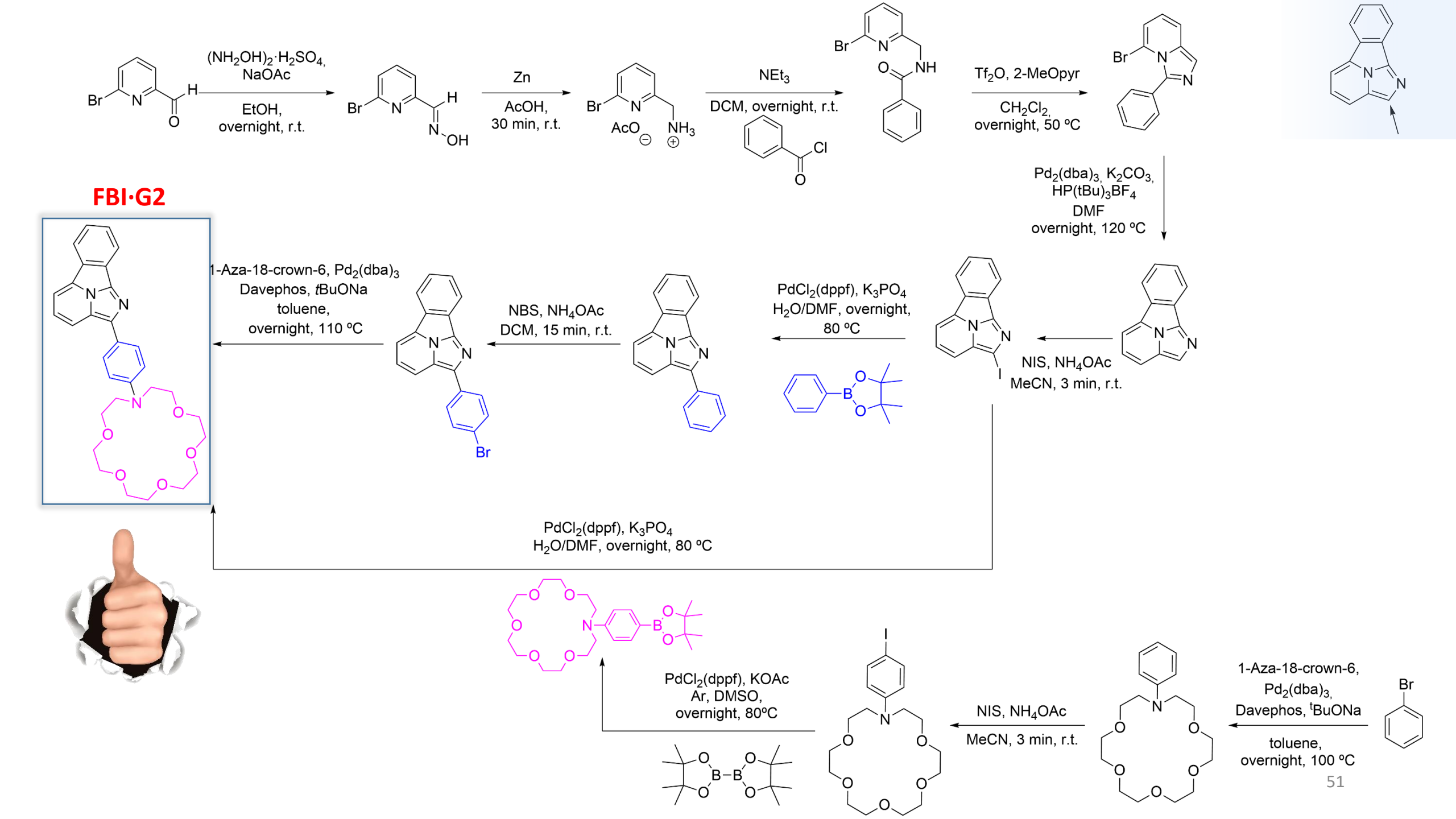


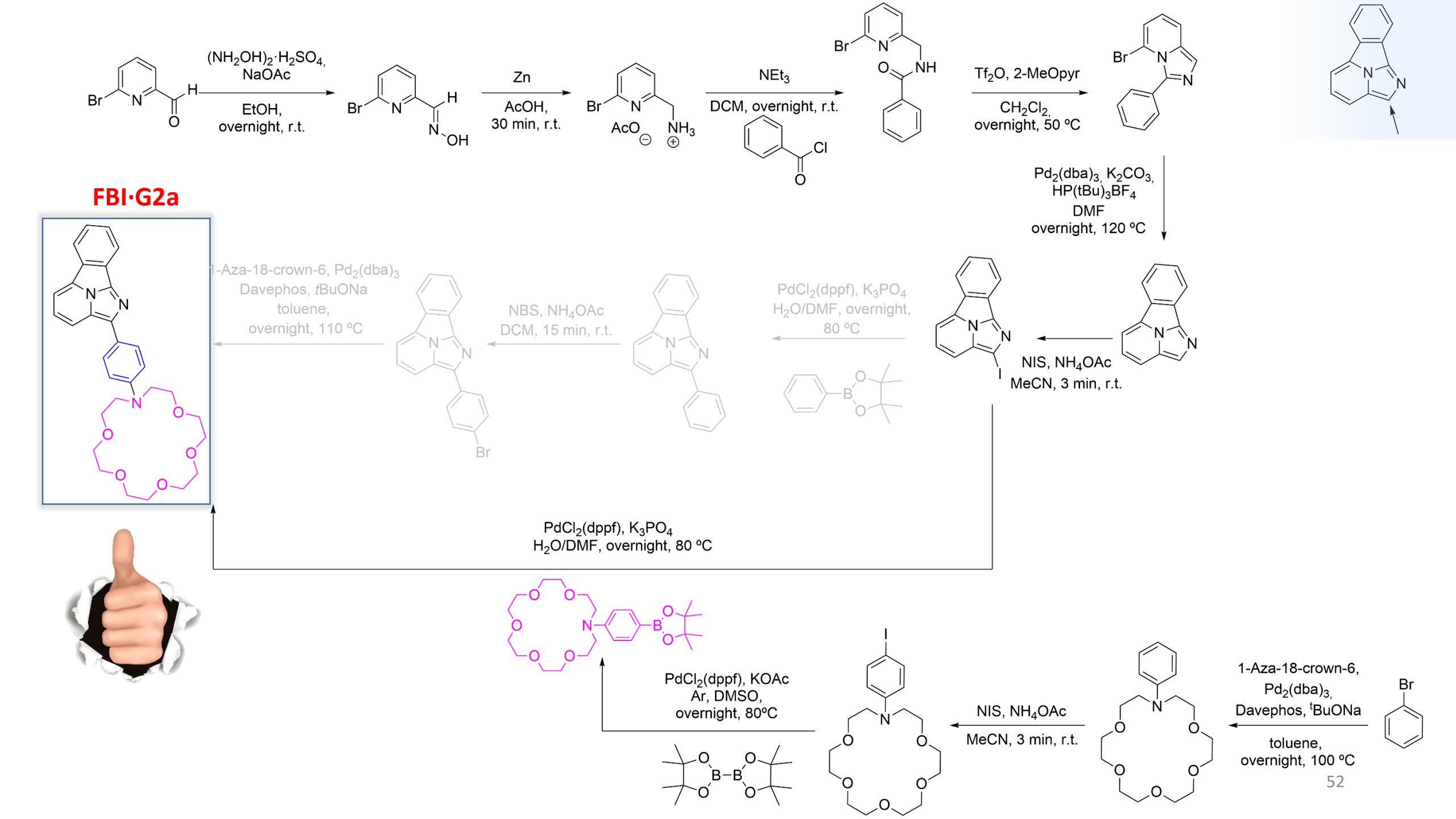
FBI-3Gc



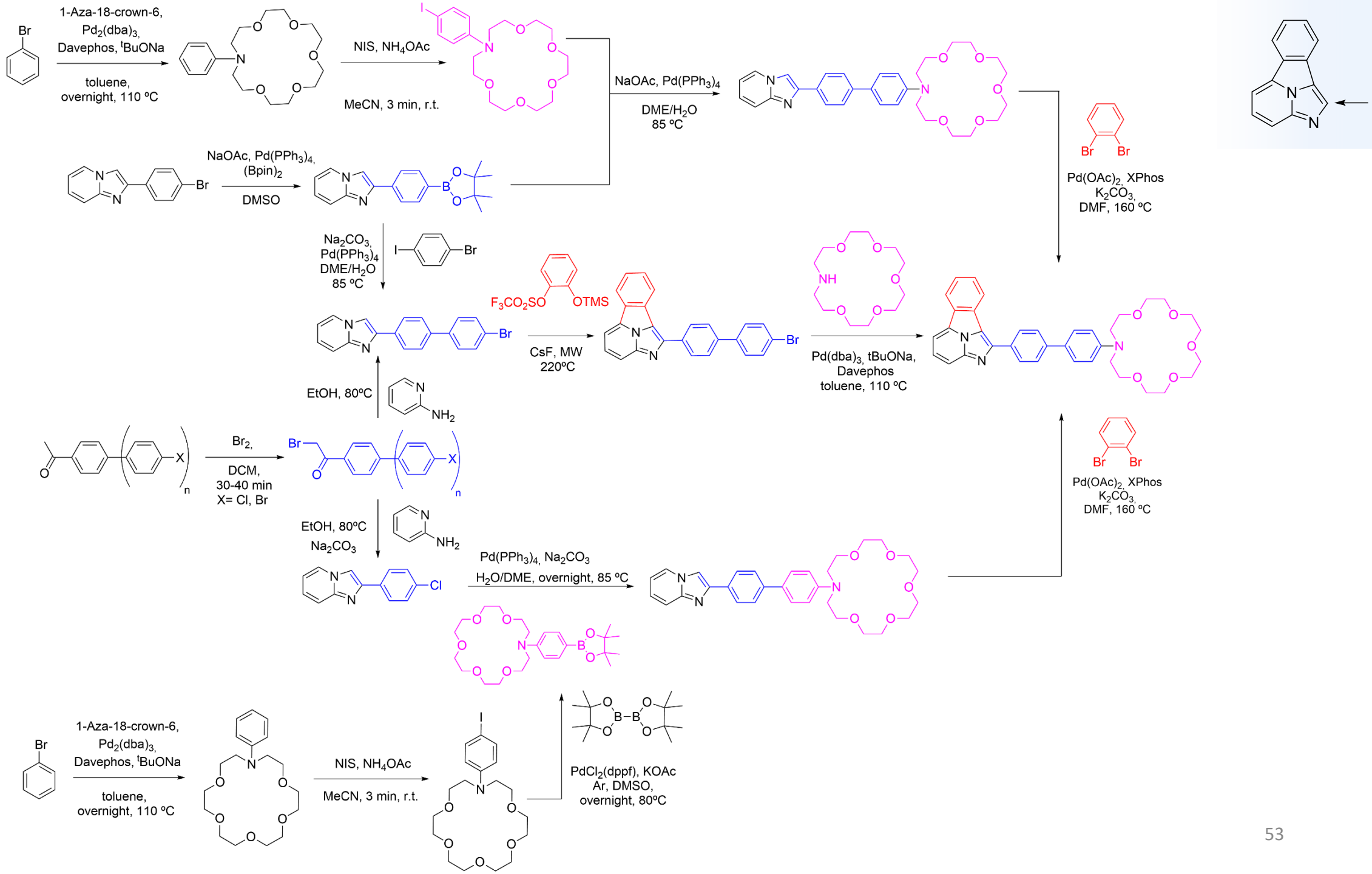
B3LYP-D3BJ/6-311++G**&LanL2DZ



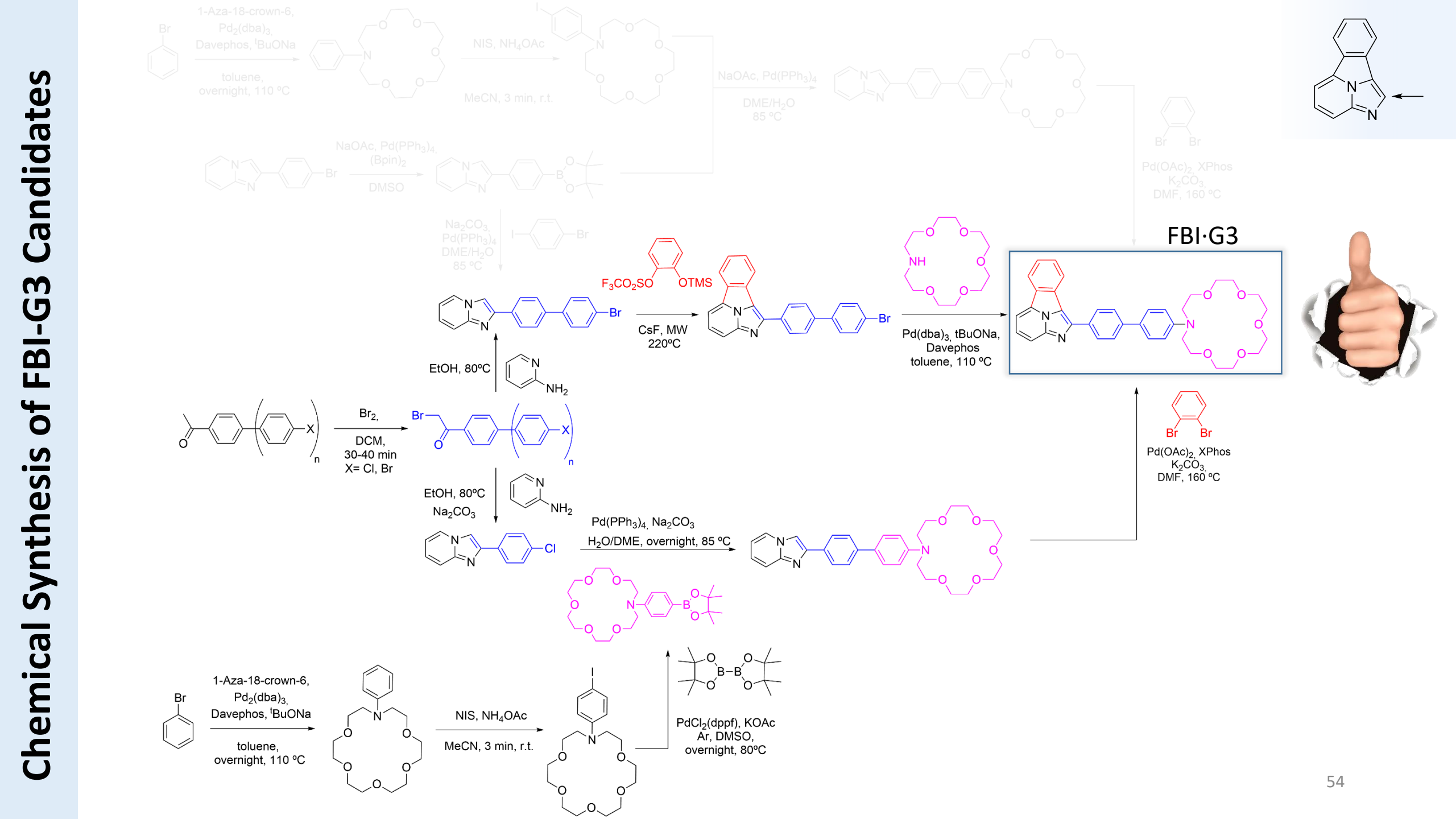

$(NH_2OH)_2{\cdot}H_2SO_4$, NaOAc
EtOH, overnight, r.t.
Zn
AcOH, 30 min, r.t.
NEt_3
DCM, overnight, r.t.
Tf_2O, 2-MeOpyr
CH_2Cl_2, overnight, 50 °C
$Pd_2(dba)_3$, K_2CO_3, $HP(tBu)_3BF_4$
DMF
overnight, 120 °C
NIS, NH_4OAc
MeCN, 3 min, r.t.
$PdCl_2(dppf)$, K_3PO_4
H_2O/DMF, overnight, 80 °C
NBS, NH_4OAc
DCM, 15 min, r.t.
1-Aza-18-crown-6, $Pd_2(dba)_3$
Davephos, tBuONa
toluene,
overnight, 110 °C
FBI·G2
$PdCl_2(dppf)$, K_3PO_4
H_2O/DMF, overnight, 80 °C
$PdCl_2(dppf)$, KOAc
Ar, DMSO,
overnight, 80°C
NIS, NH_4OAc
MeCN, 3 min, r.t.
1-Aza-18-crown-6,
$Pd_2(dba)_3$,
Davephos, tBuONa
toluene,
overnight, 100 °C


$(NH_2OH)_2 \cdot H_2SO_4$, NaOAc
EtOH, overnight, r.t.
Zn
AcOH, 30 min, r.t.
NEt_3
DCM, overnight, r.t.
Tf_2O, 2-MeOpyr
CH_2Cl_2, overnight, 50 °C
$Pd_2(dba)_3$, K_2CO_3, $HP(tBu)_3BF_4$
DMF
overnight, 120 °C
NIS, NH_4OAc
MeCN, 3 min, r.t.
$PdCl_2(dppf)$, K_3PO_4
H_2O/DMF, overnight, 80 °C
NBS, NH_4OAc
DCM, 15 min, r.t.
1-Aza-18-crown-6, $Pd_2(dba)_3$
Davephos, tBuONa
toluene,
overnight, 110 °C
FBI·G2a
$PdCl_2(dppf)$, K_3PO_4
H_2O/DMF, overnight, 80 °C
$PdCl_2(dppf)$, KOAc
Ar, DMSO,
overnight, 80°C
NIS, NH_4OAc
MeCN, 3 min, r.t.
1-Aza-18-crown-6,
$Pd_2(dba)_3$,
Davephos, tBuONa
toluene,
overnight, 100 °C

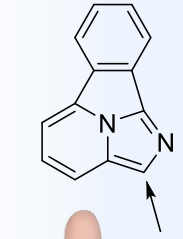
Chemical Synthesis of FBI-G3 Candidates

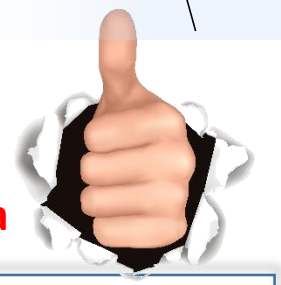


Chemical Synthesis of FBI-G3 Candidates

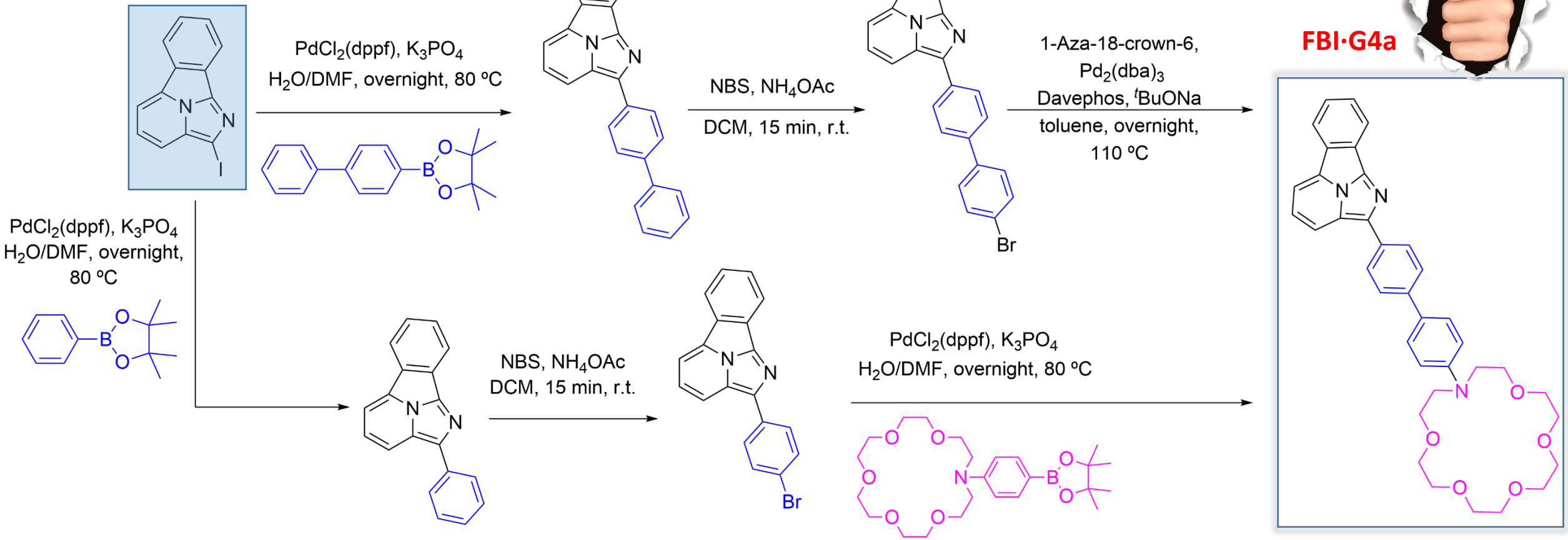


Chemical Synthesis of FBI-G4 Candidates

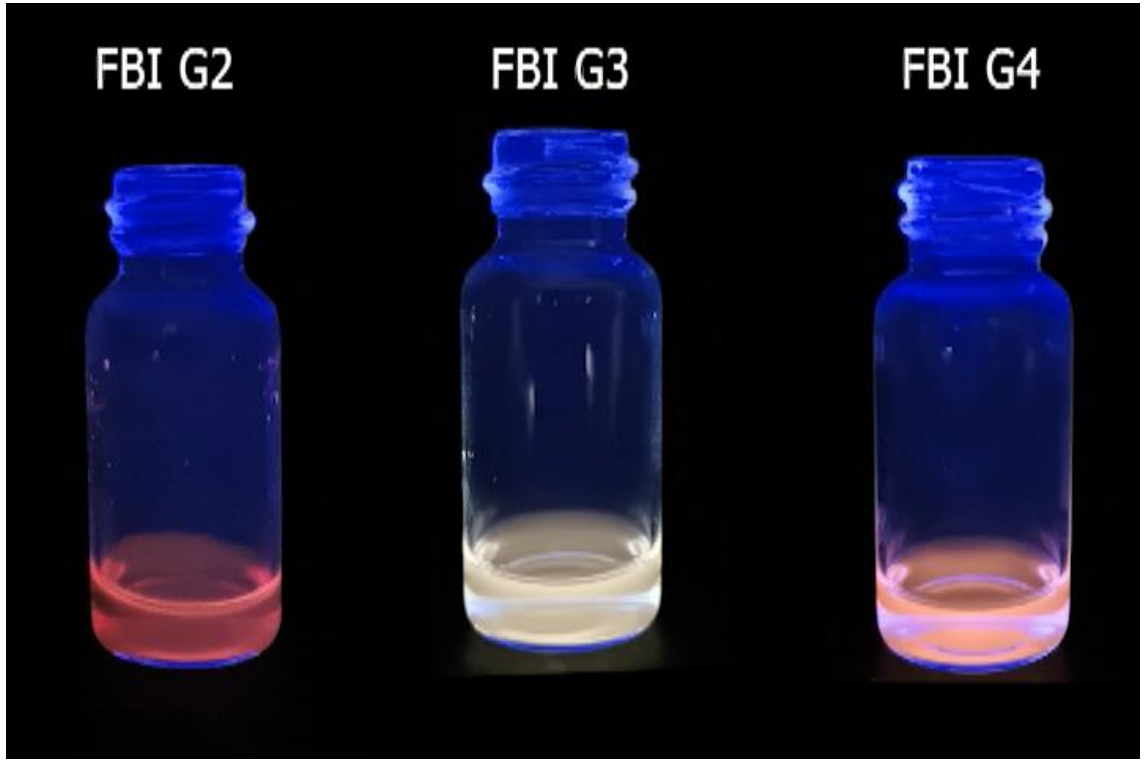




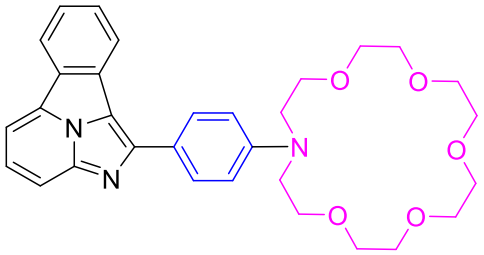
FBI·G4a

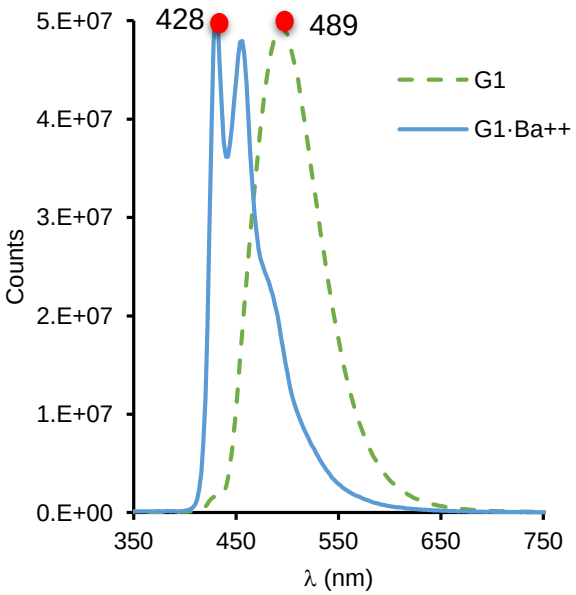


Fluorescent Bicolor Indicators G2, G3 and G4

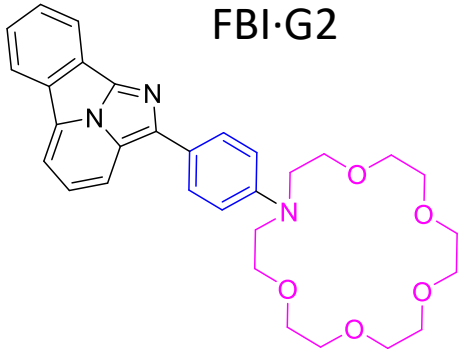


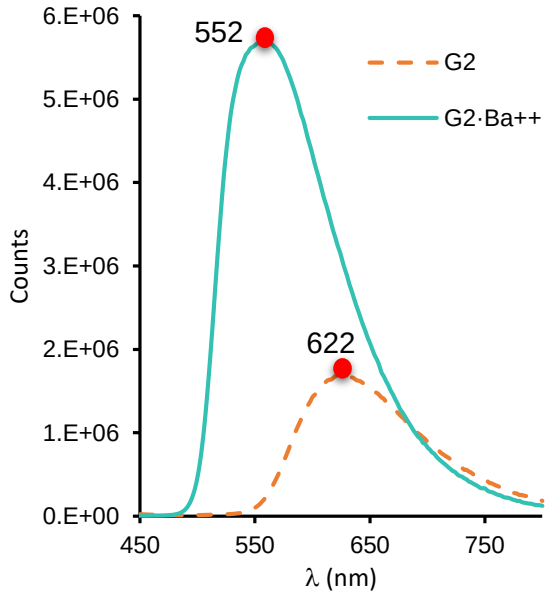
FBI·G1



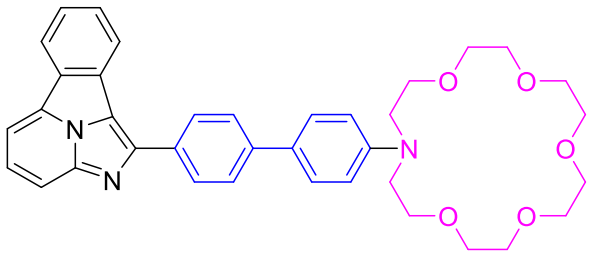


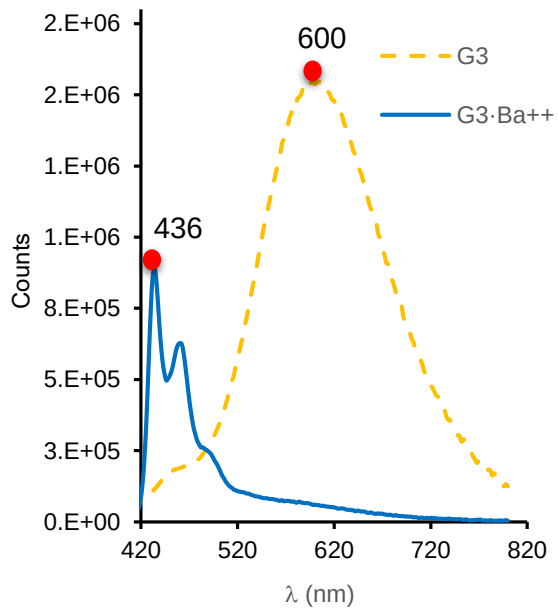
FBI·G2



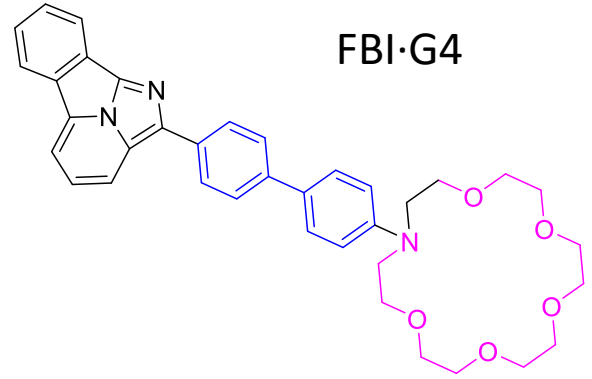


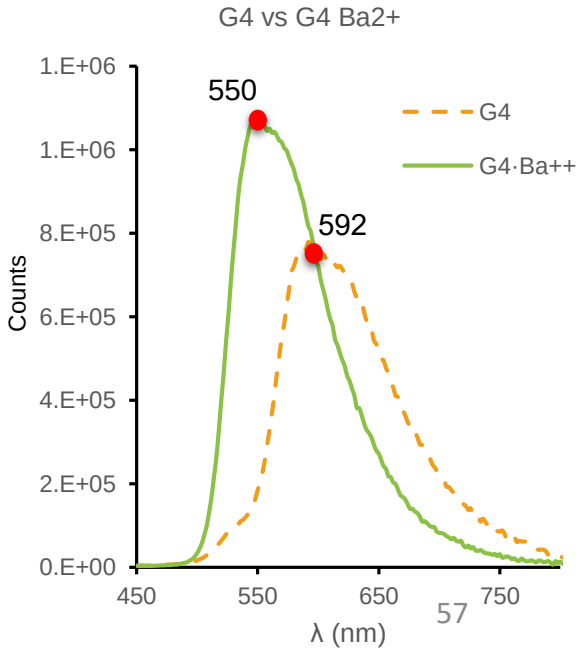
FBI·G3



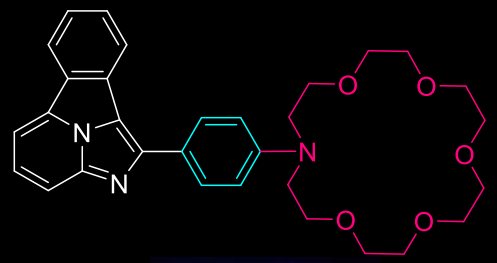


FBI·G4

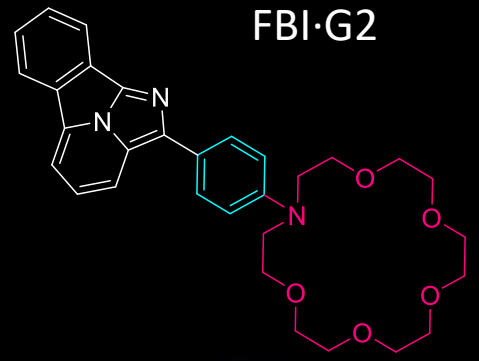




FBI·G1

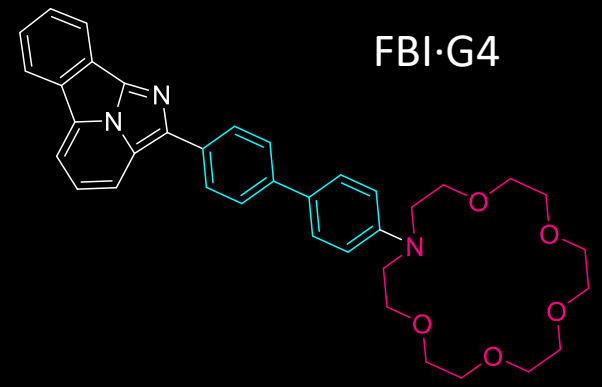


FBI·G2



FBI·G3

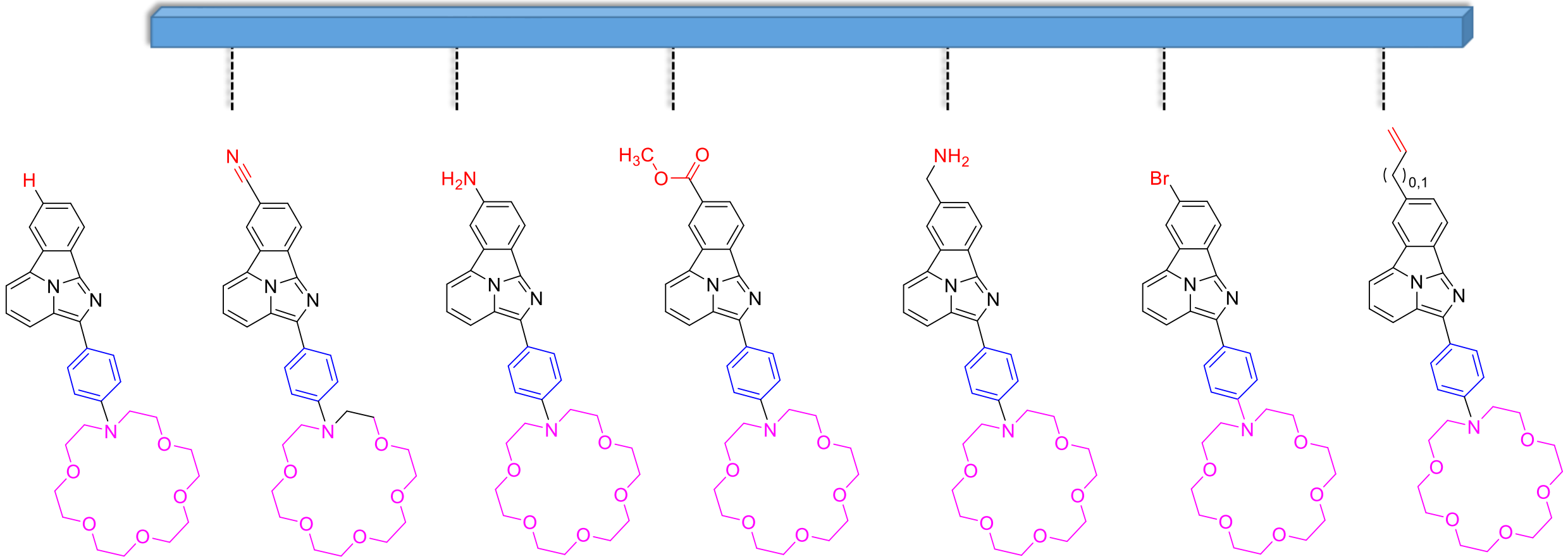
FBI·G4



Compound	λ_{em} [a] (nm)		$\Delta\lambda$ (nm)	$f^{b}_{\lambda_{em}}$	ϕ^{c}_{λ}		B^{c}_{λ} (M^{-1} cm^{-1})		$\varepsilon^{c}_{\lambda}$ ($M^{-1}\cdot cm^{-1}$)		σ^{c}_{λ} (Å^2)		K_a [d] (M^{-1})
	Gn	Gn·Ba^{2+}			Gn	Gn·Ba^{2+}	Gn	Gn·Ba^{2+}	Gn	Gn·Ba^{2+}	Gn	Gn·Ba^{2+}	
G1	489	428	61	179.7	0.67	0.45	16,388	9,937	24,460	22,084	0.94	0.84	$5.3\cdot10^4$
G2	622	552	70	210.6	0.23	0.55	5,990	16,564	26,044	30,117	1.00	1.15	$1.3\cdot10^6$
G3	600	436	164	5.5	0.74	0.61	13,380	3,068	18,081	5,031	0.69	0.19	$5.0\cdot10^5$
G4	592	550	42	8.2	0.41	0.58	5,193	5,794	12,667	9,991	0.48	0.38	$1.0\cdot10^5$

[a] Emission wavelengths λ_{em} at a λ_{exc}_max .[b] Peak discrimination factors (f_λ) with respect to unbound fluorophores Gn at λ_{em}. [c] All values for Quantum yields ϕ_λ , molecular brightness of the fluorescent emissions (B_λ), molar extinction coefficient and cross section were recorded for λ(G1) =250 nm; λ(G2) =325 nm; λ(G3)=368 nm; λ(G4)=354 nm . [d] K_a with barium perchlorate in acetonitrile at 298 K using the Benesi–Hildebrand method.

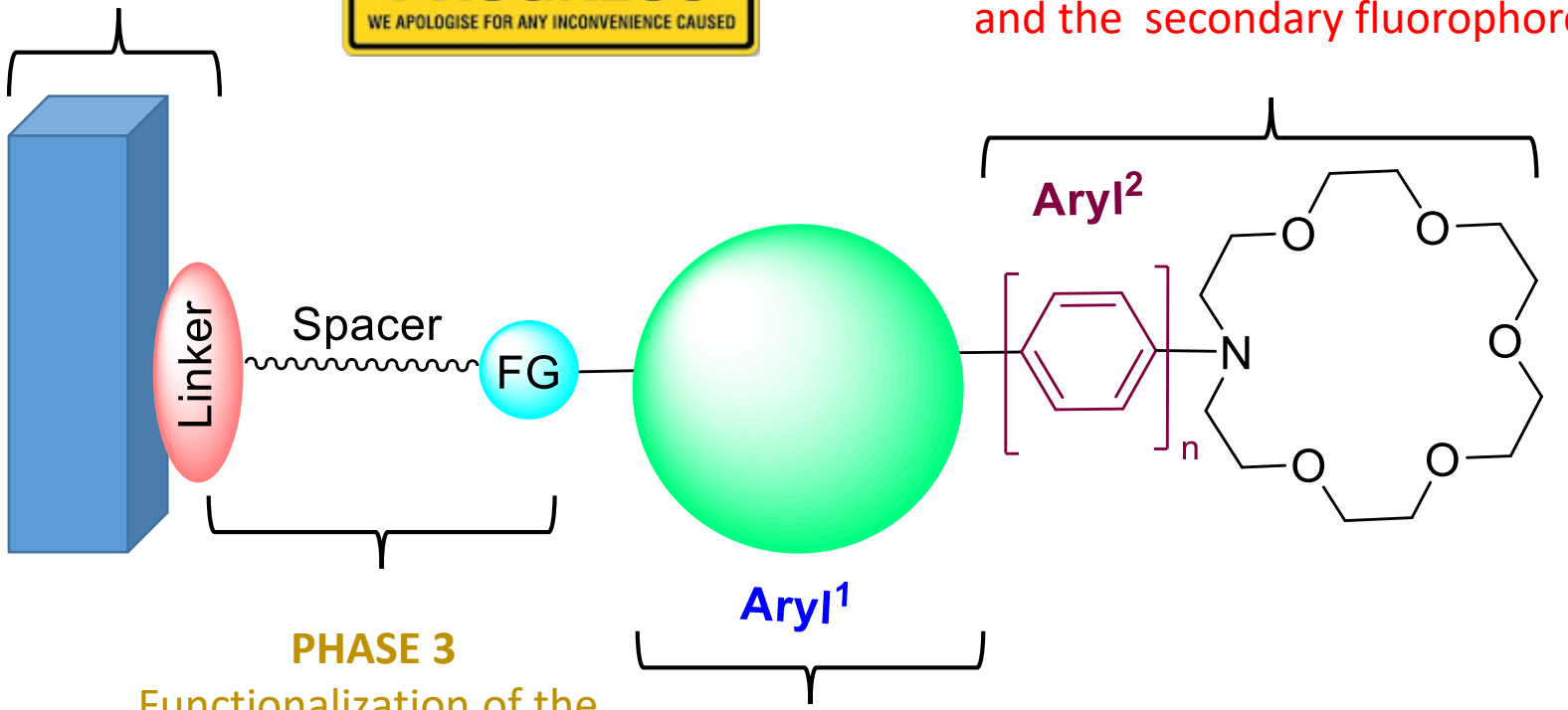
Differently Functionalized FBI-G2 compounds



A unified synthetic scheme towards functional surfaces

PHASE 4
Covalent anchoring
to the surface

PHASE 2
Coupling to the chelating group
and the secondary fluorophore

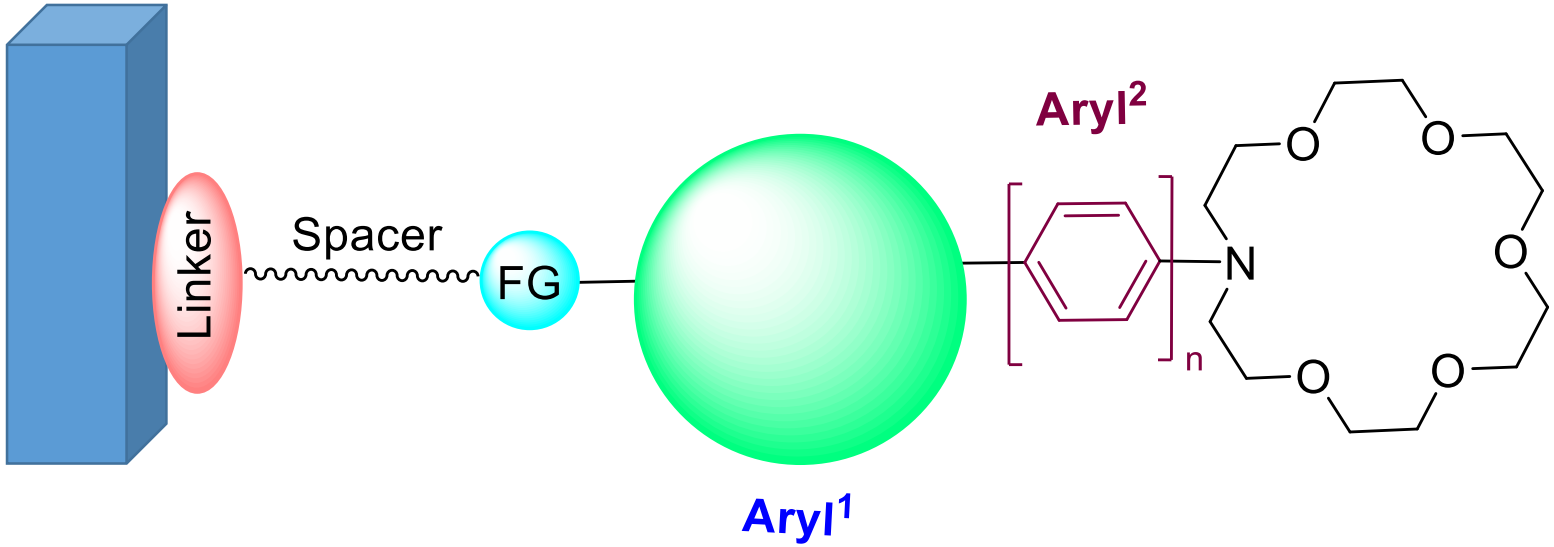


PHASE 3
Functionalization of the
spacer-linker component

PHASE 1
Synthesis
of the main fluorophore

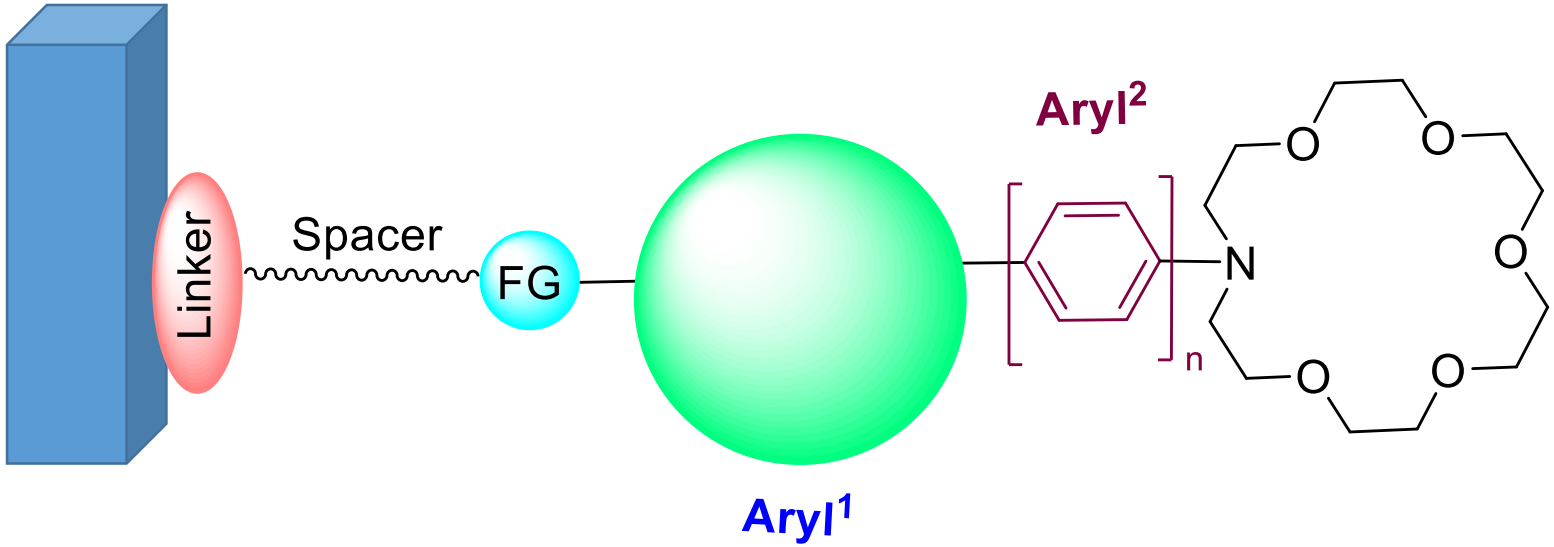
Conclusions and Outlook

- Its is possible to expand and optimize the configurational space of fluorescent bicolor indicators (FBIs) by modifying the structure of the hereroaromatic polycyclic ($Aryl^1$) and the *para*-phenylene/bipenylene ($Aryl^2$) components.



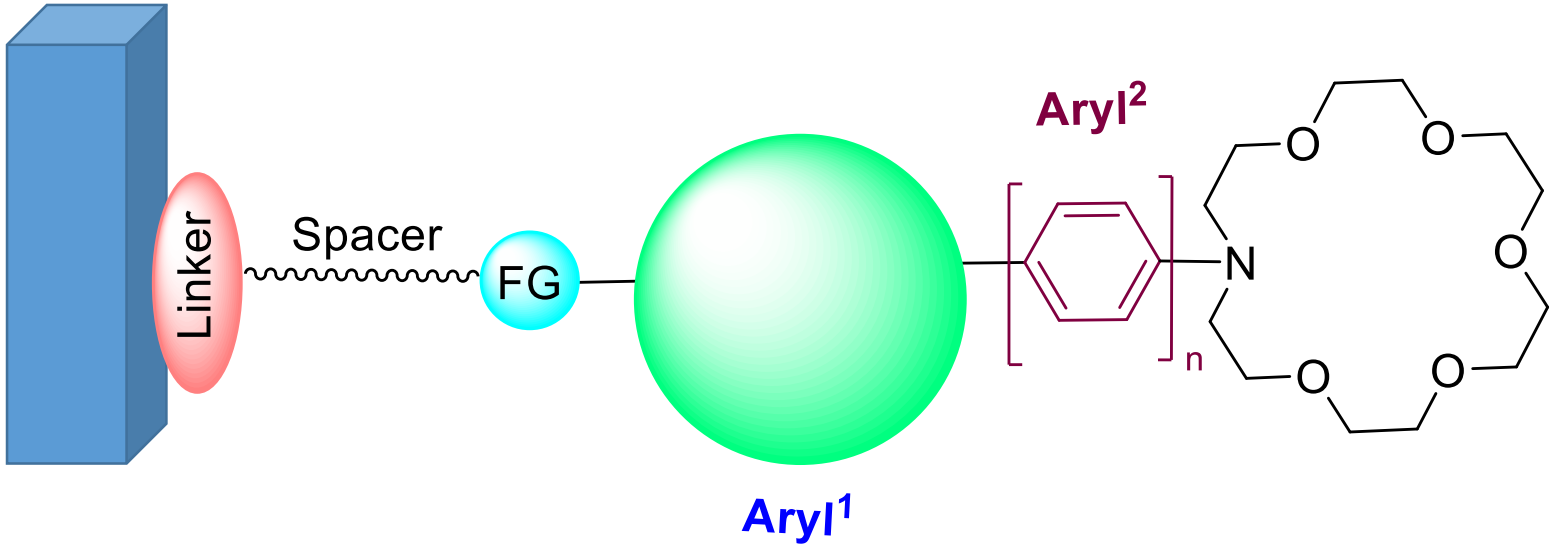
Conclusions and Outlook

- Its is possible to expand and optimize the configurational space of fluorescent bicolor indicators (FBIs) by modifying the structure of the hereroaromatic polycyclic ($Aryl^1$) and the *para*-phenylene/bipenylene ($Aryl^2$) components.
- Among the different options synthesised and tested, the FBI-G2 series is particularly promising.



Conclusions and Outlook

- Its is possible to expand and optimize the configurational space of fluorescent bicolor indicators (FBIs) by modifying the structure of the hereroaromatic polycyclic (Aryl^1) and the *para*-phenylene/bipenylene (Aryl^2) components.
- Among the different options synthesised and tested, the FBI-G2 series is particularly promising.
- Work is in progress to modify this novel family of sensors in order to generate suitable functionalized surfaces.



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arigata
grazie
thank you
spasiba
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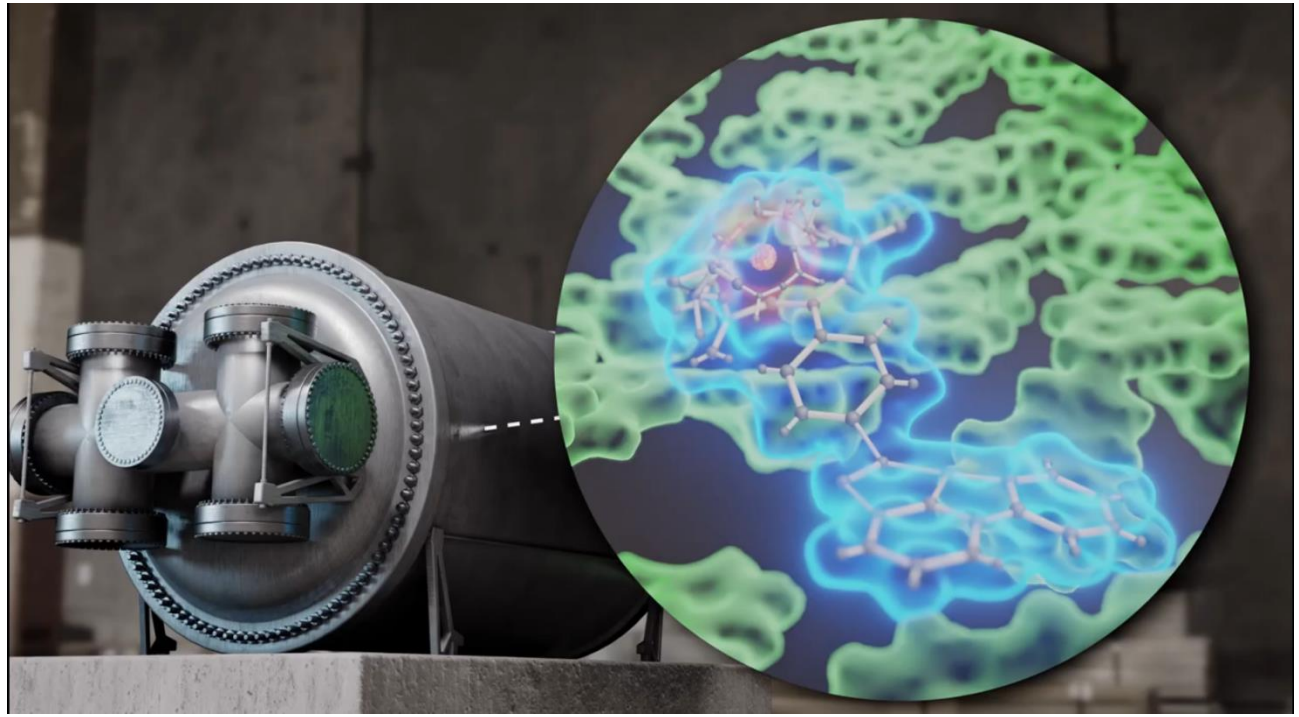
cheers
kuala
grassie
mahalo
shakkran
merkzi
blagodaria
dakujem
tänan
obrigada
dziakuju
shukriya
shukria
gratzias
waybale
matondo
multumesc
dziekuje
saha
saðol
kiitos
akiba
nkosi
tanemirt
manana
bayarlalaa
aabar
manjuthe
omol
nuhun
sulpáy
chakrane
buzyyg
murakaze
yekeniele
dankeewal
miigwech
supas
paldies
dėkoju
ahsante
tack
spas
shukran
dekuji
madlobt
madupe
talofa
soolong
tashakor
skee
abrigado
rahmat
misaotra
nandri
takk
danki
sobodi
bedankt
salamat
maururu
taiku
tenki
welalin
trugéré
marahaba
vinaka
tanmirt
barkal
mèsi
dankie
wado
waita
menlau
matondi
meharbani
gràcies
kinisou
aitäh
zikoma
ngiyabonga

Searching the Grail: A background free $\beta\beta0\nu$ experiment using Ba^{2+} tagging in a High-Pressure Xenon Chamber

Iván Rivilla and on behalf of NEXT

Zoraida Freixa, Fernando Auria-Luna, Juan Molina-Canteras, Mikel Odriozola-Gimeno, Borja Aparicio, Ane I. Aranburu, Amaia Larumbe, Virginia San Nacianceno, Nerea Alberro, Pablo García, Francesc Monrabal, Pablo Herrero, Celia Rogero, Juan J. Gómez-Cadenas and Fernando P. Cossío



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