MAPPING GLOBAL COLLABORATION IN ACCELERATOR RESEARCH

A. Zamora*, University of Lausanne, Lausanne, Switzerland

Abstract

This contribution examines particle accelerator research through a sociological lens. It combines a database of accelerator counts per country with a large corpus of accelerator-related publications from Web of Science to analyse how infrastructure distribution shapes scientific collaboration across regions and disciplines. The results reveal marked geographical asymmetries: some regions sustain dense internal publication networks while others participate primarily through cross-regional partnerships. The analysis also identifies clear disciplinary differences in how fields such as astronomy, materials science, and chemistry mobilise accelerator infrastructure through distinct collaboration configurations. Together, these patterns illustrate how scientific collaboration crystallises around shared infrastructures, how expertise circulates unevenly between regions, and how accelerators support the emergence of differentiated epistemic communities. The study offers an empirical perspective on the social dynamics underpinning global accelerator research and raises questions for future qualitative and longitudinal investigation.

INTRODUCTION

Particle accelerators occupy a distinctive position in the landscape of contemporary science, especially in science and technology studies [1–4]. Attention has extended to synchrotron light sources and other mid-range facilities serving materials science, chemistry, medical imaging, and environmental research [5–7]. Yet the relationship between infrastructure and knowledge production remains underexplored at a global scale. Existing analyses focus on specific facilities [8–10] or established communities [11, 12], rather than offering a comparative multi-regional perspective. Three questions guide this study: How are infrastructure and publication production distributed ? How are collaboration networks organised across regions? And do disciplinary communities mobilise accelerator infrastructure through distinct collaboration configurations?

METHODOLOGY

Data Sources

The accelerator database was constructed from the IAEA Accelerators Database[1] (578 facilities), expanded via the NEC World Pelletron Census,[2] the HVEE Tandetron database,[3] and scientific publications such as [13], reaching 809 facilities across 68 countries. Each entry records location, type, energy range, and commissioning year. As ~97% of the world's 30,000 accelerators serve industrial or medical purposes [14], this sample targets research-relevant facilities. Publication data were retrieved from Web of Science (1928–2022) using keyword searches for accelerator types and components (*linac, synchrotron, pelletron, van de graaff, RFQ*, and others), translated into 12 languages to mitigate language bias. The corpus does not distinguish between facility operators and user communities.

Analytical Approach

The analysis proceeds in three steps: comparing regional infrastructure and publication shares using proportional ratios; characterising collaboration profiles by distinguishing intraregional publications (all co-authors within the same region) from extraregional ones (at least one external partner), examined both in aggregate and longitudinally; and disaggregating profiles by WOS subject category to identify disciplinary collaboration patterns. Data processing was carried out in Excel and RStudio.

Classifications & Limitations

Countries were assigned to six world regions (UN M49) and to Global North or Global South (NORRAG),[4]. These categories are used as analytical tools; their limitations are acknowledged [15]. Regional affiliation reflects institutional address at time of publication, not researcher nationality or mobility. Of the 256,227 publications, 2.63% could not be regionally classified due to missing affiliation data and are excluded from regional analyses.

Three further limitations bear noting. The accelerator database remains incomplete and would benefit from broader surveying. WOS is biased toward English-language output, likely undercounting activity in underrepresented regions. The keyword-based search captures publications that explicitly mention instrument types, and user communities that do not name the facility in their output will be undercounted. This study is exploratory: the patterns documented are observations warranting interpretation, not measures of regional performance.

ACCELERATOR INFRASTRUCTURES & RELATED PUBLICATIONS

The following results examine whether and how infrastructure presence shapes scientific participation, and where other factors intervene.

Figure 1 presents the global and regional distribution of the 809 research accelerator facilities alongside 249,476 accelerator-related publications. At the global level the two distributions are nearly identical: the Global North hosts 81.21% of facilities and accounts for 82.24% of publications;

* annabella.zamora@unil.ch

[1] IAEA Accelerators Database, accessed 13 May 2026.
[2] National Electrostatics Corp., accessed 13 May 2026.
[3] High Voltage Engineering Europa B.V., accessed 13 May 2026.
[4] Network for International Policies and Cooperation in Education and Training.

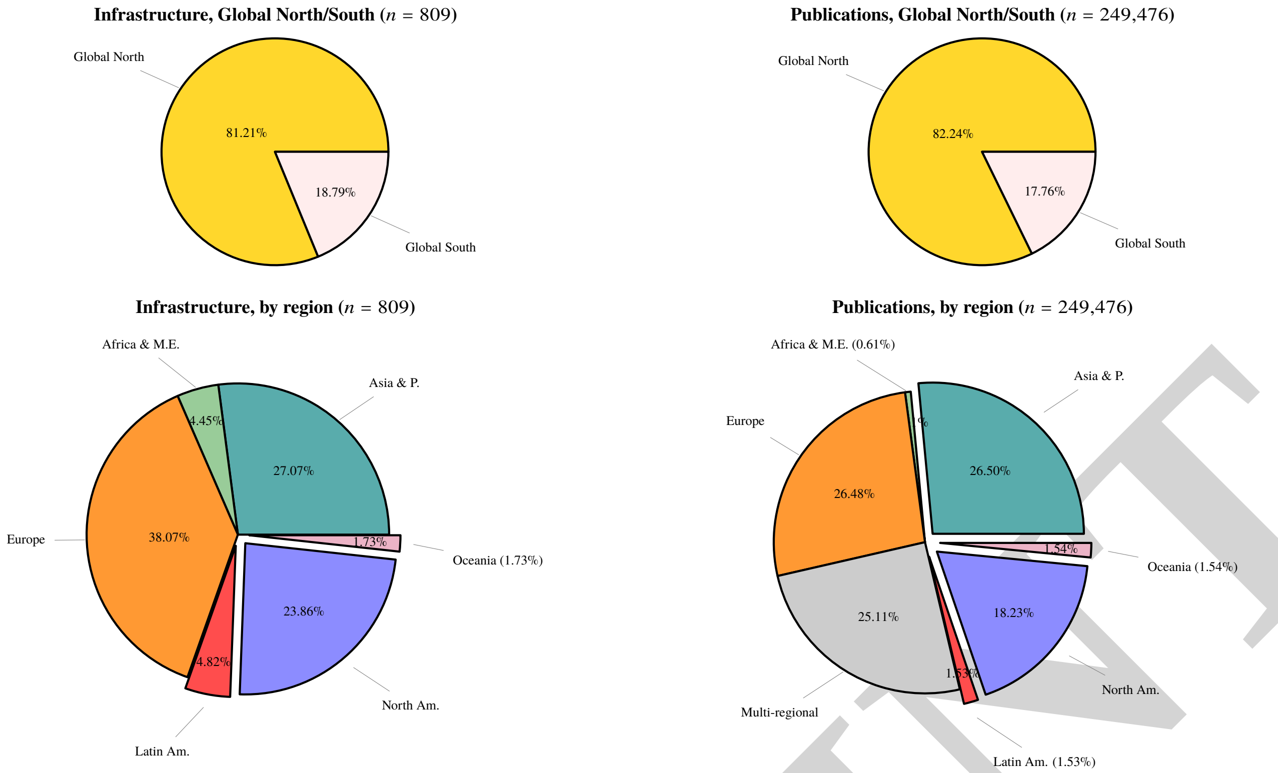

Figure 1: Global and regional distribution of accelerator infrastructures (n = 809) and accelerator-related publications (n = 249,476).

the Global South hosts 18.79% and accounts for 17.76%. The similarities between infrastructure share and publication share could suggest a structural relationship between infrastructure presence and scientific participation.

However, at the regional level this proportionality breaks down. Europe holds the largest facility share (38.07%, n = 308) and accounts for 26.48% of publications. North America shows the same pattern: 23.86% of infrastructure, 18.23% of publications. Asia and the Pacific approaches proportionality with 27.07% of infrastructure and 26.50% of publications, pointing to growing publication intensity relative to facility count. Latin America, Africa & Middle East, and Oceania hold 4.82%, 4.45%, and 1.73% of facilities, respectively. Their publication shares tell a different story: Oceania (1.54%) slightly exceeds Latin America (1.53%), while Africa & Middle East accounts for 0.61%. A further 25.11% of all output involves co-authorship from at least two regions, underscoring the fundamentally collaborative character of accelerator research.

The energy data in Table 1 introduce a further dimension. Mean energies vary substantially across regions, from 163 MeV in Latin America to 1,928 MeV in Europe, but are almost entirely driven by one or two frontier machines per region. Median energies tell a different story: they cluster between 2.5 and 6 MeV across all six regions, confirming that there are more research facilities with low-energy machines regardless of geography.

Regions with the highest mean energies, Europe and North America, show a high collaboration level in publications

Table 1: Regional Distribution Of Accelerator Infrastructures (n = 809), Average & Median Energy, And Publication Collaboration Proportions (n = 249,476)

Region	n	Mean (MeV)	Median (MeV)	Publi. Int. (%)	Publi. Ext. (%)
Africa & M.E	36	248	3.90	19.53	80.47
Asia & P.	219	769	6.00	73.90	26.10
Europe	308	1928	4.10	62.48	37.52
Latin Am.	39	163	2.50	39.95	60.05
North Am.	193	1399	4.00	53.83	46.17
Oceania	14	218	4.00	31.08	68.92

Table 2: Comparative Indicators of Publication Density Relative to Regional Infrastructure Presence

Region	Int./Acc	Dev.	Ext./Acc	Dev.
Africa & M. E.	42.03	−82%	173.17	+14%
Asia & P.	301.86	+31%	106.63	−30%
Europe	214.49	−7%	128.82	−15%
Latin America	97.87	−58%	147.10	−3%
North America	235.65	+2%	202.12	+33%
Oceania	274.64	+19%	609.14	+302%

co-authorship, while Asia, having a higher median energy, has more intraregional publications. Table 2 expresses this through publication-per-accelerator ratios (global averages: Int./Acc = 231; Ext./Acc = 151), used here as a heuristic indicator of how intensively infrastructure is associated with publication activity rather than as a measure of productivity or efficiency. Africa & Middle East, with an intraregional ra-

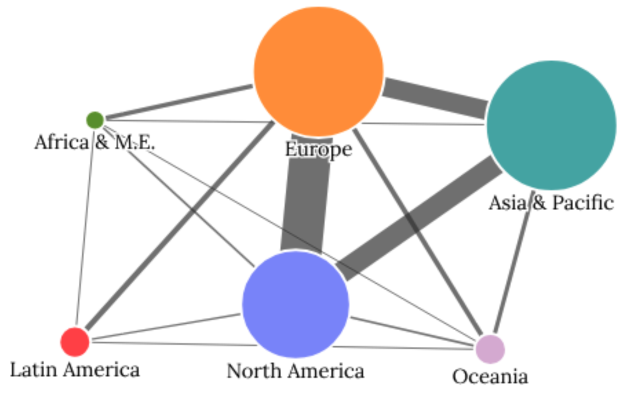

Figure 2: Regional co-authorship network from accelerator-related publication data (n = 249,476).

tio 82% below average, is associated with far less internally sustained research than the global pattern would suggest. Oceania presents the sharpest contrast: 14 facilities with a median energy of 4 MeV are associated with an extraregional ratio of 609 publications per accelerator, 302% above average, pointing to institutional and network factors rather than machine capability as the more consequential variables.

Figure 2 visualises the bilateral co-authorship structure of accelerator research. Node size reflects regional publication share; edge thickness reflects bilateral co-authorship volume. Europe and North America occupy the central positions, connected by the strongest bilateral link in the dataset (17,403 co-authored publications). Asia and the Pacific forms a second hub, with strong ties to both Europe and North America. The three Latin America, Africa & Middle East, and Oceania nodes, are peripheral, connected primarily to the Global North rather than to each other. Oceania is a notable exception signaling that network integration can substantially amplify a modest infrastructure base.

Together, these patterns suggest that infrastructure is a necessary but insufficient condition for scientific participation. Machine energy and facility count are weak predictors of output; the institutional, historical, and collaborative ecosystems surrounding a facility shape how, and how much, it contributes to scientific knowledge production.

GLOBAL SOUTH COLLABORATIONS AND DISCIPLINARY SPECIALISATIONS

Both Global South regions participate in accelerator research primarily through networks organised extraregionally, but the structure, historical trajectory, and disciplinary character of that participation differ.

Table 3 shows the main collaboration partners for each region. Multi-regional publications dominate in both cases (48% for Africa & Middle East, 43% for Latin America), confirming that Global South participation is organised primarily through large multi-partner networks rather than bilateral relationships. Europe is the leading bilateral partner in both regions, though more strongly so for Latin America (39.69%) than for Africa & Middle East (29.18%). North American shares are nearly identical (13.09% and 13.25%). Most strikingly, intra-South co-authorship is negligible: each region accounts for less than 1% of the other's external publications.

Table 3: Proportions of Collaboration Partners for Global South Regions

Partner region	**Africa & M.E. (%)**	**Latin America (%)**
Multi-regions	48.16	42.84
Europe	29.18	39.69
North America	13.09	13.25
Asia & Pacific	7.39	2.75
Oceania	1.62	0.85
Latin America	0.56	,
Africa & M.E.	,	0.61

Figure 3 shows how these profiles evolved over time. For Africa & Middle East, it was mostly North American partnerships through the mid-1990s before Europe consolidated as the primary bilateral partner; Asian partnerships have grown substantially from 2013. For Latin America, it also gave way to a strong European orientation from 1990, and Europe has consolidated further since 2010. In both regions, the multi-regional category has become the largest single component of annual output, reflecting growing participation in large international consortia rather than self-sustained or bilateral partnerships.

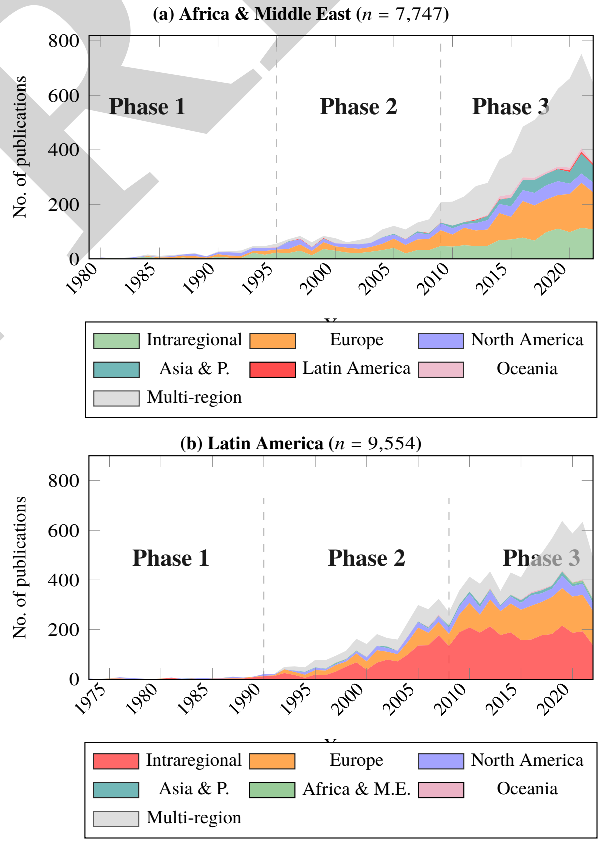

Figure 3: Accelerator-related publications by collaboration partner and Global South region, 1973–2022.

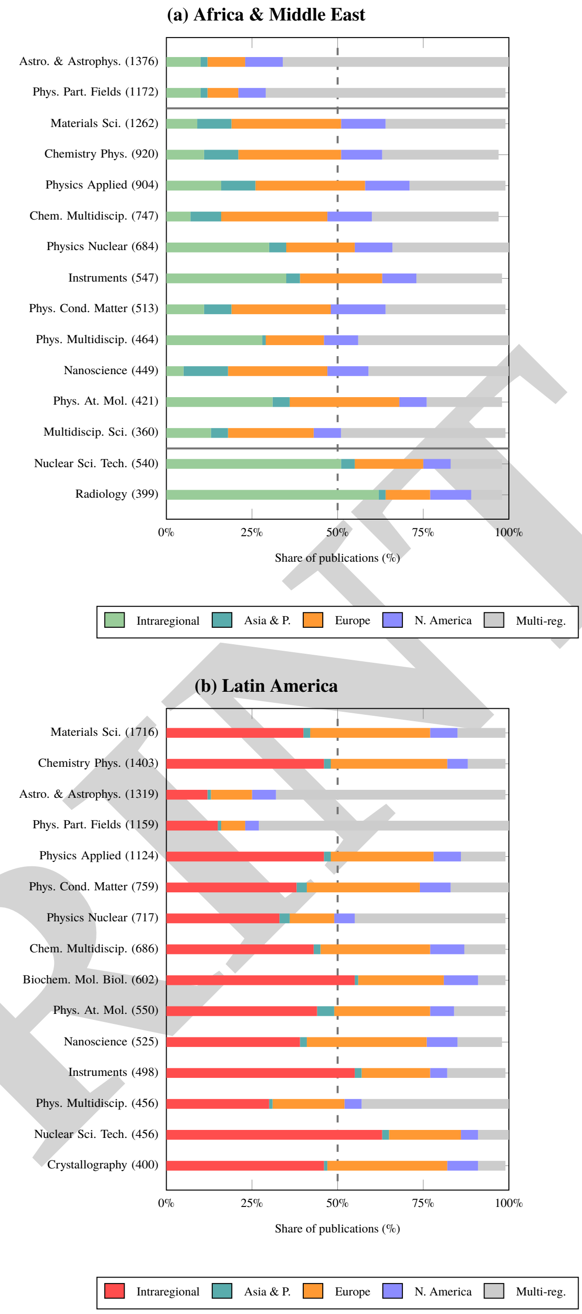

Figure 4: Disciplinary collaboration profiles for (a) Africa & Middle East and (b) Latin America (15 most frequent fields for each region).

Figure 4 disaggregates these patterns by discipline. Each bar shows the publication co-authorship distribution of a field.

Three patterns emerge. At the top of both charts, Astronomy & Astrophysics and Physics Particles & Fields show multi-regional shares between 66 and 74%: the grey segment dominates, and the intraregional segment (green for Africa & Middle East, red for Latin America) are around 10%. Both regions participate in these fields through large global networks rather than through internally sustained production.

In the middle cluster, the orange European segment leads across most fields, alongside a substantial grey multi-regional component. The intraregional segment is the key differentiator: for Latin America it ranges from 30% (Physics Multidisciplinary) to 39%(Nanoscience), while for Africa & Middle East it is below 35% in any field.

The 50% dashed line marks a clear boundary in both charts. For Latin America, three fields cross it including Biochemistry (56%), Instruments (55%), Nuclear Science Technology (63%), indicating that internally co-authored publications form the majority of output in these disciplines, reflecting the sustained activity of nationally operated synchrotrons and other facilities. For Africa & Middle East, two fields cross this threshold: Nuclear Science Technology (51%) and Radiology (62%), both concentrated in applied and clinical programmes.

Taken together, these patterns suggest that infrastructure investment is a necessary but insufficient condition for scientific capacity. The question of under what conditions participation in international networks translates into the capacity to set one's own research agenda is one the data raises but cannot resolve.

DISCUSSION AND CONCLUSION

Discussion

The findings resist a simple infrastructure-determinism reading. Publication activity broadly follows the distribution of facilities, but the relationship is mediated by scientific networks, institutional capacity, historical partnership channels, and the degree to which regions have built autonomous research ecosystems.

The data reveal not a single global research culture organised around accelerators but a set of disciplinarily differentiated communities. Astronomy and particle physics are organised through large multi-institutional consortia in which Global South institutions participate. Materials science and chemistry are structured around synchrotron light sources and bilateral European partnerships. Applied and clinical fields sustain nationally embedded ecosystems. The same infrastructure gives rise to structurally different communities depending on the type of science being done.

Publication data capture the outputs of collaboration but not its character [16–18]. Co-authorship cannot distinguish between deep intellectual partnership and peripheral participation, nor can it capture the tacit dimensions of accelerator expertise, machine operation, beam tuning, and facility management that travel through extended presence and hands-on training rather than through papers [1]. The circulation of accelerator expertise therefore depends not only on access to facilities, but also on sustained participation in transnational training and collaboration networks. Schools (ASP, JUAS, CAS, USPAS, etc.), mobility programmes, technical cooperation initiatives (such as from IAEA), and long-term laboratory presence contribute to the transmission of tacit operational knowledge that cannot be fully codified through publications or technical documentation alone. In this sense, scientific autonomy emerges not simply from infrastructure ownership, but from the gradual construction of institutional and human capacity able to maintain, operate, and direct complex research infrastructures over time.

These trajectories echo an earlier debate in the sociology of science about the conditions under which Global South institutions can move from peripheral participation to more autonomous knowledge production [19]. The structural tension lies in the fact that integration into international networks provides resources, visibility, and legitimacy, while simultaneously risking the orientation of local research activity toward questions primarily framed within Global North institutional contexts. Latin American materials science shows signs of growing intraregional consolidation, while Astronomy & Astrophysics remains among the most externally dependent fields in both regions, consistent with evidence that hosting world-class infrastructure does not automatically translate into scientific leadership when research agendas remain defined by Northern institutions [20]. The gap between co-authorship and independent epistemic capacity is precisely what makes the difference between a region that can use accelerator infrastructure and one that can build, maintain, and direct it. As an example, the development of the African Light Source explicitly addresses this gap by considering social and political infrastructure alongside physical infrastructure [5].

Beyond the methodological constraints discussed in Section 2, interpretive limitations bear noting. The regional categories used here aggregate countries with substantially different institutional capacities; country- or institution-level analysis would reveal finer-grained patterns that the regional frame inevitably conceals.

Conclusion

This study demonstrates that accelerator infrastructure alone does not determine scientific autonomy or publication capacity. Rather, the relationship between infrastructure and knowledge production is mediated by institutional ecosystems, collaboration structures, training networks, and historically uneven distributions of expertise. Three findings stand out: publication output does not scale directly with facility distribution; Global South participation remains largely organised through externally structured collaboration networks with limited intra-South integration; and accelerator infrastructures support disciplinarily differentiated scientific communities whose forms of collaboration vary according to the type of science being produced.

These findings open rather than close a broader set of questions concerning the future organisation of global accelerator science. As synchrotron facilities expand across the Global South, through infrastructures such as SESAME in Jordan or the proposed African Light Source, will they reproduce existing asymmetries of collaboration or contribute to the emergence of more autonomous regional research ecosystems? Addressing these questions will require qualitative approaches, longitudinal studies of infrastructure development, and closer engagement between the social sciences and the accelerator physics community. Decisions concerning facility design, user access, training structures, and partnership agreements are not merely technical or administrative matters, but central mechanisms through which participation, expertise, and scientific autonomy are distributed within global accelerator research.

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